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ARTIFICIAL INTELLIGENCE ADOPTION IN STARTUPS VS. CORPORATIONS

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Abstract: *This paper examines differences in artificial intelligence (AI) adoption between startups and established corporations from a management and business strategy perspective. The purpose of the study is to explore how organizational structure, managerial flexibility, and strategic priorities influence AI adoption decisions across different organizational forms. Using a comparative qualitative approach, the study draws on secondary data analysis and insights from prior empirical research to identify dominant adoption patterns. The findings indicate that startups tend to adopt AI more rapidly and experimentally, driven by agility and fast decision-making processes, whereas corporations approach AI adoption more cautiously due to hierarchical structures, risk management practices, and governance considerations. The paper contributes to the management literature by clarifying how organizational characteristics shape AI-related strategic behavior and offers practical implications for managers seeking to align AI initiatives with business strategy.*

Keywords: *artificial intelligence adoption; startups; corporations; institutional voids; Azerbaijan; digital transformation; emerging economies*

1 Introduction

The widespread and rapid dissemination of artificial intelligence (AI) technologies have attracted considerable interest from both researchers and practitioners with regards to the factors influencing AI adoption by organizations. Prior research has established that firm size, industry type, and technological capabilities are critical factors in firm adoption preparedness (Davenport & Ronanki, 2018; Mikalef & Gupta, 2021;). Relatively little attention has been given to the influence of institutional factors as a mediator in the process of technology adoption, especially in transitioning and emerging economies where institutional infrastructure is still in its infancy and regulatory frameworks and financial systems are still in their developmental stages.

This is particularly relevant where the unit of analysis is a heterogeneous category of firms. Startups and corporations are fundamentally different in terms of their position on the continuum of exploration and exploitation, as proposed by Tushman and O'Reilly (1996). Startups are marked by flexibility, experimentalism, and a lack of resources, while corporations are marked by formal structures, processes, and resources. In settings where formal institutional scaffolding is absent, the intrinsic organizational differences between startups and corporations could imply different patterns of AI adoption that are not captured by unified models of AI adoption. This has direct implications for innovation policy in a nation that aims for accelerated technological development.

Azerbaijan represents a theoretically and empirically relevant case to explore these phenomena. As a South Caucasus nation with an active digital transformation strategy, Azerbaijan has prepared various strategy documents. This includes the AI Strategy 2025-2028 (Cabinet of Ministers of the Republic of Azerbaijan [CMRA], 2025b), the Digital Economy Development Strategy 2026-2029 (CMRA, 2025a), and the Action Plan for Accelerating Digital Development 2026-2028 (CMRA, 2026). Nevertheless, Azerbaijan ranks 78 out of 83

on the Global AI Readiness Index (CMRA, 2025b), and 111 out of 188 on the Government AI Readiness Index (2024). The startup ecosystem is active, with over 200 active startups, but faces critical capital issues, with total venture capital funding for 2020-2024 amounting to only USD 17.6m, with a median seed round of only USD 50,000. Only three venture capital funds were operational in 2025 (Startup Genome, 2025). Crowdfunding and angel investing regulations are still absent (CMRA, 2026). Recent comparative policy analysis confirms Azerbaijan's national AI strategy, while ambitious in its long-term orientation, lacks the detailed sectoral roadmaps, commercialization mechanisms, and trust-building governance structures necessary to translate policy commitments into firm-level adoption outcomes (Isayev, 2025).

This institutional environment creates a natural laboratory for the exploration of the ways in which startups and corporations face the challenge of AI adoption under the condition of formal institutional constraints. The present paper aims to answer the following research questions:

RQ1: How do AI adoption patterns differ between startups and corporations in the Azerbaijani context?

RQ2: What institutional factors mediate and explain these differences?

RQ3: What policy implications follow from the identified adoption asymmetries?

Section 2 explains the development of the theoretical framework, which was based on institutional theory, dynamic capabilities, and organizational ambidexterity. Section 3 explains the methodology used in the research, while Section 4 presents the research findings. Section 5 presents the implications of the research, while Section 6 concludes the research with its contribution and future research directions.

2 Theoretical Framework

2.1 Institutional Theory and Institutional Voids

North (1990) defines institutions as the humanly devised constraints that structure political, economic, and social interaction, comprising formal rules (constitutions, laws, property rights) and informal norms (conventions, codes of conduct). In advanced market economies, dense networks of formal institutions, including capital markets, contract enforcement mechanisms, intellectual property regimes, and professional associations, reduce transaction costs and provide the infrastructure through which organizations can productively engage with transformative technologies. In many emerging and transition economies, however, these arrangements remain underdeveloped.

Such contexts have been described by Khanna and Palepu (1997, 2010) as "institutional voids," where specialized intermediaries and supporting institutions for efficient transactional activity are either nonexistent or ineffective. Institutional voids shape competitive dynamics by favoring those who can utilize alternative means of coping with them. With regard to technology adoption, the consequences of institutional voids are considerable: where formal institutional infrastructure for cloud computing markets, VC systems, or AI regulatory sandboxes is nonexistent, organizations must either develop their own indigenous means of coping with these challenges or forgo these opportunities.

Scott (2008) also further divides this pillar of institutional influence into three sub-pillars: regulative, normative, and cultural-cognitive. This distinction is helpful in understanding the coexistence of the partial presence of a regulative pillar, the partial absence of a normative pillar, and the partial absence of a cultural-cognitive pillar. AI adoption in institutional void contexts therefore unfolds against a multi-layered institutional deficit that affects startups and corporations differently. Hinings et al. (2018) extend this institutional lens directly to digital transformation, identifying digital organizational forms, digital institutional infrastructures, and digital institutional building blocks as the distinctive arrangements through

which digital technologies reshape economic activity. Applied to the AI adoption context, this framework suggests that institutional deficits in transitional economies are not merely inherited constraints but active sites of formation where nascent digital arrangements are being contested and built (Nambisan et al., 2019)

2.2 Dynamic Capabilities and Differential Adaptive Capacity

The dynamic capabilities model of competitive advantage, as proposed by Teece (2007, 2018), focuses on the organizational ability to sense new opportunities and risks, seize them through strategic investment, and change existing resource bases to fit new environmental demands. Teece (2018) extends this framework to foreground business model reconfiguration as a central dynamic capability, arguing that firms must continuously redesign their value creation and capture logics as technological environment shifts. This model is particularly applicable when discussing AI, as firms are required to operate within an environment of unclear regulation, compete for AI human resources, and implement new technologies into traditional business systems.

Dynamic capabilities are not uniformly distributed across firm types. Startups, unconstrained by legacy systems and routinized procedures, often exhibit high sensing capacity: a rapid identification of and response to emerging technological possibilities. However, the extent to which these seizing and reconfiguring actions are possible may be limited by the level of financial and human capital, and hence the presence of institutional infrastructure may be particularly important. On the other hand, large firms may have more resources at their disposal for investment in AI, but their sensing agility and inertia in terms of reconfiguring their established asset bases may be lower (Mikalef & Gupta, 2021; Tushman & O'Reilly, 1996). The institutional voids of corporate governance systems and risk management systems may also increase this problem, creating a governance trap in which risk management systems actually impede the adoption of risk management technologies, like AI.

2.3 Organizational Ambidexterity and AI Adoption

Birkinshaw and Gibson (2004), building on the foundational framework of Tushman and O'Reilly (1996) and subsequently synthesized in O'Reilly and Tushman's (2013) retrospective account, argue that organizations must simultaneously pursue exploration (pursuing new opportunities) and exploitation (refining existing competences). O'Reilly and Tushman (2013) further clarify that ambidexterity is not a static organizational design feature but a dynamic leadership challenge requiring continuous rebalancing as competitive and technological conditions evolve. Startups, oriented toward exploration by structural necessity, are predisposed toward the experimental AI adoption characteristic of that mode. Corporations, with their exploitative focus, may perceive the introduction of AI as a disruptor to their traditional efficiency gains, creating institutional resistance. This ambidexterity challenge is further complicated in institutional voids because corporations have to deal with the internal tension between exploration and exploitation without the external scaffolding that enables a managed approach to exploration in more developed economies.

2.4 Theoretical Propositions

Integrating these three frameworks, the paper advances the following theoretical propositions:

P1: In institutional voids, startups compensate for the lack of institutional infrastructure with their informal mechanisms (international networks, open-source structures), thereby facilitating the adoption of AI at a rate disproportionate to their endowments.

P2: In institutional voids, corporations display governance-amplified inertia, where their risk management structures exacerbate the institutional constraints on their AI adoption rate, which is lower than that justified by their endowments.

P3: Institutional enablers have a differential effect on corporations with institutional compliance capacity, whereas for startups, institutional voids are compensated for with international institutional substitutes.

3 Methodology

3.1 Research Design

The research method adopted is based on a mixed-methods approach, using both primary survey-based research and secondary data research. This is because of the multi-layered nature of the research questions, as well as the lack of significant quantitative data on AI adoption at the firm level in Azerbaijan. The research method is based on analytical rigor, which is suitable for a case study approach in an under-researched institutional context (Yin, 2018).

3.2 Primary Data

The primary data was collected using a survey that was designed for the purpose of this research. The survey was conducted between April and June 2025 for the purpose of a research project for an MBA dissertation. The survey targeted the Azerbaijani startup ecosystem and yielded a total of 48 usable responses from participants representing five distinct stakeholder group. Table 1 presents the full respondent breakdown.

Table 1. Survey respondent breakdown by stakeholder group (n=48)

Stakeholder Group	n	Share of total
Founders/Entrepreneurs (primary analysis group)	30	62.5%
Innovation Center Employees	8	16.7%
Investors (VC, Angel, Corporate)	6	12.5%
Academic Researchers/Professors	3	6.3%
Government Institution Representatives	1	2.1%

For the purposes of this paper, the analysis is restricted to the 30 startup founder respondents, who constitute 62.5% of the total sample. This sub-sample is selected on the methodological grounds: founders are the primary decision-makers responsible for AI adoption choices at the firm level and therefore represent the actor group most directly relevant to the research questions. The remaining 18 respondents, comprising innovation center employees, investors, academic researchers, and a government representative, offer valuable perspectives on the broader ecosystem but fall outside the scope of this paper's focus on firm-level adoption dynamics. Their exclusion from the primary analysis is acknowledged as a limitation in Section 5.3.

The founders represent a variety of different sectors, with EdTech, FinTech, and E-Commerce being the most prominent, followed by ClimateTech and HealthTech sectors. Although the survey results were intended to explore a variety of different innovation ecosystem dynamics, as opposed to specifically focusing on the adoption of AI as a dependent variable, the results are significant in terms of understanding the constraints on technology adoption and the capital constraints that affect startups. The survey data are treated accordingly: as ecosystem-level evidence illuminating the conditions under which AI adoption decisions are made, rather than as a direct measure of adoption rates.

3.3 Secondary Data Sources

Secondary data sources were selected on the basis of authority, recency, and relevance. These comprise: the Global Startup Ecosystem Report 2025 (Startup Genome, 2025); three Azerbaijani government strategy documents (AI Strategy 2025-2028, Digital Economy Development Strategy 2026-2029, Action Plan for Accelerating Digital Development 2026-2028); the UNECE Science, Technology and Innovation Gap Analysis for Azerbaijan (Aliyeva, 2020); the World Bank B-READY 2025 assessment (World Bank, 2025); and a Mastercard digital economy report on Azerbaijan (Mastercard, 2023). These sources provide complementary quantitative benchmarks, policy trajectory data, and institutional environment assessments spanning the period 2020-2026.

3.4 Analytical Approach and Limitations

The method used for the analysis is comparative institutional analysis, where the patterns of AI adoption are compared in relation to the theory developed in Section 2. The primary survey data was also supported with secondary data, which helped in providing greater validity. However, the limitations of the research are that the survey was not conducted specifically for measuring AI adoption, and there is a heavy dependence on secondary data for the corporate side of the data. The sample is also from a single country, which is a limitation for external validity.

4 Results

4.1 Azerbaijan's Digital Innovation Ecosystem: Institutional Context

Azerbaijan's digital innovation ecosystem has a complex growth and restrictive profile. The ICT sector contributed 2.8% to non-oil GDP in 2024, growing by 18% annually (CMRA, 2025a). Nevertheless, the export of ICT services was only valued at 110 million USD by 2024, compared to 882 million USD for Kazakhstan and 620 million USD for Uzbekistan (CMRA, 2025a). This shows a lower market penetration compared to other countries in the region. R&D spending stands at 0.2% of GDP compared to an average of 2.5% for OECD countries (Aliyeva, 2020), which limits the local capacity for generating knowledge to feed the innovation for AI. Table 2 shows the key digital innovation ecosystem for Azerbaijan.

Table 2. Key indicators of Azerbaijan's digital innovation ecosystem

Indicator	Value	Source
Global AI Readiness Ranking	78th out of 83 economies	AI Strategy 2025–2028
Government AI Readiness Ranking	111th out of 188 economies	AI Strategy 2025–2028
Total VC Funding (2020–2024)	USD 17.6 million	GSER 2025
Startup Ecosystem Value	USD 36.6 million	GSER 2025
Median Seed Round	USD 50,000	GSER 2025
Active Startups	200+	GSER 2025
ICT Share of Non-Oil GDP (2024)	2.8%	Digital Economy Strategy 2026–2029
ICT Exports (2024)	USD 110 million	Digital Economy Strategy 2026–2029
R&D Expenditure	0.2% of GDP	UNECE STI Gap Analysis
Venture Capital Funds	3 funds (as of 2025)	Action Plan 2026–2028
Crowdfunding/Angel Legal Framework	Absent (under development)	Action Plan 2026–2028

A particularly acute institutional constraint is the absence of major international cloud service providers. Neither Amazon Web Services (AWS), Microsoft Azure, nor Google Cloud Platform maintains a local presence, a structural barrier to AI development explicitly acknowledged in the AI Strategy 2025-2028 (CMRA, 2025b). This infrastructure gap has indirect consequences for startup AI adoption: access to cloud AI credits programs, which constitute a significant indirect subsidy for AI-adopting startups globally, is effectively foreclosed. The government intends to build a GPU Supercomputer Centre and an Azerbaijani Large Language Model as outlined in the Action Plan 2026-2028 (CMRA, 2026). However, this is still prospective in nature. B-READY 2025 results for Azerbaijan show a dichotomous business environment, with high scores in Business Entry (86/100) and accessing Financial Services (87/100) but poor scores in Market Competition (45/100) and Business Insolvency (36/100) (World Bank, 2025). These results have important implications for the risk assessment of investing in AI.

4.2 AI Adoption in Azerbaijani Startups

Survey findings and additional documentary evidence suggest that Azerbaijani startups demonstrate active and increasing engagement with AI technologies, which is manifested through experimental usage, circumventing access to infrastructure, and sectoral concentrations of AI adoption.

Perhaps the most telling figure here, however, is the distribution of the founder respondents by the different stages of the startup lifecycle, as reflected by the survey results. The majority of the founder respondents were clustered in the MVP Development and MVP Launch and Early Revenue stages, with only one founder respondent who has reached the scaling stage. This early-stage concentration has a direct bearing on AI adoption capacity: the USD 50,000 median seed round documented in GSER 2025 (Startup Genome, 2025) is insufficient to fund proprietary AI infrastructure development, and most startups are operating well before the revenue levels that would support sustained AI investment.

Funding constraints constitute the primary pain point reported by founder respondents, and this constraint cascades into a set of interrelated downstream barriers. Limited capital restricts access to paid AI tools and cloud infrastructure, constrains the ability to hire specialized AI talent, and forecloses participation in international expansion that would otherwise provide access to AWS, Azure, and Google Cloud credit programs. The structural absence of these major cloud providers in Azerbaijan thus compounds the founding capital constraint: startups cannot offset limited domestic funding through the cloud credit programs that serve as a significant informal AI infrastructure subsidy in more institutionally developed ecosystems. This chain of constraint moves from funding scarcity to infrastructure inaccessibility and is key to understanding why Azerbaijani startup AI adoption is of an informal and low-cost nature rather than the systematic adoption of enterprise-level AI systems.

Despite these limitations, startups were found to have significant informal institutional compensation ability, which aligns with Proposition P1. The international accelerators, which include programs such as Seedstars World and innovation competitions in regions, offer startups access to a network of mentors and infrastructure credits, which can be used as a substitute for VC and cloud markets domestically. The emphasis on informal institutional mechanisms as a key factor stems from the fact that, in this ecosystem, formal institutional substitutes are not yet operational, with agility and international networks as the key differentiators for AI-active startups.

In terms of industry type, FinTech Startups, especially those categorized under Payment Service Providers, were identified as the most AI-intensive industry type. This was due to both the data richness of FinTech operations and the competitive pressure of banks' digitalization initiatives. EdTech and Digital Wellness Startups revealed their AI adoption potential in

personalization and user engagement optimization. AgriTech, PropTech, and Logistics Startups revealed relatively early-stage AI adoption potential, hindered by capital costs of establishing data collection infrastructure. Azerbaijan ranks #25 in Asia for Affordable Talent (Startup Genome, 2025), representing a true competitive advantage in terms of availability of AI Engineering talent with cost structures significantly below those of European and North American ecosystems; LinkedIn statistics included in the AI Strategy 2025-2028 report by CMRA (2025b) revealed 60-fold growth in AI and machine learning job market demand between 2016 and 2022.

4.3 AI Adoption in Azerbaijani Corporations

The resource advantages and governance constraints interplay to form the environment for the adoption of corporate AI in Azerbaijan. The key players in the adoption of AI-related technologies are the financial sector, the telecommunications sector, and the state-owned enterprises undergoing digital transformation.

The Central Bank of the Republic of Azerbaijan (CBAR) has taken an active approach to regulating digital banking in the financial industry. This includes creating the FinTech sandbox and adding digital banking to prudential regulation. As of 2024, there are more than 30 FinTech companies operating in the Republic of Azerbaijan (CMRA, 2025a). These companies include both startups and established businesses. The banks that are already there are focusing on employing AI to help with fraud detection, credit scoring, and customer support. The digitization of the Republic of Azerbaijan, as per the Mastercard (2023) digitization report, has achieved a digital payment rate of 32% and banking penetration of 68%. The Digital Economy Development Strategy, which is expected to be accomplished by the year 2029, also includes the goal of enrolling 50 businesses into digital transformation programs until the year 2026, increasing to 300 until the year 2029, with the Gen AI economic impact goal of 70 million AZN until the year 2029 (CMRA, 2025a).

A phenomenon of governance-enhanced inertia, as proposed by Proposition P2, was observed across various corporate bodies. Larger firms, which are subject to various procurement regulations and compliance requirements, have elongated decision-making cycles for technology adoption compared to their smaller counterparts. In addition, the presence of legacy technologies, which is common among incumbent banks and government firms, poses integration challenges for AI systems. Although risk aversion is rational from a perspective where intellectual properties are not well protected and regulations around AI-generated content are ambiguous, this phenomenon also acts as a barrier for AI investment among corporate bodies. The reputational exposure associated with AI deployment constitutes a further governance constraint: organizations sensitive to brand integrity and stakeholder trust are acutely alert to AI-related risks including algorithmic bias, data privacy failures, and the integrity of automated outputs, creating governance-oriented hesitancy that compounds resource-based barriers to adoption (Ağtaş, 2025). The lack of Azerbaijani cloud infrastructure, however, also imposes significant constraints on corporate adopters, including data localization, bandwidth, and service latency, which can act as significant operational barriers even for firms willing to invest in cross-border cloud services.

The differential effect of CBAR's FinTech sandbox supports Proposition P3. Firms with compliance capabilities are better positioned to deal with the sandbox environment than startups, thus creating a differential effect for the development of complementary AI solutions. Startups and firms are less inclined towards AI adoption in AgriTech, Logistics, and PropTech, areas where there is a lack of support from the FinTech sandbox, implying that institutional support drives AI adoption. A comparison of AI adoption characteristics of both company types is provided in Table 3.

Table 3. *Comparative AI adoption characteristics: startups versus corporations in Azerbaijan*

Dimension	Startups	Corporations
Adoption speed	Rapid; experimental; iterative	Deliberate; phased; governed
Primary constraint	Infrastructure access; capital scarcity	Governance inertia; compliance burden
Compensation mechanism	International networks; open-source tools; agile structures	Regulatory sandboxes; procurement channels
Key AI-active sectors	FinTech (PSPs), EdTech, Digital Wellness	Banking, Telecommunications
Capital base	Limited (USD 50,000 median seed)	Substantial (retained earnings, credit)
Sensitivity to institutional voids	High: dependent on formal gap resolution	Moderate: partially self-sufficient
Dominant dynamic capability	Sensing and informal seizing	Formal resource deployment; reconfiguration lag

5 Discussion

5.1 Theoretical Implications

The empirical findings from Azerbaijan provide substantive support for the theoretical framework advanced in Section 2, while revealing nuances that extend its analytical scope. The differential adoption patterns observed between startups and corporations are consistent with the institutional void literature's prediction that weak formal institutional environments produce heterogeneous firm-level responses rather than uniformly suppressed technology adoption (Khanna & Palepu, 2010).

Confirmation of Proposition P1 is provided by the survey and documentary evidence jointly. The informal institutional compensation mechanisms identified in Azerbaijan, including international accelerator access, open-source AI deployment, and freemium tool adoption, operate through specifically technological channels not previously foregrounded in the AI adoption literature. Founder survey evidence reveals the precise structure of this compensation: accelerator and incubation programs substitute for some institutional gaps (mentorship, networking) but not others (capital, cloud infrastructure). Funding scarcity remains the primary constraint, and its downstream effects, including restricted access to cloud AI credits and the inability to fund international expansion that would unlock such access, illustrate how institutional voids compound rather than operate independently. This finding extends Khanna and Palepu's (2010) institutional void framework into the domain of AI technology adoption and clarifies the partial rather than comprehensive nature of informal substitution.

Confirmation of Proposition P2 is supported by the pattern of governance-amplified inertia documented in the corporate evidence. The Azerbaijani findings suggest that institutional voids interact with corporate governance structures in a specifically amplifying manner: the risk aversion generated by weak intellectual property protection and regulatory uncertainty compounds baseline governance inertia documented in prior technology adoption literature (Teece, 2007). This interaction has not been systematically theorized in prior AI adoption research and may constitute a contribution to the institutional economics of technology adoption.

Proposition P3 receives partial but instructive support. The CBAR FinTech sandbox illustrates the capacity for targeted institutional enablers to drive adoption across different types of firms; however, the benefits of this are asymmetrical and accrue primarily to resource-constrained incumbents. This discovery reveals a paradox for institutional design: sector-specific enablers designed to foster innovation may actually exacerbate the established corporation advantage over new firms in institutionally constrained environments.

5.2 Policy Implications

The findings carry several policy implications for the design of AI adoption support in transitional institutional contexts. Most fundamentally, the evidence supports asymmetric institutional support: interventions tailored to the distinct adoption barriers of startups versus corporations, rather than uniform innovation ecosystem policies. For startups, priority interventions include: resolution of the cloud infrastructure gap, either through attracting major cloud providers or establishing a domestically operated high-performance computing platform with international interoperability; legal enactment of crowdfunding and angel investment frameworks, acknowledged but not yet enacted in the Action Plan 2026-2028 (CMRA, 2026); and expansion of international accelerator program participation and equity-free grant instruments. For corporations, priorities include clear AI regulatory frameworks that reduce adoption risk uncertainty, procurement reform to accelerate technology adoption in state enterprises, and targeted incentives for corporate-startup AI co-development partnerships.

The government's announced Digital Nomad Visa and Digital Talent Visa programs (CMRA, 2026) represent strategically important instruments for addressing the talent constraint. The AI Academy and 500-engineer training target in the AI Strategy 2025-2028 (CMRA, 2025b) are necessary conditions but insufficient in isolation; retention mechanisms are equally important given documented brain drain risk (CMRA, 2025a). However, the achievement of the 70 million AZN by 2029 targeted by the GenAI economic impact (CMRA, 2025a) would be possible only if the gaps in the infrastructure and the institutional environment are filled in the short term. The existing adoption path, driven mainly by the informal compensation of the startup sector rather than the systematic use by the corporate sector, would not likely result in the productivity impact on the required scale within the stipulated timeframe. These findings align with recent policy analysis specific to Azerbaijan, which identifies the establishment of AI commercialization hubs, sector-specific implementation roadmaps, and an ethical governance package modeled on international best practices as the most actionable near-term instruments for closing the gap between Azerbaijan's strategic AI ambitions and current implementation capacity (Isayev, 2025).

5.3 Limitations

Several limitations should be acknowledged. First, the primary survey analysis is restricted to the 30 founder respondents drawn from a broader sample of 48 ecosystem stakeholders. The perspectives of the remaining 18 participants, comprising innovation center employees, investors, academic researchers and a government representative, are not analysed in this paper, as their roles are peripheral to the firm-level AI adoption dynamics that constitute the research focus. Incorporating these multi-stakeholder perspectives in future research could provide a richer institutional ecosystem view and triangulate the founder-reported constraints against the observations of supporting actors. Second, documentary and secondary sources are overrepresented for the corporate side, which limits the depth of the insights gained. Finally, the single-country focus limits the generalizability of the findings. Future research should address the above limitations by conducting specifically designed survey research for AI adoption, qualitative research for corporate AI projects, and multi-country analyses for the CA and SC economies.

6. CONCLUSIONS

In this paper, the different patterns of AI adoption in startups and corporations in Azerbaijan have been explored, with inspiration coming from the understanding that the institutional environment does have a systematic impact on the process of technology adoption, which existing unified models fail to capture in a satisfactory way. With the help of a series of primary survey results (48) from the Azerbaijani startup ecosystem, as well as a comprehensive

analysis of government strategy reports and international ecosystem reports, three key results have been established in this paper.

First, Azerbaijani startups exhibit active, agile AI adoption driven by informal institutional compensation mechanisms, including international accelerator networks, open-source tools, and diaspora connectivity, despite operating within one of the most institutionally constrained AI environments globally. Survey data from the 30 founder sub-sample, drawn from a broader study of 48 ecosystem stakeholders, confirm the structural underpinnings of this pattern: the majority operate at early development stages (MVP Development and MVP Launch), and funding constraints are the primary reported pain point, cascading into downstream barriers including access to cloud infrastructure and international expansion capacity. Second, corporations demonstrate governance-amplified inertia that compounds the constraining effects of institutional voids, producing AI adoption below the level predicted by resource endowments alone. Third, sector-specific institutional enablers, most notably the CBAR FinTech regulatory sandbox, can catalyze adoption across firm types when present, but distribute benefits asymmetrically toward compliance-capable incumbents.

The theoretical contribution is based on the combination of institutional voids, dynamic capabilities, and organizational ambidexterity theories for understanding the heterogeneity of AI adoption in transition economies. The policy contribution is based on the formulation of asymmetric institutional support as a guiding principle for transition economies that wish to capitalize on AI for economic transformation. Resolving the cloud infrastructure gap, developing legal frameworks for VC and crowdfunding, and overhauling procurement systems for corporate tech adoption emerge as the top priorities based on the evidence. Future research should include comparative studies in the South Caucasus and Central Asian regions, longitudinal studies on the effects of institutional development on AI adoption, and sectoral studies in AgriTech and Logistics.

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FINANCE-GROWTH NEXUS AND ADOPTION OF ARTIFICIAL INTELLIGENCE IN AZERBAIJAN

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Abstract: *This article investigates the relationship between financial development and economic growth in Azerbaijan within 2000–2024 period. Findings from the Autoregressive Distributed Lag (ARDL) Bounds Test reveal a significant long-term cointegration among financial development, physical capital investments, and economic growth, suggesting that access to finance for the private sector is a strong accelerator for economic growth. While domestic credit to the private sector shows a weak positive short-run impact, its long-run impact is negative. The divergence between the positive impact of physical capital and the negative impact of credit expansion in the long run implies that even though physical investments enhance productivity, the financial markets might be inefficient in the allocation of resources by moving funds toward non-productive sectors and creating a misallocation constraint on economic growth. To improve the efficiency in financial markets, digitalisation of financial services and integration of AI-based models were evaluated as key strategic priorities. This study also employs a SWOT analysis to explore opportunities and challenges for successful adoption of AI.*

Keywords: *financial development, economic growth, artificial intelligence, Azerbaijan*

1 Introduction

Nowadays, financial market development plays a role of an engine in the proliferation of economic growth, which leads to better social welfare. The relationship between financial development and economic growth has been a cornerstone of development economics for over a century. The classic theoretical approach claims that financial systems ensure the efficient allocation of resources, promote investment opportunities, and enhance technological innovation. The factors affecting financial market development can vary depending on country-specific implications. Helhel (2026) provides evidence for supply-led growth hypothesis by showing unidirectional causality from stock market development to economic growth in the “Fragile Five” emerging economies experiencing high market volatility. The various dimensions of financial development may alter the growth outcomes differently. For instance, Girma, and Huseynov (2025) find out for African economies that dimension of efficiency has a positive effect which supports the financial intermediation hypothesis.

In parallel with traditional financial development, the global financial sector is undergoing a rapid digital transformation driven by the introduction of artificial intelligence (AI). The widespread adoption of GenAI on a daily basis is a relatively recent trend, emerging only over the past few years. However, engagement of financial sector with AI is more broadly and far from being new. The findings of IMF claim that many participants in financial markets perceive Generative Artificial Intelligence (GenAI) as a tool that can accelerate progress in developing and emerging economies by improving access to credit and strengthening financial development (IMF, 2024). However, if the fixed costs of adopting AI are high, richer countries may benefit from it more quickly than poorer ones.

AI technologies such as machine learning, natural language processing, and predictive analytics are increasingly used in banking and financial services to improve credit assessment, fraud detection, customer service, and risk management. Traditionally, the industry has relied on technology for high-frequency trading and data management; however, currently newly applied tools are fundamentally reshaping the landscape. They propose sophisticated levels of product customization, more intuitive client interfaces like chatbots, and more sophisticated decision-making analytics, meanwhile significantly cutting costs through automation (IMF, 2024).

Compared to asset (wealth) management, banking sector adopted these technologies more gradually. Despite being successful in early innovative applications related to the adoption of ATMs and online banking, the overall progress was initially decelerated by strict data privacy and proprietary concerns. However, the process of adoption is now accelerating as banks face pressure from fintech competitors. Today, AI and machine learning (ML) is being integrated into banking to improve client relationships, personalize product offerings via behavioural data, and facilitate essential functions like risk management, credit underwriting, and back-office operations. AI supports the banking sector with personalized approach for its customers, such as chatbots and virtual assistants, which allow personalized financial and portfolio management advice (Nusrat et al., 2023). While developed economies have made substantial progress in AI adoption, emerging economies such as Azerbaijan face unique economic, technological, and regulatory challenges that influence the pace and effectiveness of AI integration in finance. The potential channels of usage of AI can be customer service and support, investment advice and portfolio management, automation of tasks, risk management, compliance and fraud detection. However, it is important to take into account the risks and limitations of the integration of AI in financial system. There are four main drawbacks of this integration: uncertain markets, discriminatory data and algorithmic biases, cyber and virtual threats, systematic risks and financial accidents (Lin, 2019).

Considering the bank-dominated structure of the financial system and current efforts of Azerbaijan to diversify its economy, this study seeks to explore whether the development of financial markets has contributed significantly to economic growth over the study period. On the other hand, the research focuses on the integration of AI tools in the financial sector of Azerbaijan. Specifically, by applying the SWOT analytical framework, this study aims to determine both the key drivers and the main barriers preventing AI adoption in the financial system.

1.1 Theoretical Foundations and Empirical Literature

From theoretical perspective economic growth models recognize several leading factors contributing to economic growth. According to the Solow growth model (1956), economic growth is driven by capital accumulation, labour growth, and exogenous technological progress.

Modern endogenous growth models recognize financial development as a key driver of long-term economic growth. The next generation of endogenous growth models emphasized the role of finance-growth nexus for outcomes, showing that financial development can affect total factor productivity by reducing information asymmetries and facilitating innovation (King & Levine, 1993; Levine & Zervos, 1998).

The report provided by the World Economic Forum (WEF, 2012) identifies financial development as the combination of structural conditions, policies, and institutional arrangements that enable efficient financial intermediation, well-functioning financial markets, and widespread access to capital and financial services. Within this framework, financial development can be measured through seven core dimensions:

- Institutional environment
- Business environment
- Financial stability
- Banking financial services
- Non-banking financial services
- Financial markets
- Financial access

These categories reflect the main features of a healthy financial system, such as governance standards, effectiveness, business climate, infrastructure, and so on. Together, these seven pillars provide a multidimensional framework for assessing the depth, efficiency, stability, and inclusiveness of a country's financial system. The most frequently used indicators to assess financial development generally fall into three broad categories: financial depth, the bank ratio, and financial activity (Valickova et al., 2013).

Traditional empirical studies accept the approach that banking sector development plays a crucial role in promoting economic growth, particularly in developing economies where banks are the leading financial intermediaries. Early cross-country studies demonstrated that measures of banking development, such as domestic credit to the private sector and liquid liabilities, are strongly associated with growth outcomes (Beck et al., 2000).

In the context of developing and emerging markets, recent empirical literature further highlights the importance of banking development. Ekanayake and Thaver (2021) analyse panel data from 138 developing countries and find the existence of bi-directional causality between financial development, proxied by four variables and economic growth. Similarly, a study of OECD countries conducted between 1990-2018 confirms that banking sector performance and financial globalization and investments positively influence economic growth, highlighting the continued importance of bank-based measures even in more advanced emerging economies (Sümerli Sarigül & Avcı, 2024).

Despite robust positive associations, scholars mention that the quality of intermediation also matters: excessive credit growth, if directed toward unproductive sectors or accompanied by weak risk management, can lead to financial instability without contributing to sustainable growth. Nevertheless, in the context of underdeveloped capital markets, the credit channel remains the primary mechanism through which financial systems influence real economic activity. The role of capital markets is less profound in economies with shallow or nascent markets.

In spite of a robust positive association between banking and growth in many emerging markets, this relationship exhibits some heterogeneity across developing and resource-dependent economies. In region-specific framework, capital markets often play a secondary role, largely due to institutional constraints and market imperfections.

Dependence of the economy on natural resources, including those heavily dependent on energy prices, creates additional complexity to the finance–growth nexus through Dutch Disease effects and fiscal dominance. In resource-dependent economies, increasing bank credit to tradable sectors is important for reducing the risk of Dutch Disease by facilitating capital availability for non-oil tradable sectors and enhancing their export capacity (Hasanov & Huseynov, 2013). These patterns suggest that the relative contribution of banking and capital market development to growth is conditional on broader structural and institutional factors, including market maturity, regulatory quality, and the nature of economic specialization.

The financial system of Azerbaijan is characterized by its strong dominance of banking sector and relatively underdeveloped capital markets. Since independence, Azerbaijan has implemented significant reforms aimed at strengthening banking supervision, enhancing

regulatory frameworks, and stabilizing macroeconomic conditions. Despite this progress, the banking sector remains the dominant channel of financial intermediation, with domestic credit to the private sector and bank deposit instruments accounting for the majority of financial activity. In contrast, capital markets develop more slowly.

The financial markets of Azerbaijan are related to the developing financial markets. After the transition to a market economy, the development of the financial market and strengthening of its competitiveness is considered a necessary issue in Azerbaijan.

Empirical evidence on financial development in Azerbaijan offers mixed insights but generally underscores the importance of the banking sector. Seyfullayev (2023) examines the relationship between financial development and non-oil economic growth and finds that improvement in non-oil lending rates are associated with higher growth rates in non-oil sector, even though the study does not extensively analyse capital markets due to data. A complementary study by Zeynalova (2023) provides an econometric analysis of the impact of domestic credit volume on money supply and growth outcomes, further reinforcing the central role of credit expansion and admits the important role of oil sector for driving the credit volume in Azerbaijan. The limited role of capital markets in Azerbaijan can be attributed to several structural factors, including low levels of private sector listings, shallow investor participation, and limited liquidity. These findings are consistent with the broader pattern observed in oil-dependent economies, where financial systems tend to be bank-centric and capital markets remain shallow. However, the absence of extensive time-series evidence that simultaneously evaluates banking and market channels in Azerbaijan highlights a significant gap in the literature.

2 Research Design and Methodology

The economic transition in Azerbaijan was accompanied by reliance on bank-dominated financial system, which makes efficiency important in this context. By analysing both financial activity and efficiency, this study provides a more detailed investigation of the finance–growth nexus in Azerbaijan, while also setting the frame for examining AI adoption as a complementary driver of financial modernization.

Despite rich cross-country evidence on the finance–growth nexus, country-specific research on Azerbaijan remains limited, particularly in terms of distinguishing the separate effects of banking sector development and capital market development.

To address this gap, this study proposes an empirical analysis using ARDL bounds testing to capture long-run and short-run relationships between financial development indicators and economic growth. Specifically, this analysis will test the following hypothesis:

H1: Financial sector development positively affects economic growth in Azerbaijan.

This hypothesis was built on the theoretical and empirical foundations reviewed above and ensures a structured basis for the subsequent econometric analysis.

This study utilizes a mixed-methods research design, combining quantitative econometric analysis with qualitative analysis. The quantitative component examines the impact of financial market development on economic growth in Azerbaijan using time-series data, while the qualitative component explores AI adoption in the financial sector through SWOT analysis.

2.1 Model Specification

We integrate a general functional form to examine the relationship between variables. The conceptual model represents a form where GDP growth is a function of three explanatory variables:

$$GDPgrowth_t = f(Domestic\ credit_t, Exports_t, Gross\ Capital_t)$$

Where:

- $GDPgrowth_t$: GDP Growth (Annual %) at time t
- $Domestic\ credit_t$: Domestic Credit to the Private Sector by banks (% of GDP) at time t
- $Exports_t$: Exports of Goods and Services (% of GDP) at time t
- $Gross\ Capital_t$: Gross Capital Formation (% of GDP) at time t

The advantage of the ARDL model is the possibility to apply regardless of whether the underlying regressors are purely I(0), purely I(1), or a mixture of both. The time horizon for research lies between 2000 and 2024.

The Error Correction Model (ECM) can be represented by the following equation (1):

$$\Delta GDPgrowth_t = \alpha_0 + \sum_{i=1}^p \beta_i \Delta GDPG_{t-i} + \sum_{j=0}^{q_1} \gamma_j \Delta DCPS_{t-j} + \sum_{k=0}^{q_2} \delta_k \Delta EXG_{t-k} + \sum_{m=0}^{q_3} \theta_m \Delta GCF_{t-m} + \lambda ECT_{t-1} + \varepsilon_t \quad (1)$$

Notation:

- $GDPgrowth_t$: annual GDP growth rate at time t.
- $DCPS_t$: Domestic credit to the private sector by banks as a percentage of GDP at time t.
- EXG_t : Exports of goods and services as a percentage of GDP at time t .
- GCF_t : Gross capital formation (Investment) as a percentage of GDP at time t.
- α : The intercept or constant term of the model.
- λ : coefficient of Error Correction Term (ECT), representing the speed of adjustment.
- ECT_{t-1} : lagged error correction term, derived from the long-run cointegrating relationship.
- ε_t : The stochastic error term, assumed to be normally distributed with zero mean and constant variance

3 Results

Before starting with a long-term modelling, it was crucial to check the integration properties of the time-series variables. The study employed Augmented Dickey-Fuller (ADF) test to check for the presence of unit roots (Dickey & Fuller, 1981).

The initial testing of ‘Exports of Goods and Services’ in levels yielded a p-value of 0.16, indicating a failure to reject the null hypothesis of non-stationarity. Graphically and statistically, the series exhibits a stochastic trend characterized by significant volatility and structural shifts, notably around 2015 and 2020 rather than a smooth linear trend (see Figure 1). According to the Figure 1, domestic credit provided to the private sector by banks as a percentage of GDP exhibits a visible upward drift between 2000 and 2015, and then we observe a subsequent structural break and volatility until the end of 2024. This pattern implies a stochastic rather than a deterministic trend. The Augmented Dickey-Fuller test with a drift term for domestic credit yielded a p-value of 0.07. In this case, the null hypothesis of a unit root could not be rejected at the conventional 5% level. To ensure the robustness of the ARDL bound test, the variable was first-differenced. The consequent test on the differenced series I(1) was highly significant ($p < 0.01$). This approach justifies treating the variable as I(1) and utilizing the ARDL bounds test to distinguish between its persistent growth path and short-term fluctuations. These obtained results confirm that the variables are integrated of order one, I(1). When it comes to plots of investment levels and GDP growth represented in Figure 2, the series also do not show any deterministic trend.

Figure 1. *Ts line for export of goods and services*



Source: Calculation of authors

Figure 2. *Ts line – Gross capital formation and GDP growth*



Source: Calculation of authors

Diagnostic Tests

To ensure the reliability of the statistical model, we test the residuals of the ARDL regression for normality (see Table 1). After applying the Jarque-Bera test, the model shows a p-value of 0.71. Since this value is substantially higher than the standard 5% significance level, we accept the null hypothesis of normality. This indicates that the error terms are normally distributed, confirming that the t-statistics and F-statistics used for hypothesis testing are valid and that the model does not suffer from significant bias. As Bounds Test under Pesaran et al. (2001) assumes that the residuals are serially uncorrelated and normally distributed, obtaining p-value of 0.71 provides a strong evidence in favour of our critical values. Another task is to check for serial correlation, therefore we use the Breusch-Godfrey test. The resulting p-value of 0.10 indicates that we fail to reject the null hypothesis of no serial correlation. Given the annual frequency of the data and the relatively small sample size, the first-order test confirms the model is sufficiently specified to provide reliable long-run and short-run estimates.

Table 1. *Jarque-Bera tests for Normality*

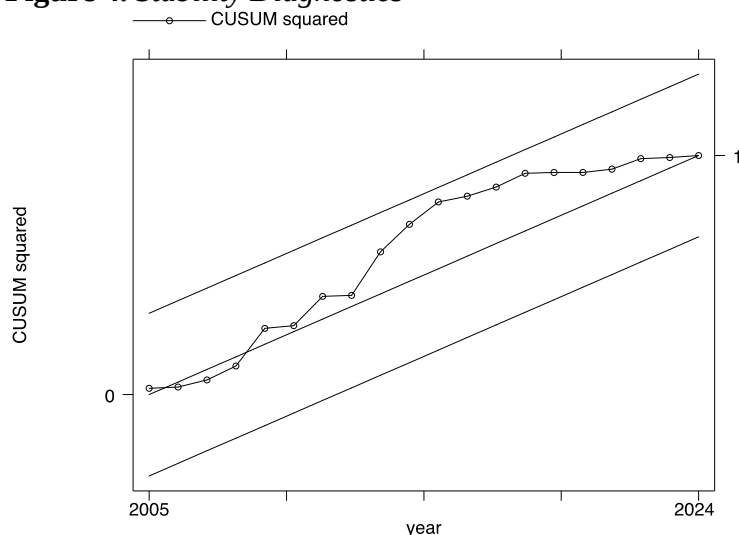
Test	Result	Validity
Jarque-Bera	p = 0.71	Passed (Normality confirmed)
Breusch-Godfrey Test	p = 0.10	Passed (No serial correlation)

Source: Calculation of authors

The validity of the ARDL model was checked for the structural stability by Cumulative Sum of Squares (CUSUMSQ) test. As illustrated in Figure 4, the CUSUMSQ statistic remains

strictly within the 5% critical values within the sample period (2000–2024). This indicates that the coefficients in a time-series regression are stable over time and that the model is not subject to structural instability or parameter shifts. Consequently, the evidence from long-run and short-run coefficients reported in this study can be considered relevant for policy recommendations.

Figure 4. Stability Diagnostics



Source: Calculation of authors

To investigate the long-run and short-run dynamics between GDP growth and its determinants, this study applies the Autoregressive Distributed Lag (ARDL) bounds testing approach developed by Pesaran et al. (2001). Given the sample size ($T=24$), the ARDL framework stands as relevant because it provides more reliable outcomes in small samples compared to traditional cointegration tests like Johansen Test. Although the VAR Selection Order Criteria suggested an optimal lag length of four based on the AIC, given the limited sample size, using four lags would severely affect the degrees of freedom and lead to risk of overfitting. Therefore, we limited the maximum lag to 1 given the annual frequency of the data and the sample size. The model was estimated using the Bayesian Information Criterion (BIC) to ensure parsimony and prevent overfitting, resulting in ARDL (1, 1, 0, 1) specification.

The existence of a long-run relationship is tested using the ARDL Bounds Test for cointegration (see Table 2). If the F-statistic exceeds the upper critical bound, we reject the null hypothesis of no cointegration and proceed with the Error Correction Model to interpret the long-run coefficients. The results indicate that F-statistic is 8.95, and it significantly exceeds the upper bound critical value of 4.35 at the 5% significance level. Consequently, the null hypothesis of no cointegration is rejected. This finding reveals a stable, long-term relationship between GDP growth, domestic credit to the private sector, exports, and gross capital formation.

Table 2. ARDL Bounds Test

Test Statistic	F-statistic	I(0) bound	I(1) bound
K (3)	8.95	3.23	4.35

Source: Calculation of authors

FINANCE-GROWTH NEXUS AND ADOPTION OF ARTIFICIAL INTELLIGENCE IN AZERBAIJAN

3.1 Descriptive Statistics

Initial investigation of the key descriptive features in Table 3 provides several important insights about the data:

- GDP growth exhibits relatively high volatility, with a standard deviation 9.4% that actually slightly exceeds its mean 7.4%. The large difference between a minimum and a maximum confirms the presence of significant structural shocks in the economy.
- The high mean value of 50.3% for exports indicates that the economy of Azerbaijan is highly open and export-oriented.
- Domestic credit to the private sector issued by banks has a mean of 18.3%, but its maximum achieves 38.4% proposing about the period of extensive credit growth.
- Gross Capital Formation averages 25.6% of GDP, which is a good level for the development of economy with its peak at 57.9% suggesting about periods of massive capital investment.

Table 3. Descriptive statistics

Variable	Obs.	Mean	Std. Dev	Min	Max
<i>Domestic credit to private sector by banks</i>	25	18.3%	8.5%	5.1%	38.4%
<i>Exports</i>	25	50.3%	8.9%	35.6%	68.1%
<i>GDP growth</i>	25	7.4%	9.4%	-4.1%	34.4%
<i>Gross capital formation</i>	25	25.6%	10.8%	12.0%	57.9%

Source: Calculation of authors

Expectations regarding a sign of coefficients are summarized in Table 3.

Table 4. Expectations on sign of coefficients

Variable	Expected sign
Exports (Trade openness)	(+) because of export-led growth
Capital Formation (Investments)	(+) reflects productive capacity
Domestic credit to private sector by banks (Financial Development)	(+/-) depending on the efficiency of allocation

Source: Calculation of authors

Table 5. Correlation analysis

	GDP growth	Domestic credit	Exports	Gross capital formation
GDP growth	1.00			
Domestic credit	-0.56	1.00		
Exports	0.60	-0.24	1.00	
Gross capital formation	0.29	-0.34	-0.14	1.00

Source: Calculation of authors

To identify the existence of multicollinearity, we perform correlation analysis in Table 5 and find out that independent variables do not exhibit strong correlation among each other. Notably, there is a strong negative correlation between economic growth and domestic credit to private sector with a coefficient of -0.56.

3.2 ARDL model: Empirical Results**Table 6.** Regression Output

	Coefficient	p-value
Adjustment Term		
GDP growth (Lag 1)	-0.6264***	0.000
Long-Run Coefficients (LR)		
<i>Domestic Credit</i>	-0.6657*	0.010
<i>Exports of Goods and Services</i>	0.0045	0.987
<i>Gross Capital Formation</i>	0.3653*	0.042
Short-Run Coefficients (SR)		
Δ <i>Domestic Credit</i>	0.4683	0.087
Δ <i>Gross Capital Formation</i>	-0.7082***	0.001
<i>Constant</i>	5.8775	0.587
<i>R-squared</i>	0.71	

Source: Calculation of authors

Table 6 represents both long-run coefficients and short-run coefficients for ARDL (1, 1, 0, 1) regression model. Attained results in the long run correspond to our expectations and align with previous findings from descriptive statistics. Error correction term, which reflects our adjustment term stands out as a very important indicator, because it is estimated at -0.62 and is statistically significant ($p < 0.05$). The negative sign and significance admit the stability of the model. This coefficient shows the speed of adjustment, where 62% of the deviation from the long-run equilibrium in one period is corrected in the following year.

Meanwhile, a capital investment appears to be a prominent driver of growth in Azerbaijan in the long run. Interestingly, the change in the amount of capital investments had a negative impact in the short run, presumably because of the fiscal burden from large-scale projects especially in oil and gas sectors of the economy. Unexpectedly, exports did not stand as significant factor contributing to economic growth in Azerbaijan. To be more precise, under the period of study, the 'export-led growth' hypothesis was not valid for this economy. While the descriptive statistics show that exports account for a large portion of GDP with a mean value of 50.3%, export volume does not appear to be a primary driver of long-term GDP growth when compared to capital investment and credit volume. In the context of Azerbaijan, the main exported goods are raw materials that low-value added and as a result do not create spillover effects on growth. In typical Dutch Disease framework, the reliance on low-value-added raw materials prevents the development of a well-diversified manufacturing sector, which is the primary engine of sustainable export-led growth. As a result, this concentration in the sector of natural resources triggers currency appreciation, making non-resource exports uncompetitive.

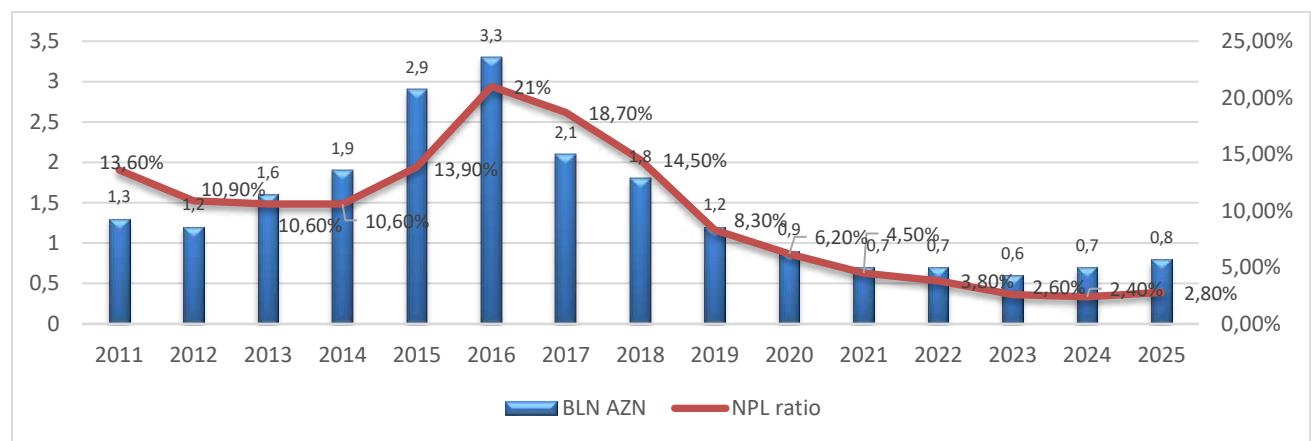
When it comes to credit volume provided by banks to the private sector, we find remarkable results. According to regression findings, a credit volume has a significant detrimental impact in the long run. Empirical evidence suggests that excessive levels of debt relative to GDP in the observed period might hampered long-term growth. But in the short run, a change in credit volume affected GDP growth in a positive way even though not significant. Negative long run coefficient for domestic credit can be explained as debt overhang when lending by banks and non-bank financial institutions directed towards unproductive sectors. Under the "Debt Overhang" hypothesis, credit expansion initially facilitates economic growth primarily via increased spending and consumption; however, after a while, accumulation of

private sector debt might be the case due to inefficient allocation of financial resources or high debt-servicing costs that eventually suppress long-term growth.

The divergence between the positive impact of physical capital and the negative impact of domestic credit implies a "financial-real sector gap." While physical assets contribute to the productive capacity, the financial tools may be inefficient or directed toward non-productive sectors, creating a long-term constraint on economic expansion.

To revise the historical background of the banking sector and support debt overhang hypothesis we decided to analyse asset quality of the banking sector from 2011 to 2025 in Azerbaijan (Central Bank of the Republic of Azerbaijan, 2024b). As it becomes clear from the descriptive graph (Figure 3), there was an upward trend in the ratio of non-performing loans (NPL) with a peak in 2016 at 21%. Only after 2018, asset quality improves and NPL drops below 9%. A high NPL ratio indicates that a significant portion of domestic credit was not used for productive, income-generating activities. Instead, it suggests financial resources might be allocated to projects that failed to generate the growth needed to pay the interest.

Figure 3. *Dynamics of non-performing loans in the banking sector*



Source: Central Bank of the Republic of Azerbaijan. Financial Stability Report (2024)

3.3 SWOT Analysis on adoption of AI in Azerbaijan

The adoption of AI in the financial sector of Azerbaijan reflects a broader goal of transition toward data-driven, automated, and increasingly digitalised financial systems. A critical factor affecting this transition is the strategic policy framework, reflected particularly in the Financial Sector Development Strategy 2024–2026 and the Artificial Intelligence Strategy for 2025–2028.

The Financial Sector Development Strategy 2024–2026 focuses on the modernization of financial infrastructure, the expansion of digital payment systems, the strengthening of financial stability, and the promotion of innovation within the banking and fintech ecosystem (Central Bank of the Republic of Azerbaijan, 2024a). Within this framework, AI is implicitly perceived as a capable technology that can enhance efficiency, improve supervisory capabilities, and support more resilient financial systems. At the same time, the AI Strategy (2025–2028) provides a more explicit roadmap for the adoption of artificial intelligence across sectors, including finance.

"Azerbaijan 2030: National Priorities for Socio-Economic Development" offers a great chance to introduce AI in the financial sector with a focus on digital transformation, development of human capital, innovation-based competitiveness, and restructuring of the economy in a sustainable way (Isayev, 2025).

Within the context of Azerbaijan's Financial Sector Development Strategy, the adoption of such technologies responds to broader goals of digital transformation and innovation. However, these advancements also introduce new risks, including model opacity, algorithmic bias, and the potential for market volatility caused by high-frequency trading strategies. These challenges underscore the importance of integrating these technologies with robust SupTech and RegTech frameworks, ensuring that regulators can effectively monitor algorithmic behaviour through real-time data analytics. The strong data management systems are particularly critical, as AI models need large volumes of high-quality data to function accurately.

The advantages of the implementation of AI in the financial industry include the ability to enhance financial stability through the improvement of risk management, liquidity optimization, as well as the improvement of operational efficiency, as they are capable of analysing enormous amount of data quickly and accurately compared to human beings. Therefore, they enable the bank or any player in the market to make the most appropriate decisions taking into account the dynamics of the market. Moreover, the existence of ML, deep learning, and natural language processing presents great opportunities to switch from linear or historical precedents to the analytics that autonomously identify emerging patterns and continuously refine their predictive accuracy as new data becomes available (Sarna et al., 2025).

Table 7 summarizes the key strengths, weaknesses, opportunities and threats expected from adoption of AI in the financial sector.

Table 7. SWOT analysis

Strengths	Weaknesses
Strong policy framework (Financial Sector Development Strategy 2024–2026 and AI Strategy 2025–2028)	Limited availability of specialists in this field
Rapid digitalisation of financial infrastructure and development of payment systems	Skills gap in AI, data science, and interdisciplinary expertise
Risk-based supervision approach	Dependence on foreign AI technologies
Government commitment to digitalisation, innovation, and fintech growth	Early-stage adoption of advanced AI (e.g., generative AI, robo-advisory)
Growing data generation due to digital payments and banking platforms	Limited domestic research in AI
Opportunities	Threats
Strategic promotion for AI adoption under AI Strategy (2025–2028)	Insufficient regulatory framework regarding AI governance
Expansion of cashless economy and digital financial services	Imperfections of AI-based systems (hallucinations, opacity, bias, lack of explainability)
Development of SupTech and RegTech under financial sector reforms (integration of AI and ML in risk scoring)	Cybersecurity risks and vulnerabilities in AI-driven systems
Potential to build a regional fintech and AI innovation hub	Over-reliance on global AI providers and technological dependency
Human capital development and AI education initiatives	Global competition from technologically advanced economies
Adoption of open-source AI to localize solutions and reduce costs	Low acknowledgment and adoption barriers among users and institutions

4 Discussion

This article provides a comprehensive framework for studying dynamics and implications of financial development in Azerbaijan. The research design of study consists of time series regression analysis and qualitative SWOT analysis. The main research question is to find out the impact of financial development on economic growth in Azerbaijan within 2000-2024 period. The results of regression analysis reveal that in the short run credit expansion facilitates access to finance as it is supported by classical financial intermediation theory, whereas in the long run enlarging size of debt burden influences the economic growth rate in detrimental way. This pattern implies that debt overhang can cause emergence of Ponzi Finance (Minsky, 1975). These results coincide with empirical finding of Deryag and Khalifa (2024) where the financial development exhibited a negative relationship with economic growth across selected Arab economies. In these countries, financial systems might be oriented toward servicing government and resource-related sectors and possess weak institutions.

Besides that, another important finding demonstrates the existence of gap between real and financial sector stemming from possible inefficient allocation of financial resources in the economy when funding was not channelled to the productive sectors. Such inefficiency might imply about prevalence of costly intermediation or weak monitoring measures similarly discussed in the study of Moemeke et al. (2025). In addition to these findings, our estimates did not confirm the export-led growth hypothesis for the economy despite initial expectations. This contradiction can be explained by the tendency of resource-based economies to concentrate most of the factors of production in resource sector (crude oil, natural gas, minerals) and to appreciate real exchange rate thus making domestic production uncompetitive.

We can conclude that economic diversification is essential in this case through targeted investments in infrastructure, manufacturing, human capital, and technology to improve a competitiveness of non-oil sector. A stable real exchange rate and effective counter-cyclical fiscal rules can help a country to reach a path to sustainable and long-term development. The role of financial markets in achieving this goal is crucial as there is a clear evidence on positive effect of financial intermediation on economic growth. The public authorities can achieve this target by introducing policy incentives to stimulate investments in productive sectors.

Nowadays automated and digitalised financial systems can promise fast and long-lasting development phase for developing nations by removing liquidity constraints, ensuring efficiency and stability, and enhancing supervisory capability in financial markets. AI appears to be a significant modifier and contributor to digitalization of financial services. The implementation of AI-based models in financial sector promotes innovation and profitability, however, their execution is accompanied with a lot of challenges such as cyber-attacks, algorithmic bias, opacity, hallucinations, black-box problem and etc. To preserve financial stability, integration of AI and ML into financial sector requires strict supervisory and regulatory framework. A SWOT analysis shows that there is a necessity to establish comprehensive regulatory framework for AI governance to overcome these challenges for foreseeable future in Azerbaijan.

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FUTURE OF LOGISTICS: AI-DRIVEN TRANSFORMATION IN MULTINATIONAL CORPORATIONS

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Abstract: *The current work explores how multinational companies (MNCs) utilize artificial intelligence (AI) in logistics processes while ensuring the value-added contribution of human expertise cannot be substituted. A systematic literature review combined with a comparative case study approach that analyzes six MNCs provides an assessment of how different AI capabilities and human contributions are employed in four key logistics sectors: demand forecasting, transport optimization, warehouse operation, and risk management within the supply chain. It is shown that there are tangible benefits from using artificial intelligence, such as cost savings estimated at 100 million miles a year achieved by UPS ORION as well as over 750 thousand autonomous robots used by Amazon without reducing the number of employees. Still, artificial intelligence performs poorly when dealing with non-stationary situations and new risks, thus requiring human expertise for efficient performance. The major conclusion made in this work is that the most successful logistics operations treat artificial intelligence and human contribution as complements rather than substitutes.*

Keywords: *artificial intelligence, global logistics, multinational corporations, supply chain resilience, human-AI collaboration, digital twins, operational efficiency*

1 Introduction

The global logistics industry is undergoing a fundamental transformation driven by artificial intelligence. For multinational corporations (MNCs), which manage supply chains spanning dozens of countries, thousands of suppliers, and millions of daily transactions, AI has moved from a peripheral technology investment to a strategic operational necessity. Machine learning algorithms now forecast demand with accuracy that manual methods cannot match. Autonomous vehicles and robotics are redefining warehouse operations. Predictive analytics identifies supply chain disruptions before they materialize. Digital twin technologies allow entire logistics networks to be simulated, stress-tested, and optimized in real time (Kagermann et al., 2013; Toorajipour et al., 2020). The strategic significance of AI in logistics extends beyond firm-level operations; at the national policy level, governments in emerging economies are increasingly recognizing AI-driven logistics optimization as a core instrument of economic diversification and infrastructural modernization (Isayev, 2025)

Nevertheless, there remains a constant and overlooked dichotomy throughout the AI-assisted logistics literature and industry applications: what AI systems can analyze and what human knowledge can comprehend. AI is adept at recognizing patterns within vast databases, optimizing for certain criteria, and implementing routine tasks in bulk. However, it is inept when it comes to handling unfamiliar circumstances, making moral decisions, and dealing with interpersonal relationships that will make or break the logistics initiative (Shyam Sundar, 2020). If an AI route optimization algorithm generates suggestions that seasoned logistics

professionals see as unfeasible, then the AI's suggestions must be corrected by a human operator. If a customs agency enforces a rule outside the scope of training data used in machine learning algorithms, then those same algorithms could generate erroneous results before receiving further training.

This paper addresses a research question that sits at this intersection: How do MNCs effectively integrate AI into logistics operations while preserving and leveraging the irreplaceable contributions of human expertise? The question is practically urgent. MNCs that adopt AI without addressing the human-AI integration challenge risk over-reliance on algorithmic outputs in contexts that require contextual judgment, and under-utilization of AI capabilities in contexts where data-driven optimization could significantly enhance performance.

The paper proceeds as follows. Section 2 reviews the literature on AI applications in logistics, the limitations of AI systems, and the role of human expertise. Section 3 describes the methodology. Section 4 presents a comparative analysis of AI capabilities and human contributions across four core logistics domains, illustrated with MNC case evidence. Section 5 proposes a conceptual framework for human-AI synergy in logistics. Section 6 discusses implications for practice. Section 7 concludes.

2 Literature Review

2.1 AI Applications in MNC Logistics

The literature on artificial intelligence applications is growing to illustrate its extent within logistics operations. For instance, Toorajipour et al. (2020) carried out a systematic review on the usage of AI in supply chain management and concluded that demand forecasting, inventory management, transport route planning, and supplier selection were among the most researched areas for AI implementation. Machine learning, especially deep learning and ensemble models, has been found to dominate artificial intelligence applications within these areas due to access to large transaction data and measurable performance results.

Forecasting is considered to be one of the most developed AI applications in logistics. Conventional approaches to demand prediction like exponential smoothing or Autoregressive Integrated Moving Average (ARIMA) models work effectively only during times of demand stability, while their performance falls apart during the times of demand volatility caused by the effect of some external variable like the state of the economy, society, or weather (Carbonneau et al., 2008). In its turn, machine learning can integrate both structured and unstructured data in addition to the time series and produce more precise forecasts. One of the most examined cases of applying Machine Learning (ML) algorithms to demand prediction belongs to Amazon, where improvements in forecast precision resulted in lower inventories and decreased chances of shortages (Brynjolfsson & McAfee, 2017).

Route optimization using AI technologies has proved to be revolutionary in planning and logistics management. Traditional approaches used to solve vehicle routing optimization problems involving many routes in the logistics of multinational corporations are simply unrealistic to consider. Such approaches include genetic algorithm, reinforcement learning, and graph neural network, providing near-optimal solutions in a relatively short time (Bengio et al., 2020). One can cite UPS ORION technology as an example that uses advanced routing algorithms in its deliveries and saves over 100 million miles of driving per year (UPS, 2018).

Warehousing automation using computer vision, robotics, and artificial intelligence-based inventory management is yet another application area that is witnessing accelerated implementation. In this regard, the application of around 100,000 robots by Amazon robotics for performing warehouse functions is the testimony that could be considered regarding the current AI-based automation of warehousing. According to reports by DHL Trend Radar

(2024), DHL has employed AI-based vision technology to improve sorting processes and quality checks.

The development of digital twins which are virtual copies of logistics processes that receive updates in real time based on operational data is another relatively new but fast-growing use of AI. Through simulation of the logistics network process in different scenarios, digital twins can help MNCs find any weaknesses in their system, develop a strategy to mitigate risks, and optimize their network configuration without affecting operational processes (Grieves & Vickers, 2017). This technology has received considerable attention from both Maersk and Siemens.

2.2 Limitations of AI in Logistics

Despite its demonstrated capabilities, AI in logistics is subject to well-documented limitations that constrain its performance in real-world MNC operating environments. However, such challenges are not necessarily issues that result from technical flaws per se, rather they are the limitations associated with the nature of what the system is able to accomplish.

Quality and availability of data are among fundamental limitations. Machine learning algorithms are built based on historical data and their effectiveness highly depends on the quality and adequacy of such data (Toorajipour et al., 2020). Quality issues related to data in MNC logistics are ubiquitous: legacy IT systems generate non-uniform data, visibility within supply chains tiers is often insufficient, and real-time data from the logistics providers and suppliers might be unattainable.

Distribution shift – the decline in model effectiveness resulting from differences between actual circumstances and training data – is a critical issue in logistics. Logistics operations involve constantly evolving networks that could be impacted by geopolitical tensions, policy shifts, sudden surges in demand, and other factors that are not included in training data. The coronavirus pandemic has highlighted the vulnerability of the logistics AI systems built using pre-pandemic demand trends; AI models that worked well for decades suddenly gave incorrect results when demand patterns changed (Ivanov & Dolgui, 2020).

The problem with explainability constraints is the reduced effectiveness of the AI output when understanding the decision-making process of recommendations by the decision maker is necessary. This issue emerges since most successful AI models like deep neural networks and gradient boosting algorithms are black boxes, meaning that their output does not contain an explanation of its process. This poses governance problems for decision makers dealing with logistics issues where recommendations are contractually, safely, or legally bound (Shyam Sundar, 2020).

2.3 The Human Factor in AI-Enabled Logistics

The weaknesses of AI technology indicate that human knowledge will remain indispensable in logistics management. Logistics managers with hands-on experience have a bundle of skills that is fundamentally distinct from the skills provided by AI-based technologies, which include contextual reasoning, relationship management, ethical reasoning, and sensing and responding to emerging situations beyond the scope of historical training datasets.

Research on human-AI collaboration in organizational contexts suggests that the most effective configurations are neither full automation nor full human control, but rather structured complementarity in which AI handles the tasks it performs better high-volume, data-intensive, pattern-recognition tasks and humans handle those they perform better contextual interpretation, stakeholder management, ethical oversight, and exception handling (Wilson,

2018). In logistics, this complementarity is increasingly documented in empirical research and practitioner accounts.

Interpersonal cooperation between various departments represents another example of a human input that cannot be substituted by an artificial intelligence. For instance, efficient logistic management of a multinational enterprise requires perpetual collaboration between such business divisions as procurement, production, sales, customs, and customer services. It is only a human logistic specialist who is able to maintain interpersonal relationships within the company in order to facilitate productive cooperation at tough times (Christopher, 2016).

3 Methodology

The methodology for this research will involve a two-step process: (1) a literature review of peer-reviewed journal papers (2013–2026) listed on Scopus, Web of Science, and Google Scholar; and (2) case study analysis of the implementation of MNCs based on public reports. The case study part of this research will include cross-case comparative analysis of selected MNCs in terms of AI implementation processes, performance statistics, and human-AI collaboration models, focusing on six different companies: Amazon, UPS, DHL, Maersk, Siemens, and Walmart. Numerical measures from company reports and peer-reviewed articles, such as increased forecast accuracy and reduced number of errors, will be used as empirical support for any theoretical claims developed. This type of methodology is most suitable for this particular research because its purpose is to create a practically driven conceptual model of human-AI integration in MNC logistics.

The literature review stage adopted the modified Preferred reporting items for systematic reviews and meta-analyses (PRISMA) approach. Sources were found by searching Scopus, Web of Science, and Google Scholar for academic papers using keywords such as artificial intelligence logistics, machine learning supply chain, human-AI cooperation, digital twin logistics, MNC supply chain management, and more. The time limit was set to articles written between 2013 and 2026, capturing the period during which commercial logistics started making use of AI technologies. Articles published in peer-reviewed journals were preferred, complemented by conference papers and professional reports published by industry research institutions such as DHL Trend Radar, McKinsey & Company, and Gartner.

The empirical case evidence stage relies on public sources of information about leading MNCs using AI logistics solutions: Amazon, UPS, DHL, Maersk, Siemens, and Walmart. Such companies were chosen based on the availability of data and their coverage of various logistics sectors: e-commerce fulfilment logistics, parcel delivery logistics, freight logistics, maritime logistics, industrial logistics, and retail supply chain logistics. Empirical data was obtained from company reports, published case studies, and peer-reviewed journal articles without conducting any fieldwork, which is considered the shortcoming of the present research.

The analysis proceeds through two stages. In the first stage, AI capabilities and human contributions are mapped across four core logistics domains demand forecasting, transportation optimization, warehouse operations, and risk management drawing on both literature and case evidence. In the second stage, the patterns identified in the domain-level analysis are synthesized into a conceptual framework for human-AI synergy. The framework is assessed against the case evidence for coherence and practical relevance.

4 AI Capabilities and Human Expertise Across Logistics Domains

4.1 Demand Forecasting

Demand forecasting is among the topmost valuable use cases for AI technology in MNC logistics operations and also one of the most extensively researched topics. Machine learning algorithms, especially Long Short-Term Memory (LSTM) neural networks, gradient boosting models, and ensemble methods, significantly surpass statistical techniques when it comes to

large-scale and multivariate demand forecasting (Carbonneau et al., 2008). Amazon's machine learning forecasting system analyzes billions of data points every day using historical sales data, price information, promotional schedules, competitor actions, and macroeconomic factors to produce forecasts at the item level in its international online marketplaces. Third-party estimates suggest that AI-powered demand forecasting has enabled Amazon to save approximately 20%–30% more compared to the traditional approach regarding holding costs. At the same time, stockout risk on high-velocity Stock-Keeping Units (SKUs) is likely lower by 15%–25% (Brynjolfsson & McAfee, 2017; McKinsey & Company, 2025). Walmart reports similar improvements, as its machine learning forecasting system used in more than 10,000 stores worldwide has cut forecast errors by about 20% compared to the preceding statistical methods, allowing corresponding savings on safety stock.

In contrast, the coronavirus disease outbreak was a world-wide natural experiment that highlighted the limitations of data-based demand forecasting techniques. During the abrupt change in consumer behavior in March 2020 when consumer demand for certain products plummeted while other categories experienced unpredictable growth, the forecasts generated by models based on years of data were consistently erroneous (Ivanov & Dolgui, 2020). Human logistics planners at major retailers and consumer goods companies described overriding AI forecasts based on qualitative intelligence news reports, supplier communications, customer conversations that the models could not process. Walmart's supply chain teams provide a well-documented illustration: in April 2020, as AI models continued to recommend drawdowns in sanitiser and paper goods inventory based on pre-pandemic baselines, experienced supply chain planners manually overrode replenishment orders by factors of 3–5× in affected categories, drawing on store-level manager reports of empty shelves and direct supplier calls that preceded data system updates by 48–72 hours. It is estimated that this human intervention saved from stockouts worth hundreds of millions of dollars in the United States Walmart network during the crucial March-May 2020 period (Ivanov & Dolgui, 2020; McKinsey & Company, 2025). The episode illustrates both the economic stakes of human-AI complementarity and the conditions under which human override authority generates measurable commercial value.

This episode illustrates the complementarity principle in forecasting: AI systems perform best under conditions of distributional stability, while human experts provide critical value during distributional shifts that fall outside model training ranges. Effective MNC forecasting practice increasingly embeds this complementarity in formal processes using AI outputs as baselines that human planners review, annotate, and adjust based on contextual intelligence that the models do not incorporate.

4.2 Transportation Network Optimization

Transportation optimization represents a domain where AI's computational advantage over human cognition is particularly pronounced. Vehicle routing that maximizes the efficiency of delivery schedules using algorithms over extensive networks with time windows, capacity restrictions, and traffic flows cannot be done manually and is unsolvable using traditional computing. AI-based vehicle routing takes care of these issues constantly by integrating real-time data gathered from Global Positioning System (GPS), traffic flows, weather patterns, and fuel costs to create and update the best possible routes (Bengio et al., 2020).

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Table 1. Illustrative MNC Case Evidence: AI Deployment, Quantified Outcomes, and Human-AI Integration

MNC	Domain	Quantified AI Outcome	Human Integration Role	Economic Tie
Amazon	Warehouse automation	750,000+ AMRs; 3× processing speed uplift; pick accuracy >99.9%	Picking, packing, exception handling, robot fleet oversight	Reduced mis-ship costs; workforce grew to 1.5M despite automation
UPS	Route optimization	~100M miles saved/year; ~\$400M annual cost savings; 100,000t CO2 reduction	Driver override authority (~5–8% of routes); local knowledge integration	Fuel, emissions, and delivery cost savings; driver roles upskilled
DHL	Parcel sorting & routing	30,000 parcels/hr throughput; mis-sort rate <0.01%; 15–20% hub labour cost saving	Exception handling (~3–5% of volume); Quality Assurance (QA) supervision; route review (15–20% of cases)	Reduced delivery error costs; stable human oversight share signals structural role
Maersk	Risk management	50,000+ variables monitored; 48–72hr disruption lead time; ~3–5 major delays avoided/month (\$0.5–2M each)	Command centre operators hold rerouting authority; apply regulatory & commercial judgment	Proactive cost avoidance in millions per incident; preserves customer relationships
Walmart	Demand forecasting	~20% forecast error reduction vs prior methods; 10,000+ stores globally; safety stock proportionally reduced	Planners manually overrode AI orders by 3–5× during COVID-19; applied qualitative supplier intelligence	Hundreds of millions in stockout costs avoided during pandemic; lower carrying costs in normal operations

Note: Quantified outcomes derived from corporate reports, peer-reviewed analyses, and McKinsey & Company (2025). Estimates are indicative and subject to methodological variation across sources.

The ORION system developed by UPS is one of the best-documented examples of AI-based route optimization in an MNC environment. ORION operates based on information collected for about 55,000 routes every day. It includes over 250 million addresses along with data on operations in order to create optimized routes for drivers. Thanks to its use, UPS saves about 100 million miles driven each year, which results in an annual savings of around \$400 million in terms of fuel costs and emissions of 100,000 metric tonnes of Carbon Dioxide (CO₂). This pattern of AI-driven route optimization generating measurable economic and environmental gains is not confined to Western MNCs. In state-coordinated AI ecosystems such as China's, digital platform infrastructure, including logistics optimization engines developed by firms such as Alibaba and Huawei has enabled AI diffusion into logistics operations across enterprises of varying scales, suggesting that the competitive advantages documented in UPS's case are increasingly accessible beyond the largest global operators (Isayev, 2025). Importantly, it is vital to understand that ORION acts as a decision-making aid rather than a completely autonomous system; the drivers still possess the discretion to disregard the algorithm-generated routing instructions based on their knowledge about the state of particular roads or customers' accessibility, factors not included by the system. According to UPS, it is estimated that the number of cases where the drivers override the instructions generated by the system comprises about 5-8% of all daily routing decisions; analysis has proved that in many cases, such actions help deliver better results compared to those provided

by the algorithm itself (UPS, 2018). Finally, the example of the ORION system demonstrates the process of the job transition typical for good Human + AI Delivery Lifecycle (HAIL) systems.

DHL's use of AI-powered dynamic route optimization across its express delivery network similarly demonstrates both the scale of AI contribution and the continuing role of human expertise. DHL logistics operations managers report that algorithm-generated routes require human review in approximately 15–20% of cases, where local knowledge, regulatory requirements, or unusual operational circumstances require adjustment (DHL Trend Radar, 2024). This review function human validation of AI outputs at the exception boundary is a recurrent pattern across MNC logistics operations.

4.3 Warehouse Automation and Operations

Warehouse operations represent perhaps the most visible domain of AI deployment in MNC logistics. Computer vision systems for parcel sorting, identification, and quality inspection; autonomous mobile robots for goods-to-person fulfilment; AI-powered inventory management systems; and predictive maintenance platforms have collectively transformed the economics and performance characteristics of large-scale warehouse operations.

The use of autonomous mobile robots (AMRs) by Amazon Robotics across the entire fulfillment network owned by the company is the most well-researched instance. As per information available as of 2023, Amazon uses more than 750,000 AMRs in their fulfillment centers where robots manage the movement of inventory pods and humans take care of picking, packing, and any exception handling activities that require manual skills on the job (Greenawalt, 2025). According to Amazon, fulfillment centers supported by AMRs process orders almost 3× faster than those without robots and have pick accuracies greater than 99.9%, metrics that can be translated into savings on the cost of mis-ships, returns, and call centers for customer services. More importantly, the workforce of Amazon grew with the increase in deployment of AMRs; while the workforce stood at 250,000 in 2019, the number jumped to 1.5 million by 2023 (Greenawalt, 2025). This highlights the fact that the deployment of AMRs transformed human roles rather than diminished them. Human-robot collaboration at Amazon was designed keeping the following idea in mind; the robot took care of repetitive work whereas the human did what a robot could not do. Human job profiles in AMR-enabled facilities have evolved toward roles in robot fleet oversight, exception resolution, quality assurance, and systems configuration higher-skill categories commanding correspondingly higher compensation.

The deployment of AI-powered vision systems in DHL for the sorting of parcels in sorting centers also follows the same trend. Computer vision is used to classify, sort, and analyze parcels at an output of up to 30,000 parcels per hour, which is roughly 4-5 times faster than the maximum rate achieved by humans at the sorting center, all the while ensuring that fewer than 0.01% of parcels are mis-sorted compared to the human error rate of around 0.1-0.3%. Nonetheless, there are still areas where humans have some supervisory responsibility within the process: exception handlers sort parcels when the visual recognition system is unable to reliably classify them (about 3-5% of the total parcel volume), quality controllers evaluate system performance and look for patterns of decline, and operations managers make sense of the system's performance information to inform decisions about configuring and maintaining the system (DHL Trend Radar, 2024). DHL has found that routes planned using algorithms for their express delivery service network need human intervention about 15-20% of the time, and this proportion has not changed even as their AI capabilities have improved over time.

4.4 Risk Management and Supply Chain Resilience

Supply chain risk management is a domain where the complementarity of AI and human expertise is particularly consequential, because the stakes operational disruptions, financial

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losses, reputational damage are high and the range of relevant risk factors is broad, heterogeneous, and difficult to fully encode in training data. Enterprise resilience in the context of digitalization has been defined as the capacity of organizations to integrate digital technologies in order to maintain competitiveness, ensure business process continuity, and absorb shocks of various kinds (Sorokina & Lebedeva, 2025). In the specific domain of MNC logistics, this general principle acquires particular operational urgency: supply chain risk management is a domain where the complementarity of AI and human expertise is especially consequential, because the stakes, operational disruptions, financial losses, reputational damage are high and the range of relevant risk factors is broad, heterogeneous, and difficult to fully encode in training data

AI-based risk management in logistics relies mainly on anomaly detection, disruption prediction, and scenario testing. Machine learning models based on disruption information from past events help detect unusual supplier lead times variations, weather patterns, port congestion signals, which will likely precede supply chain disruptions allowing for preventive measures to be taken against them (Toorajipour et al., 2020). The application of AI-based risk management by the shipping company Maersk is a great example of how useful it can be in business operations. This risk management system is based on tracking more than 50,000 variables every minute, such as Automatic Identification System AIS signals from vessels, weather data, port congestion, and geopolitical risks with a lead time of disruption warnings being given 48-72 hours before the disruption impact becomes observable (Maersk, 2022). Maersk believes that having early warning capabilities of such a nature means that preemptive rerouting decisions can be made which would not lead to delays of three to five large vessels per month, which would have a monetary value ranging from \$500,000 to \$2 million each, dependent on the size of the ship, value of cargo onboard, and any additional implications that may arise due to delays. The output from the AI is also taken by human operators in order to make decisions about risks, wherein Maersk's operations command center is responsible for making all decisions regarding the rerouting of ships.

However, the most consequential supply chain risks are by definition the least historically precedented geopolitical shocks, pandemic events, major climate disruptions, sudden regulatory changes. These types of risks can only be predicted to an extent using machine learning based on historical data. Companies that coped best with supply chain disruptions in the context of the pandemic were those whose logistics management teams had considerable experience with analyzing new circumstances, leveraging their supplier network through personal contacts, and making decisions in conditions of uncertainty and lack of data (Ivanov & Dolgui, 2020). These capabilities the judgment, relationships, and situational assessment of experienced human professionals are not substitutable by algorithmic systems operating within the bounds of their training distributions.

Table 2 summarizes the complementary roles of AI and human expertise across the four logistics domains examined.

Table 2. *Human-AI Complementarity Across Core MNC Logistics Domains*

Logistics Domain	AI Contribution	Human Contribution	Integration Point
Demand forecasting	Pattern recognition; multi-variable processing; baseline generation	Contextual adjustment; qualitative intelligence; distributional shift response	Human review and annotation of AI baseline forecasts
Transportation optimization	Real-time multi-variable routing; fuel and time optimization	Local knowledge; safety judgment; exception routing	Human override authority on AI-recommended routes

Warehouse operations	High-volume repetitive tasks; vision classification; predictive maintenance	Dexterous manipulation; exception handling; system oversight	Human-robot task division by capability type
Risk management	Anomaly detection; historical pattern matching; scenario simulation	Novel risk assessment; relationship mobilization; strategic judgment	Human-led response to out-of-distribution risk events

Note: Based on synthesis of reviewed literature and publicly available MNC case evidence.

5 A Conceptual Framework for Human-AI Synergy in MNC Logistics

From the analysis of MNC logistics operations on a domain level conducted in Section 4, it can be observed that both the use of artificial intelligence and human expertise can be more effective in settings where their strengths correspond to the nature of the operation being performed. The following section is dedicated to developing an integrated model for this collaboration.

The framework is organized around two axes. The first axis is task structure: the degree to which a logistics task involves well-defined parameters, large data volumes, and historically stable patterns conditions favorable to AI versus novel situations, contextual complexity, and relational dynamics conditions favorable to human expertise. The second axis is decision consequence: the operational and strategic significance of errors in task performance. Together, these axes define four quadrants that correspond to different optimal human-AI configurations.

In the high-structure, lower-consequence quadrant routine optimization tasks such as standard route planning, reorder point calculations, and parcel sorting full or near-full AI automation is appropriate and well-documented in practice. In the high-structure, high-consequence quadrant demand forecasting for strategic inventory positioning, risk monitoring for critical supply routes AI output with mandatory human review represents the dominant practical model. In the low-structure, lower-consequence quadrant exception handling for minor logistics deviations, routine supplier queries human judgment with AI-assisted information retrieval is appropriate. In the low-structure, high-consequence quadrant crisis response to major supply chain disruptions, strategic network redesign under uncertainty human leadership with AI-supported scenario analysis is the appropriate configuration.

This framework has three practical implications for MNC logistics management. First, AI deployment decisions should be preceded by task characterization along the two framework dimensions, rather than driven by technology availability or competitive imitation. Not all logistics tasks are equally suitable for AI automation, and misalignment between task characteristics and AI deployment creates performance risks. Second, human expertise development should be explicitly designed to address the domains where human contribution is most critical: contextual judgment, relationship management, ethical oversight, and crisis response. The risk that AI deployment erodes these human capabilities over time through skill atrophy in roles that become AI-dependent is a real organizational concern that requires deliberate management (Wilson, 2018). Thirdly, the interaction interfaces in which human decision makers interact with AI systems must be built to foster successful collaboration instead of merely outputting the results to be consumed by humans. This will involve using explainability technologies to help humans understand the reasoning of the AI technology, developing escalation procedures, and allowing human intervention in case there is any error in the operation of the AI system.

Table 3 presents the framework in structured form.

Table 3. *Human-AI Complementarity Across Core MNC Logistics Domains*

Quadrant	Task Characteristics	Optimal Configuration	MNC Example
High structure / lower consequence	Routine, data-rich, stable patterns	Near-full AI automation	Parcel sorting; standard route optimization
High structure / high consequence	Data-rich but strategically critical	AI output + mandatory human review	Demand forecasting; risk monitoring
Low structure / lower consequence	Novel but low-stakes	Human judgment + AI information support	Supplier exception handling; minor disruptions
Low structure / high consequence	Novel and strategically critical	Human leadership + AI scenario support	Crisis response; network redesign

Note: Based on synthesis of reviewed literature and publicly available MNC case evidence.

6 Discussion

There are some important implications of the findings presented within this paper that go beyond the technical issue of whether AI should be implemented within logistics processes or not. First of all, the fact that human expertise still plays an important role within the application of AI in logistics processes of MNCs refutes the widely spread belief that technologies, such as AI, could fully replace humans in the labor market. Instead, this finding implies that, through the application of AI, the nature of human activity will be transformed from being merely routine to managing exceptions.

For logistics managers in MNCs, the practical challenge is not whether to adopt AI but how to structure the organizational conditions that enable effective human-AI collaboration. This requires attention to several dimensions that the technology literature often underemphasizes. First, workforce development must anticipate the changing skill requirements of AI-enabled logistics roles: data literacy, algorithm interpretation, exception management, and cross-functional coordination capabilities become more critical as routine operational tasks are automated (Wilson, 2018). Second, governance structures must explicitly address the accountability questions raised by algorithmic decision-making: who is responsible when an AI routing decision contributes to a delivery failure, a safety incident, or a contractual breach? Clear accountability frameworks not merely technical safeguards are necessary for responsible AI deployment at MNC scale.

The case evidence reviewed in this study suggests that the MNCs achieving the strongest logistics performance outcomes from AI are those that have invested comparably in both AI capabilities and human capability development, and that have designed explicit integration interfaces between the two. The Amazon human-robot cooperation model, the UPS ORION model with the authority to override AI decisions by drivers, and the DHL model involving humans who oversee AI-based vision systems all illustrate that the organizations behind them have consciously designed their operations in ways that view AI and humans as complements to each other in their respective capacities. This finding aligns with broader empirical evidence on enterprise digitalization: organizations that fail to embed digital technologies structurally, rather than adopting them selectively or partially, demonstrate substantially reduced adaptability to macroeconomic and geopolitical shocks, with measurable negative consequences for operational continuity (Sorokina & Lebedeva, 2025). In the logistics context, partial AI integration, deploying optimization algorithms without redesigning human oversight structures, represents precisely this form of incomplete digitalization, and carries analogous resilience risks

One weakness of this analysis that needs mention is that most of the case examples discussed above come from only a few MNCs who lead in terms of technological advancements. The logistics experience with AI technologies for mid-level MNCs or developing countries could be quite different from the cases presented above. Further analysis through surveys, interviews, and case studies conducted via primary research would improve the empirically-driven nature of this model.

7 Conclusion

This essay has looked at how artificial intelligence can be incorporated into the logistic functions of an MNC with a focus on how humans will remain vital within the process. Through the discussion of four key logistics areas (forecasting demand, optimizing transportations, warehouse management, and managing risks within the supply chain), it can be seen that successful incorporation of artificial intelligence in logistics does not mean replacing human decision making but finding complementarity between human and machine skills. This essay makes an interesting contribution to an expanding academic literature by challenging some of its assumptions.

With respect to what is confirmed and expanded, the results of this paper support the core theory put forth by Wilson (2018), which suggests that the most successful human-AI collaborations depend on structured complementarities rather than substitutions. Nonetheless, while Wilson's theory is more conceptual and sector-independent, this paper provides specific quantitative domain-focused evidence related to MNCs' logistics, an area that is mostly unexplored in the previous research. In turn, according to Toorajipour et al. (2020), who systematically reviewed the state of AI use in the logistics sector and found demand forecasting and route optimization to be the most developed logistics subdomains with respect to the use of AI technology, the role of human judgment was not addressed. This paper contributes to Toorajipour et al.'s research by showing that, despite being the most mature with regard to the application of artificial intelligence, the role of human judgment and its authority in such domains can still be highly valuable and financially beneficial, as the Walmart example shows.

In terms of what is new, this paper makes an original conceptual contribution through the proposed two-dimensional human-AI synergy framework, organized around the axes of task structure and decision consequence. While prior frameworks in the human-AI collaboration literature have tended to organize tasks along a single automation continuum (from fully manual to fully automated), the two-dimensional framework proposed here captures an important insight that is poorly addressed in earlier work: the appropriate degree of human involvement is not determined by automation potential alone, but by the intersection of that potential with the strategic consequences of error. A high-structure task with high consequence, such as strategic demand forecasting, warrants a different human-AI configuration than a high-structure task with low consequence, such as standard parcel sorting, even though both are algorithmically tractable. This distinction has practical implications for how logistics managers should design their AI deployment strategies that go beyond what earlier domain-specific studies have recommended.

Where this paper differs from much of the existing literature is in its treatment of AI limitations not as temporary technical deficiencies to be overcome through model improvement, but as structural features of any data-driven system operating in a dynamically evolving environment. The distribution shift problem, demonstrated most starkly by the collapse of pre-pandemic AI forecasting models during COVID-19, is not merely an engineering challenge; it reflects a fundamental asymmetry between the historical-data orientation of machine learning and the novelty-facing orientation of strategic human judgment. This paper argues that this asymmetry is permanent rather than transitional, which has significant implications: investment in human expertise development must continue in

parallel with AI capability investment, not as a compensatory measure for current AI inadequacies but as a permanent organizational necessity.

The study also carries implications for the broader debate on the labor market effects of AI in logistics. The Amazon case, in which the deployment of 750,000 autonomous mobile robots coincided with workforce growth from 250,000 to 1.5 million employees, provides empirical grounding for the argument that AI-driven logistics automation transforms rather than eliminates human roles. However, this finding should not be interpreted uncritically. The Amazon case represents a frontier adopter operating at exceptional scale; the labor transformation effects at mid-market MNCs or in developing-economy logistics contexts may differ substantially. The generalizability of the framework and findings proposed in this paper therefore constitutes a primary direction for future research.

Several directions for future research emerge from this analysis. First, the human-AI synergy framework proposed here requires empirical validation through primary research (survey-based studies, structured interviews with logistics executives, and longitudinal case studies) that would allow the framework's quadrant assignments to be tested and refined against practitioner experience. Second, the framework could be extended to incorporate a third dimension: organizational maturity in AI governance. The evidence suggests that MNCs with more developed AI governance structures (explicit accountability frameworks, explainability requirements, and escalation protocols) achieve better human-AI integration outcomes, but this relationship has not been formally modelled. Third, future research should examine AI-logistics integration in mid-sized MNCs and in emerging-market supply chain contexts, where data infrastructure, institutional capacity, and regulatory environments differ substantially from the frontier cases examined here. Comparative research across these settings would significantly strengthen the external validity of the conclusions drawn from the present study.

The future of logistics in MNCs will be shaped not by the capabilities of AI systems alone, but by the organizational wisdom to deploy those systems in configurations that amplify rather than undermine the human expertise that remains central to supply chain performance. The evidence reviewed in this paper suggests that the most consequential competitive differentiator in AI-enabled logistics is not the sophistication of the algorithms deployed, but the quality of the human-AI integration architecture within which those algorithms operate. This is as much a management challenge as a technology challenge, and it is one that deserves sustained attention from researchers and practitioners alike.

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THE EU CARBON BORDER ADJUSTMENT MECHANISM (CBAM) AND ALGERIA'S HYDROCARBON EXPORTS: LEGAL FRAMEWORK AND ECONOMIC ADAPTATION STRATEGIES

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Abstract: *The European Union's carbon border adjustment system was implemented in October 2023. This mechanism influenced international commerce by linking climate objectives to trade restrictions and levying taxes primarily on carbon-intensive and high-emission imports. The objective of this approach was to avert carbon leakage and to guarantee equitable competition. This mechanism poses significant challenges for developing nations dependent on fossil fuel exports, like Algeria, where exports to the EU primarily consist of fossil fuels and carbon-intensive goods, potentially reducing its revenue and market access opportunities. This study employs a descriptive and analytical methodology to delineate the legal framework of the carbon border adjustment mechanism, assess its compliance with World Trade Organization regulations, and evaluate its economic implications for Algeria. The data indicate that the mechanism has a negligible impact on Algeria's economy, accounting for approximately 0.2% of the nation's GDP. The mechanism's impact is concentrated in the fertilizer, steel, and iron sectors, jeopardizing the nation's competitiveness and employment opportunities. Furthermore, the carbon tax exacerbates the existing structural vulnerabilities within the Algerian economy. The vulnerabilities include overdependence on hydrocarbons, high carbon intensity, insufficient use of renewable energy, and the absence of a regional carbon pricing mechanism.*

Keywords: *Carbon border adjustment mechanism, Carbon pricing, Climate policy, EU-Algeria trade, Hydrocarbon exports.*

1. Introduction

In alignment with its ambitious European Green Deal and its pledge to achieve carbon neutrality by 2050, the EU initiated the Carbon Border Adjustment Mechanism (CBAM) in October 2023. This novel policy instrument signifies a major advancement in climate and trade policy in recent decades. The CBAM seeks to avert carbon leakage, which transpires when EU firms transfer production to nations with more lenient climate legislation or when EU goods are supplanted by imports with elevated carbon emissions (European Commission, 2023). CBAM presents a significant issue for developing nations such as Algeria, whose economy is largely dependent on the export of carbon-intensive products to the EU. The World Bank (2024) reports that hydrocarbons constitute over 91% of Algeria's exports, rendering the nation significantly susceptible to climate-related trade regulations. The EU imports significant quantities of natural gas, oil products, steel, fertilizers, and aluminum from Algeria, all of which fall within the initial scope of CBAM. The execution of CBAM poses a multifaceted challenge to Algeria's economic framework. As the European Union's third-largest supplier of natural gas and a significant exporter of fertilizers and steel, Algeria faces the threat of reduced competitiveness in its key export markets (IMF, 2025). This study uses a qualitative methodology that incorporates many research approaches to examine these topics. The document encompasses a legal analysis of EU Regulation 2023/956 and its

conformity with WTO regulations, an assessment of policy and institutional reports from the European Commission, the World Bank, the IMF, and the International Energy Agency, as well as an evaluation of trade data between Algeria and the EU from 2020 to 2025. The study also derives insights from the responses of other developing nations to CBAM in order to pinpoint effective tactics for Algeria.

2. The EU Carbon Border Adjustment Mechanism: Legal Framework and Implementation

2.1 Origins and Policy Context

The revised EU Emissions Trading System (ETS) sets stricter emission reduction targets, which makes it harder for European industries to compete with producers in places where carbon pricing is not as strict (European Commission, 2023). CBAM's goal is to "level the playing field" by making sure that imported goods have the same carbon cost as goods made in the EU under the ETS. CBAM has three political goals. First, it tries to stop carbon leakage by making it less appealing to move carbon-intensive production outside the EU. Second, it wants to get other countries to use carbon pricing systems and cut down on the amount of pollution their industries make. Third, it is a way to make money, with CBAM expected to bring in €7.2 billion a year for the EU budget by 2030 (Brookings Institution, 2024).

2.2 Legal Framework and Regulatory Architecture

The European Parliament and Council passed Regulation (EU) 2023/956 on May 10, 2023, and it was published in the Official Journal on May 16, 2023. The regulation went into effect on October 1, 2023, and there is a transitional reporting period that lasts until December 31, 2025. (EUR-Lex, 2023). The following areas are covered: The first part of the CBAM covers six industries that use a lot of carbon:

- ✓ **Cement (HS code 2507, 2523):** Emissions from making clinker directly.
- ✓ **Iron and steel (HS code 72, 73):** This includes both finished and semi-finished goods.
- ✓ **Aluminum (HS code 76):** This includes both primary and secondary aluminum.
- ✓ **Fertilizers (HS code 31):** Nitrogen-based fertilizers, especially ammonia and urea.
- ✓ **Electricity:** Things that come from outside the EU.
- ✓ **Hydrogen (HS code 2804):** All types, such as grey, blue, and green hydrogen.
- ✓

2.3 Operational Mechanics

Under CBAM, EU importers of covered commodities are required to acquire a "CBAM certificate" that reflects the greenhouse gas emissions associated with their importation. The cost of these certificates is determined weekly according to the average auction price of EU ETS allowances, expressed in euros per tonne of CO₂ equivalent. (European Commission, 2023). Implementation phase:

- ✓ **Phase 1: Transition period (October 2023 – December 2025):** The initial report, covering the period October to December 2023, was scheduled for submission by 31 January 2024. This transitory period aims to achieve multiple objectives: acquainting firms with the reporting requirements, allowing the Commission to enhance the methodology using actual data, and providing third countries with the opportunity to adjust their standards. (European Commission Implementing Regulation/1117323).
- ✓ **Phase 2: Determined governance (from January 2026):** As of 2026, importers must obtain the status of "Authorized CBAM Declarant" from their national authorities. They will purchase CBAM certificates for imports from the previous calendar year and deliver them by 31 May annually. Notably, the introduction of full CBAM obligations coincides with the gradual phasing out of free ETS allowances for EU industries. Free allocations

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will be reduced linearly from 2026 to 2034, when they will be phased out completely, and the CBAM will provide complete border protection (European Parliament, 2023).

Table 1. CBAM Implementation Timeline and Key Phases

Phase	Period	Obligations	Key Features
Transitional	Oct 2023 - Dec 2025	Quarterly reporting only	No financial payments; Data collection; Methodology refinement
Definitive	Jan 2026 - 2034	Certificate purchase & surrender	Full CBAM charges; Gradual ETS free allocation phase-out
Full Implementation	From 2034	Complete border carbon adjustment	100% CBAM coverage; Zero free ETS allocations

Source: (European Commission, 2023).

Table 1 provides a broad overview of CBAM's implementation timeline, while Table 2 describes the specific sectors and products covered by the mechanism's initial scope.

Table 2. CBAM Covered Sectors and Products (Initial Scope)

Sector	HS Codes	Key Products	Emissions Coverage
Cement	2507, 2523	Clinker, cement	Direct emissions
Iron & Steel	72, 73	Semi-finished & finished steel products	Direct emissions
Aluminum	76	Primary & secondary aluminum	Direct + Indirect (from 2026)
Fertilizers	31	Ammonia, urea, NPK fertilizers	Direct + Indirect (from 2026)
Electricity	2716	Imported electricity	Direct emissions
Hydrogen	2804	All hydrogen types	Direct emissions

Source: (European Commission Implementing Regulation, 2023)

2.4 Legal Controversies and WTO Compatibility

There has been a lot of debate about whether the CBAM follows World Trade Organization (WTO) rules. Several WTO rules may be useful:

- ✓ **The Most Favored Nation (MFN) principle (GATT Article I):** says that CBAM charges the same carbon price for imports from all non-EU countries, no matter how developed they are or how much they have historically been responsible for emissions. Developing nations assert that this contravenes the principle of "common but differentiated responsibility" (CBDR) established in the Paris Agreement and the UN Framework Convention on Climate Change (Mehling et al., 2023).
- ✓ **National treatment (GATT Article III):** Critics say that CBAM is unfair to foreign producers because it doesn't recognize their different but equally effective decarbonization strategies (Gore et al., 2021).

The EU says that CBAM is a legal environmental measure that allows trade restrictions that are needed to protect human, animal, or plant life or health and are related to the protection of natural resources that can't be used up. The European Union says that CBAM is fair, reasonable, and needed to reach its climate goals (European Commission Legal Service, 2023).

3. Global Implications and Impacts on Developing Countries

3.1 Macroeconomic Effects on Global Trade

CBAM has a big effect on the flow of goods around the world and the global trading system. This system first applies to about 3% of all EU imports by value, which is about €50 billion a year. But this percentage doesn't show how much of an effect it has on certain regions and countries. For instance, iron and steel products are expected to bear 75% of the economic impact of CBAM because they have a lot of carbon and trade volume (S&P Global, 2024). Preliminary economic modeling indicates that CBAM may decrease imports from impacted nations by 5–15%, contingent upon variations in carbon intensity and the capacity to transfer costs to consumers. The IMF says that the Middle East and Central Asia region has an annual cost of \$1.7 billion, which is the same as a 14% tariff on CBAM-related exports to Europe (IMF, 2025).

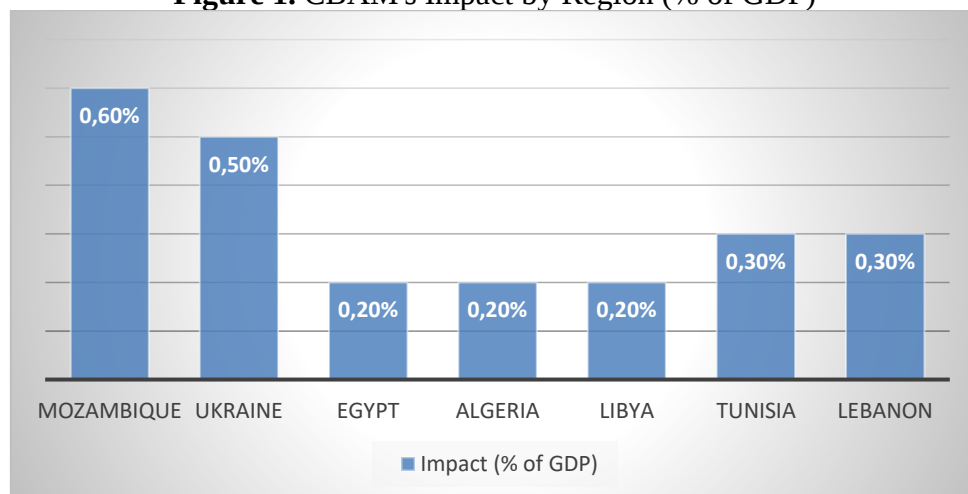
3.2 Differential Impacts on Developing Countries

There are a number of reasons why developing countries are especially vulnerable to CBAM:

- ✓ **High carbon intensity:** Many developing countries get their electricity from coal-fired plants and have old industrial infrastructure, which means they release a lot more carbon than the EU's benchmark. Electricity in Algeria has a carbon intensity of 488 grams CO₂e per kWh, while electricity in France has a carbon intensity of 85 grams and electricity in Sweden has a carbon intensity of 45 grams (Our World in Data, 2023). Because of this difference, Algerian producers will have to pay much higher CBAM fees for the same amount of production.
- ✓ **Limited ability to cut carbon emissions:** Many developing countries don't have access to low-carbon technologies, green finance, or the technical know-how needed to quickly cut emissions. The World Bank says that meeting CBAM standards could cost middle-income countries like Algeria between \$2 and \$5 billion, which is hard to get because they have other development priorities (World Bank, 2025).
- ✓ **No carbon pricing in the home country:** Most developing countries don't have carbon taxes or systems for trading emissions. Kazakhstan and Mauritania are the only CBAM-vulnerable countries that have put in place or plan to put in place a way to charge for carbon. Exporters can't get reductions under CBAM without domestic carbon pricing. This means they have to pay the full European carbon price, which is currently around €80–100 per tonne of CO₂ (ICAP, 2024).

Figure 1 and Table 3 show that the effects of CBAM are very different in developing countries.

Figure 1. CBAM's Impact by Region (% of GDP)



Source: prepared by authors based on (IMF, 2025), (World Bank, 2025)

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Table 3. Most Affected Developing Countries by CBAM (2026–2030)

Country	Main Affected Exports	Annual Impact (USD million)	% of Total Exports to EU
Mozambique	Aluminum	150-200	54.1%
Algeria	Fertilizers, Steel	100-170	3-4%
Egypt	Fertilizers, Steel, Cement	180-250	5-6%
Tunisia	Steel, Cement	80-120	4-5%
Turkey	Steel, Cement	800-1,200	6-8%
South Africa	Steel, Aluminum	400-600	7-9%

Source: (World Bank, 2025).

4. Algeria's Case: Exposure, Vulnerabilities, and Economic Impacts

4.1 Algeria-EU Trade Relations: Structural Overview

Algeria's closeness to the larger European market offers a competitive edge, the nation's excessive reliance on this singular market renders it vulnerable to policy changes like the CBAM.

Table 4. Algeria–EU Trade Statistics (2020–2024)

Year	Exports to EU (€ billion)	Imports from EU (€ billion)	Trade Balance (€ billion)	% of Total Algerian Exports
2020	18.5	14.2	4.3	52%
2021	22.8	15.8	7.0	53%
2022	32.1	17.2	14.9	56%
2023	28.7	16.9	11.8	54%
2024	26.4	16.1	10.3	51%

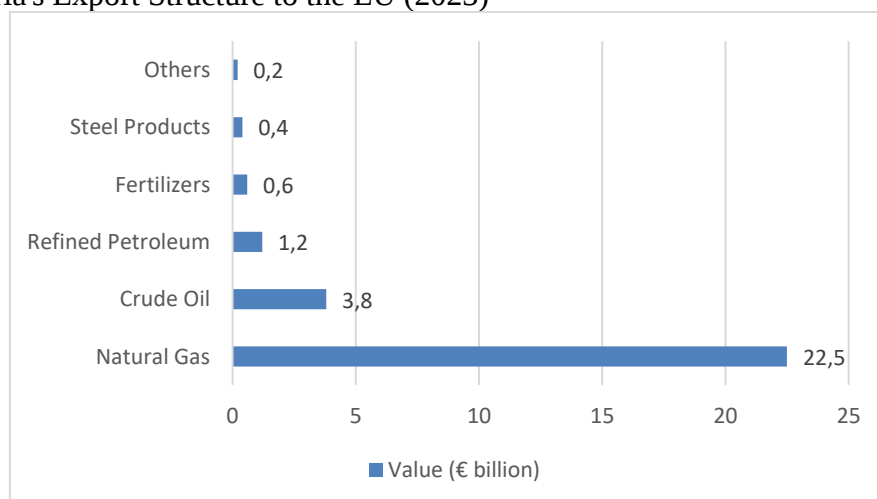
Source: (Eurostat, 2024), (ONS Algeria, 2024).

An overview of the development of Algeria's commercial ties with the European Union over the course of the last five years is presented in Table 4. The European Union (EU) typically receives more than fifty percent of Algeria's total exports, notwithstanding changes in trade that are occurred as a result of the volatility of hydrocarbon prices.

4.2 Sectorial Analysis of CBAM Exposure

The composition of Algeria's exports to the European Union is depicted in Figure 2.

Figure 2. Algeria's Export Structure to the EU (2023)



Source: (Eurostat, 2024)

- ✓ **Fertilizers Sector:** One of the industries that is most immediately impacted by CBAM is the fertilizer sector in Algeria. The value of Algeria's fertilizer exports to the European Union in 2023 was approximately 500–700 million euros. This accounted for approximately twenty percent of the region's entire production and two percent of the overall exports of the country (World Top Exports, 2024). One of the most significant products is ammonia, which is the primary component responsible for the production of nitrogen fertilizer from natural gas. The use of urea as a fertilizer is quite frequent in European agricultural. The nitrogen, phosphorus, and potassium (NPK) fertilizer is a form of compound fertilizer that contains all three elements at the same time.

Algeria's fertilizer industry uses a lot of carbon because it relies on natural gas for both raw materials and energy. Natural gas is cleaner than coal-fired generation, which is common in China. However, Algerian plants often use older technology that is less energy-efficient than modern EU plants. Initial estimates indicate that CBAM costs may elevate Algerian fertilizer exports by €50–100 million annually following the implementation of the fixed regime in 2026, representing 10–15% of the current export value (IMF, 2025).

- ✓ **Iron and Steel Products:** The steel industry in Algeria is mostly owned by the government and is mostly based in the El Hadjar and Annaba complexes. It sends €300–500 million worth of steel products to the EU every year. The industry itself employs about 20,000 people and supports about 50,000 jobs in related fields (Ministry of Industry Algeria, 2024). But Algerian steel production has a lot of problems to deal with:
 - **Infrastructure that is getting old:** Most of the buildings, which were built in the 1970s and 1980s, have not been updated much.
 - **Energy intensity:** Using blast furnace technology releases about 1.8–2.2 tonnes of CO₂ for every tonne of steel, which is higher than the EU average of 1.3–1.6 tonnes.
 - **Limited scrap utilization:** A low recovery rate for steel means that iron ore is more important for making new steel.
- ✓ **Cement Sector:** Algeria's cement exports to the EU are not very high, only about €50–100 million a year. The main focus of the sector is on building homes in Africa and in the region. However, CBAM's inclusion of cement could mean that there will be more barriers in the future and could make foreign investors less likely to invest in Algeria's cement industry, which was meant to grow (African Development Bank, 2023).
- ✓ **Natural Gas: Indirect CBAM Exposure.** As the EU moves forward with its energy transition, the long-term demand for Algerian gas may go down. However, it is still enough for now because Europe needs to find new sources of gas to replace Russian ones (IEA, 2024).

Table 5. Exposure of Algeria's CBAM-Covered Sectors (Detailed Analysis)

Sector	Exports to EU 2023 (€ mn)	Carbon Intensity (tCO ₂ /t)	EU Benchmark (tCO ₂ /t)	Gap vs. Benchmark	Est. CBAM Cost (€ mn)	% of Export Value
Fertilizers – Ammonia	350	2.8	2.0	+40%	55–75	16–21%
Fertilizers – Urea	250	2.2	1.6	+37%	25–35	10–14%
Fertilizers (Subtotal)	600	2.5*	1.8*	+39%	80–110	13–18%
Steel Products	400	2.0	1.4	+43%	40–70	10–17%
Cement	75	0.70	0.65	+8%	5–10	7–13%
TOTAL	1,075	—	—	—	125–190	12–18%

Source: Author calculations based on (European Commission, 2023), (S&P Global, 2024), (World Bank, 2025).

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4.3 Quantitative Impact Assessment

Based on trade data and carbon intensity estimates, we can project CBAM's financial impact on Algeria:

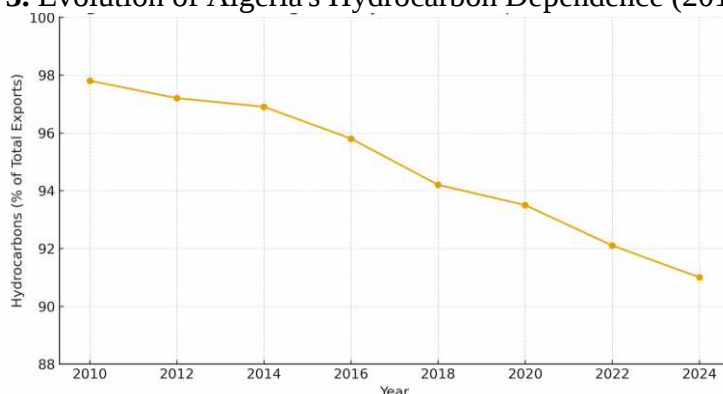
Table 6. Estimated Annual CBAM Costs for Algeria (2026 onwards)

Sector	Export Value (€ million)	Average Emissions Intensity	Estimated CBAM Cost (€ million)	% of Export Value
Fertilizers	600	2.5 tons CO ₂ /ton product	60-90	10-15%
Steel	400	2.0 tons CO ₂ /ton product	40-70	10-17%
Cement	75	0.7 tons CO ₂ /ton product	5-10	7-13%
Total	1,075	-	105-170	10-16%

Source: Authors calculations based on (European Commission, 2023), (IMF, 2025), (World Bank, 2025)

These estimates show that Algeria's annual CBAM costs are between €100 million and €170 million, which is about 0.2% of GDP and 0.3% to 0.5% of all exports. Even though this seems small when looked at as a whole, the fact that it has a big effect on certain areas and sectors could have big effects on the economy and society.

Figure 3. Evolution of Algeria's Hydrocarbon Dependence (2010-2024)



Source: (ONS Algeria, 2024), (World Bank, 2024)

4.4 Indirect and Systemic Impacts

Algeria will have to contend with a range of indirect effects in addition to the direct costs imposed by CBAM. The mechanism's impact—raising the prices of carbon-intensive goods in the EU market by an estimated 10% to 16%—is likely to undermine Algeria's competitiveness. This could result in a loss of market share to countries with lower carbon footprints, such as Egypt, which is currently modernizing its steel industry. Furthermore, the uncertainty surrounding the future evolution of CBAM and its potential expansion represents a significant risk to investment.

4.5 Algeria's Current Decarbonization Efforts: Achievements and Gaps

The Algerian government has set lofty goals for the use of renewable energy sources. One of the goals of the National Program for Renewable Energy Development is to increase the capacity of renewable energy sources to 22,000 megawatts by the year 2030. This includes 13,500 megawatts (MW) of solar photovoltaic power, 5,000 megawatts (MW) of wind energy, 2,000 megawatts (MW) of concentrated solar power, and 1,000 megawatts (MW) of concentrated solar power and minor hydropower power. As a result, the use of renewable energy technology might increase from less than one percent at the present time to twenty-seven percent by the year 2030 (Ministry of Energy and Renewable Energy, 2021).

Despite the fact that targets have been defined, the reality of execution demonstrates that progress has been slow.

Algeria has integrated only about 450–500 MW of renewable energy capacity as of 2024, which falls significantly short of what is required to meet its 2030 targets. Of this total, only around 60 MW comes from operational wind and solar installations, while the remainder is generated by the hybrid gas-solar complex at Hassi R'Mel (IEA, 2024). This deployment gap can be attributed to several factors. From a financing perspective, constraints include limited access to concessional capital and increasing pressure on public finances. In addition, regulatory barriers—such as complex approval procedures and an unclear investment framework—continue to hinder progress.

Furthermore, Algeria remains one of the top ten gas-flaring countries globally, with approximately 10–12 billion cubic meters of gas flared annually. According to the World Bank's Global Gas Flaring Tracker (2024), although the government aims to capture and utilize associated gas, progress has been slowed by persistent infrastructure and technological challenges.

In contrast to several peer countries, such as Kazakhstan and South Africa, Algeria has yet to implement carbon pricing mechanisms, including carbon taxes or emissions trading systems. The absence of a domestic carbon price prevents Algerian exporters from benefiting from potential CBAM reductions, effectively requiring them to bear the full cost of the European carbon price. As highlighted by the International Monetary Fund (2024), this lack of carbon pricing removes a critical policy lever for incentivizing industrial decarbonization.

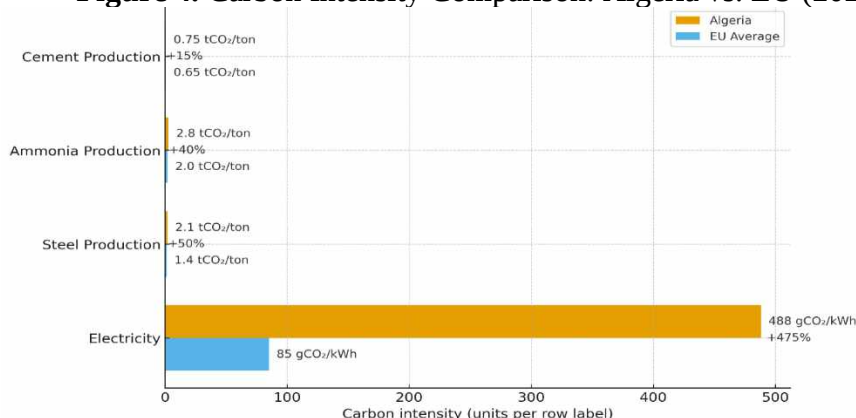
Table 7. Algeria's Renewable Energy Targets vs. Actual Progress

Technology	2030 Target (MW)	2024 Actual (MW)	Achievement Rate (%)	Required Annual Addition (MW)
Solar PV	13500	380	2.8	2187
Wind	5000	60	1.2	823
Concentrated Solar Power	2000	25	1.25	329
Biomass & Hydro	1000	35	3.5	161
TOTAL	22000	500	2.3	3500

Source: (Ministry of Energy Algeria, 2024), (IEA, 2024), (Middle East Institute, 2024)

Figure 4 provides more evidence of the significant carbon intensity difference that exists between the production processes in Algeria and those in the EU, which explains the widespread exposure to CBAM.

Figure 4. Carbon Intensity Comparison: Algeria vs. EU (2023)



Source: Our World in Data (2023), European Commission (2023)

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5. Adaptation Strategies and Policy Recommendations

5.1 Short-Term Measures (2025-2027)

- ✓ **Establish CBAM Compliance Infrastructure:** It is imperative that Algeria quickly enhance its institutional capability in order to properly manage compliance with CBAM regulations. This should include the establishment of a National CBAM Coordination Unit, which is an autonomous agency that is either part of the Ministry of Commerce or the Ministry of Environment. This body should be staffed with individuals who are knowledgeable in the fields of law, technology, and trade. The development of measuring, reporting, and verification (MRV) systems in industries that are covered by CBAM is required for emissions monitoring systems. It is possible that the European Union or the World Bank might provide funding for this endeavor.
- ✓ **Diplomatic Engagement with the EU:** Algeria should engage in constructive dialogue with European institutions through:
 - **Bilateral negotiations:** Leveraging Algeria's strategic importance as a gas supplier to obtain transitional arrangements, which could include longer compliance periods or technical assistance.
 - **Building a coalition:** Cooperating with North African and Middle Eastern countries (such as Tunisia, and Egypt) to ensure a unified position in EU-MENA trade and energy discussions.
 - **Highlighting its role in energy security:** Emphasizing Algeria's contribution to European energy security, especially in light of the EU's efforts to reduce reliance on Russian gas, as a rationale for requesting accommodations or special arrangements.
- ✓ **Immediate Sectoral Interventions:**
 - **Fertilizer Industry:**
 - ❖ **Technology Audits:** Conduct full energy and emissions audits of the largest fertilizer plants (e.g., Solfert, ASMIDAL) to identify simple ways to improve efficiency.
 - ❖ **Best Available Technology (BAT):** Begin planning to transition to more energy-efficient production methods, possibly with support from international partners.
 - ❖ **Green Ammonia Roadmap:** Explore the possibility of producing green ammonia using renewable electricity and water electrolysis.
 - **Steel Sector:**
 - ❖ **Use More Scrap:** Build additional steel recycling facilities to enable secondary steel production, which has 70–80% lower emissions compared to primary production.
 - ❖ **Electric Arc Furnaces:** Plan for a gradual transition from blast furnaces to electric arc furnaces powered by renewable energy.
 - ❖ **Energy Efficiency Retrofits:** Take immediate measures to improve energy efficiency in facilities (such as recovering waste heat and optimizing furnace operations) to reduce emissions by 10–15%.

5.2 Medium-Term Strategies (2027-2030)

- ✓ **Accelerated Renewable Energy Deployment:** Algeria needs to speed up the use of renewable energy right away to lower the amount of emissions in the economy:
 - By the year 2030, the primary objective is to concentrate on the construction of utility-scale solar photovoltaic (PV) projects, with the potential to be conducted through worldwide competitive bidding.
 - Our objective is to utilize Algeria's wind resources, particularly in the High Plateaus region, with the objective of achieving a power output of between 1,000 and 1,500 megawatts by the year 2030.

- It is recommended that modifications be made to the rules in order to facilitate the acquisition of permits for renewable projects, enhance the clarity of power purchase agreements (PPAs), and reduce the local content restrictions that hinder investment opportunities.
- Green finance mobilization involves the utilization of international climate financing instruments such as the Green Climate Fund, the African Development Bank, and the European Investment Bank in order to fulfill the financial obligations of green infrastructure.
- ✓ **Introduction of Domestic Carbon Pricing:** In the home country, establishing a price for carbon would alleviate several problems, including the following:
 - Algerian exporters should be allowed to deduct the cost of carbon emissions in their own nation from their CBAM charges. This will result in a reduction of their overall expenses when compared to other countries.
 - Acquire funds to finance initiatives that aid in the preservation of the environment and safeguard the rights of individuals.
 - Companies should be provided with incentives to reduce their emissions and invest in energy efficiency in order to bring about a change in behavior.

It is possible that Algeria might consider imposing a modest carbon tax of fifteen to twenty dollars per ton of carbon dioxide, with the proceeds going toward subsidies for renewable energy and the modernization of industry. This price, which is lower than EU ETS prices, would show a commitment to reducing carbon emissions and give some relief from the CBAM (World Bank Carbon Pricing Dashboard, 2024).

- ✓ **Industrial Modernization and Green Investment:**
 - **Green Steel Initiative:** Start a pilot project to build a green steel facility that uses hydrogen direct reduction or electric arc furnace technology as a demonstration.
 - **Partnerships with other countries:** To get to new markets and technology, look for joint ventures with steel companies in Europe or Asia.
 - **Retraining the workforce:** Make programs to teach steelworkers how to use new technologies.
 - **Development of the Circular Economy:** Waste-to-Energy: Put money into biomass and waste-to-energy plants to replace the use of fossil fuels.
 - **Industrial Symbiosis:** Set up industrial parks where waste heat and byproducts from one facility can be used as inputs for another, making better use of resources overall.
- ✓ **Export Diversification:** The EU will remain an important market, but Algeria should reduce its overreliance on this single market:
 - **African Continental Free Trade Area (AfCFTA):** Algeria's ratification in 2019 should be leveraged to increase exports to African markets, which currently account for only 5% of Algerian exports.
 - **Asia-Pacific Markets:** Seek opportunities to sell steel and fertilizers in Asian markets, while keeping in mind that other major economies may implement CBAM-like measures in the future.
 - **Value-Added Processing:** Develop downstream industries (such as petrochemicals and manufactured goods) to generate higher revenues, create more jobs, and move up the value chain.

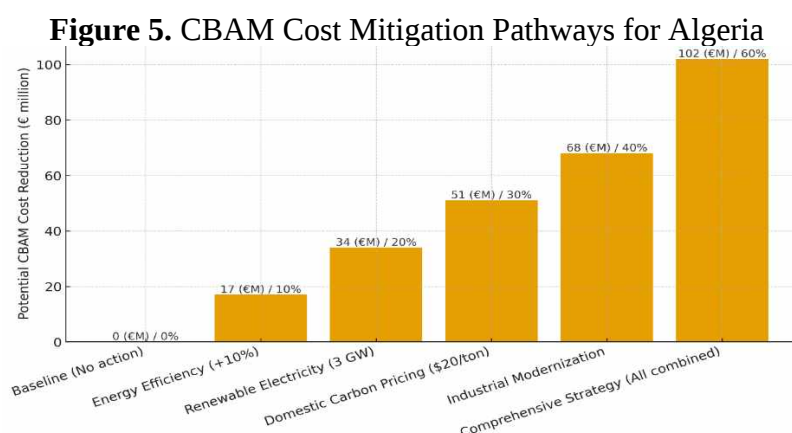
Table 8 presents a full adaptation plan for 2025–2035 with estimated costs between €13 and €20 billion.

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Table 8. Proposed Adaptation Roadmap for Algeria (2025–2035)

Time Period	Priority Actions	Expected Investment (€ billion)	Expected Impact
Short-term (2025-2027)	CBAM compliance infrastructure; Industrial energy audits; EU negotiations	0.1-0.2	Reduced CBAM costs by 10-15%
Medium-term (2027-2030)	5 GW renewable energy; Carbon pricing introduction; Steel/fertilizer modernization	3-5	Emissions reduction 15-20%; CBAM costs cut by 30%
Long-term (2030-2035)	15 GW renewables; Green hydrogen production; Economic diversification	10-15	Hydrocarbons <70% exports; 27% renewable electricity

Source: Author's analysis based on (World Bank, 2024), (IMF, 2024)



Source: prepared by the Authors.

Table 9. Regional Comparison: Climate Policy Preparedness (2024)

Country	Renewable Energy (% of electricity)	Carbon Pricing	CBAM Readiness Score (1-10)	Estimated CBAM Impact
Egypt	11	None	5	Medium
Tunisia	6	None	4	Medium-High
Algeria	1	None	3	Medium-High
South Africa	7	Yes (\$8/ton)	6	Medium
Turkey	17	Planned (2025)	6	High

Source: prepared by the Authors.

6. CONCLUSIONS

The EU's carbon limit adjustment mechanism is a pivotal intersection of climate policy and international trade. For Algeria, the CBAM presents a multifaceted challenge, with projected direct expenses significantly beyond 100-170 million euros annually. This method indicates that the Algerian economy faces significant challenges, including an excessive reliance on hydrocarbon exports, elevated carbon intensity in industrial output, slow progress in renewable energy adoption, and the absence of a domestic carbon pricing system. The quantitative analysis in this paper reveals that the immediate budgetary impact of the CBAM on Algeria is very minor (about 0.2% of GDP), although the effects are markedly concentrated in particular sectors. The fertilizer and steel sectors, employing over 35,000 individuals and exporting items valued at €1 billion annually, are required to remit CBAM taxes ranging from 10% to 16% of the export value. This may impair their competitiveness in the crucial European market, leading to reduced employment, lower output, and lower revenue from international sales.

This study advocates for the creation of a national CBAM coordination unit and the prompt initiation of emissions monitoring in the relevant industries, alongside the expansion of at least 5,000 MW of renewable energy by 2030 through regulatory simplification and the acquisition of supplementary international green financing. It underscores the necessity of establishing a carbon price of \$15–20 per ton of CO₂ and allocating the revenues to facilitate the green transition, thereby improving CBAM compliance and advancing decarbonization, while also launching targeted modernization initiatives in the fertilizer and steel sectors, concentrating on green ammonia production and electric arc furnaces.

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FESTIVAL CRUISES AS A HYBRID TOURISM FORMAT: AN EXPLORATORY TARGET GROUP ANALYSIS IN GERMANY

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Abstract: *This study addresses a notable research gap concerning festival cruises, a hybrid format largely unexplored scientifically, aiming to identify potential target groups and analyze their needs and expectations for successful long-term establishment. A quantitative-empirical research design with an explorative approach was employed, utilizing a standardized online questionnaire completed by 833 participants, with 579 interested individuals forming the basis for further analysis. Data analysis involved a Two-Step Cluster analysis to segment target groups based on socio-demographic and travel behavioral characteristics, followed by a success factor analysis using descriptive statistics and ABC analysis, differentiated by cluster. The results identified two distinct target segments: a younger, festival-affine, lower-income group without prior cruise experience (Cluster 1) and an older, comfort-oriented, higher-income group with extensive cruise and music festival experience (Cluster 2). Both clusters prioritize a fitting music genre, retreat areas, long restaurant opening hours, and an uncomplicated online booking process, while also identifying unsuitable music and financial aspects as key booking barriers. However, differences exist, with Cluster 1 emphasizing festival atmosphere and sustainability more, and Cluster 2 showing a slightly higher willingness for premium pricing. These findings indicate that festival cruises appeal to diverse segments with shared core requirements but also distinct preferences, necessitating differentiated offerings and communication strategies for successful market positioning.*

Keywords: *tourism segmentation; consumer behavior; experience economy; cruise tourism; music tourism; travel preferences*

1 Introduction

The cruise industry has long been the fastest-growing sector in tourism (Schulz & Auer, 2010). The cruise market reached a new peak of 34.64 million cruise passengers in 2024 (CLIA, 2025). As a new hybrid model, festival cruises combine key elements of cruises and music festivals and have great potential for the tourism market. This combination is considered a special format in both the cruise and music festival sectors. Although there has been little academic research into the synthesis to date, it holds great market potential due to the combination of two established tourism formats, particularly in light of the diversification of offerings (Business Insider Editorial Team, 2025).

The first offers for festival cruises already exist in the US and Europe. However, there has not yet been a comprehensive scientific analysis that examines the specific target group potential and success factors of this hybrid format. Of particular interest is the question of which target groups can be specifically addressed in which form and which aspects these groups consider to be particularly important for festival cruises. Consequently, the study aims to provide valuable insights for the long-term establishment of festival cruises by identifying

potential target groups and analyzing their needs and expectations from a demand perspective. For this purpose, an online survey was conducted to identify the potential participants for festival cruises and to analyze what expectations, needs and wishes potential participants have regarding the hybrid-format festival cruise.

2 Theoretical framework

2.1 Fundamentals of cruise tourism

Today, cruises are the most important form of maritime tourism. A cruise is a multi-day voyage characterized by resort-style amenities, which is carried out as a round trip with a pre-planned route. It calls at one or more ports where passengers have the opportunity to leave the ship to visit the destinations there. With a cruise, the character of pure passenger transportation between several places is transcended and the ship itself serves as an independent vacation destination (Schulz & Auer, 2010).

A cruise is a package tour organized by a cruise line company on a ship with a predefined passenger capacity. It is therefore a comprehensive product bundle and includes various individual services such as transportation, accommodation, catering, entertainment and use of all onboard amenities, such as theaters, sports and shopping facilities. The aim is to ensure that all passengers' needs are met (Steinecke, 2018).

In contrast to river cruises, traditional ocean cruises are the foundational model of the industry. Club cruises are the most popular type of cruise worldwide. Within the cruise industry, niche cruises can also be differentiated as a specific form of cruise offer. One form of niche cruise relevant to this study is the theme cruise, where the majority or the entirety of trip is themed. (Kizielewicz 2013) By focusing on specific themes, such as music or sport, cruise operators try to differentiate their offers from those of their competitors and continuously offer the target group new, interesting offers (Cashman 2014; Cashman and Hayward 2014; Schulz & Auer, 2010).

2.2 Basics of festival tourism

An event is characterized by the fact that it is planned, limited in time, tailored to a specific audience and organized for various reasons (Getz, 2008). According to Holzbaaur et al. (2010), an event is described as an event if it also has a special experience factor. Events are characterized, among other things, by a high positive memory value and uniqueness as well as an additional benefit for the participants. Ultimately, an event is defined by the subjective experience of the participant and thus varies with individual impressions (von Graeve, 2011; Holzbaaur et al., 2010).

Events are particularly relevant in the tourism industry as they attract visitors and contribute to the positioning of destinations (Getz & Page, 2016, p. 595; Grubelnik, 2015, p. 17). Furthermore, festival marketing is subject to specific customer centricity factors that are relevant for visitor loyalty (Bauer et. al., 2025b).

Belonging to the experience economy, a music festival is a specific form of event (Rivera et al. 2015; Morgan 2008; Pine and Gilmore 1998). Bellinghausen (2015) defines the term "music festival" as an event at which a number of artists present their music to an audience. The performing musicians can usually be assigned to a common musical genre or a thematic focus.

With a 99% market share, music festivals are the dominant festival form in Germany (Festivalfire, 2023). Electro, rock and pop festivals are the most popular types of festival, with techno being the most popular festival genre at 81%, followed by electronic dance music, or EDM for short, at 61%. Rock music is the fifth most popular genre with 19% (Bauer et al., 2022; Festivalfire, 2023).

2.3 Festival cruises as a hybrid format

From a tourism viewpoint, the combination of cruises and music festivals is an innovative hybrid offering that draws on two established formats, cruise tourism and festival tourism. The festival cruise combines the two concepts by using the cruise ship both as a means of transportation and a venue. This combination leads to a new perception of the travel experience that cannot be exclusively categorized as either a cruise or a classic festival, giving it an innovative character (Bauer et. al., 2022; Betz et al., 2017, Cashman 2021, 2019, 2017).

Festival cruises can be assigned to the category of themed cruises (Steinecke, 2018; Kizielewicz 2013). In the context of festival cruises, the focus is on music events that take place on board and which generally focus on a specific musical genre (seetours, 2025). Not only are classic cruise elements such as transport, catering and on-board entertainment offered, but a music festival program is also integrated into the trip (Travelbook, 2024; Bauer et. al, 2022). Informal interactions between fans and musicians are common on festival cruises outside of the shows. (Cashman 2016)

Providers—especially cruise operators—can derive substantial benefits from the hybrid festival cruise format, as it offers them various strategic advantages. On the one hand, it offers the opportunity to develop unique selling propositions that help providers stand out from standardized cruise offers. On the other hand, festival cruises help to extend the season for both festival-goers and cruise tourists. This specialization simplifies the targeting of new target groups for both festival and cruise providers (Steinecke, 2018).

From a conceptual perspective, festival cruises can be understood as hybrid tourism products, as they combine elements from two established but distinct experiential formats: cruise tourism and music festivals. Cruise tourism provides the spatial, infrastructural and service-based framework, including accommodation, gastronomy, mobility and destination-related components. Music festivals, in contrast, contribute the event-related, atmospheric and community-oriented dimension of the experience. The hybrid character of festival cruises therefore does not merely result from placing concerts on a ship, but from the integration of two different experiential logics into one tourism product. (cf. chapters 2.1 and 2.2)

This interpretation is closely linked to the experience economy perspective. Following Pine and Gilmore (1998), tourism products increasingly compete through staged experiences rather than through services alone. Festival cruises can be interpreted as such experience-oriented products because they combine entertainment, escapism, aesthetic staging and social participation within a temporarily bounded tourism setting. This makes them particularly relevant for research on product hybridization, experience design and tourism segmentation.

3 Methodology

Given the limited state of research on festival cruises, this study follows an exploratory rather than a hypothesis-testing research design. Therefore, no confirmatory hypotheses were formulated. Instead, the empirical analysis was guided by exploratory research questions focusing on three aspects: first, the identification of potential target group segments for festival cruises; second, the description of differences between these segments in terms of socio-demographic and travel-related characteristics; and third, the identification of perceived success factors and preferences relevant to the design and marketing of festival cruises.

3.1 Research design

A quantitative-empirical research design with an exploratory approach was chosen for this study, as the topic of festival cruises has been a research gap to date. The focus is on the exploratory identification and segmentation of relevant target groups based on socio-

demographic and behavioral characteristics as well as the subsequent identification and weighting of success factors based on the assessments of the target group segments.

3.2 Survey procedure

In order to answer the research questions empirically, a standardized online questionnaire with 52 items was created which were derived from the theoretical framework briefly outlined above in Chapters 2.1 to 2.3 (Reinders et al., 2022). It first asked for basic demographic data. This was followed by questions on previous travel behavior and previous participation in cruises and music festivals. Then, a filter question on general interest in festival cruises followed. In the next step, the remaining participants were asked questions to explore perceptions of the concept of festival cruises in order to formulate success factors.

The evaluation was carried out using a five-point Likert scale, the endpoints of which were "Not at all important" and "Very important" (Ritschl et al., 2023). In the next step, the participants were asked about their willingness to pay. They were then asked to indicate in a multiple-choice question which, if any, additional services they would book on board, as well as the reasons that would dissuade them from booking a festival cruise despite a suitable offer. The survey ended with that question.

The questionnaire was not designed to measure latent constructs using reflective multi-item scales, but to collect exploratory, item-based evaluations of preferences, experiences and perceived success factors related to festival cruises. Consequently, the items were analyzed individually and were not aggregated into composite indices. For this reason, classical reliability measures such as Cronbach's alpha and procedures for construct validation or item reduction, such as exploratory factor analysis, are not given here.

3.3 Data collection and analysis

The online questionnaire was distributed via the newsletter and social media channels of the employer of one of the authors, who works in the tourism industry, as well as through a snowball effect via other social media channels, portals, and groups, and within the authors' own networks. The questionnaire was created using the "Google Forms" tool. Participation was anonymous and compliant with data protection regulations.

After a pre-test with ten participants, the data collection was carried out in the period from March 21, 2025 to April 30, 2025 and analyzed using the statistical program Statistical Package for the Social Sciences (SPSS). The first step involved a cluster analysis (Bacher et. Al., 2010; Schendera, 2010) in order to segment potential target groups within the respondents interested in festival cruises. The aim was to use exploratory segmentation to identify similar segments in terms of demographics and travel behavior which differ as clearly as possible in terms of key characteristics such as age, occupation, travel behavior and experience with cruises and music festivals. The two-step cluster method (IBM Documentation, 2025; Bacher et. al., 2010) was used.

The variables included in the cluster analysis were selected based on their relevance for tourism segmentation and the exploratory objectives of the study. They covered socio-demographic characteristics as well as travel- and experience-related variables, including age, marital status, profession, income, travel frequency, cruise experience and festival experience. These variables were chosen because they reflect both life-stage-related differences and prior experience with the two reference formats of festival cruises: cruise tourism and music festivals (cf. chapter 2).

A Two-Step cluster analysis was applied because it is suitable for exploratory segmentation with larger datasets and can handle categorical variables. The procedure also allows the number of clusters to be determined automatically based on statistical criteria. The

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resulting two-cluster solution was selected because it provided a plausible and interpretable segmentation of the respondents.

Since the aim of the analysis was exploratory rather than confirmatory, no additional stability testing or significance testing of cluster differences are given here. The identified clusters should be interpreted as indicative target group profiles rather than statistically generalizable market segments.

Second came the success factor analysis. Subsequently, descriptive statistics were used in SPSS, whereby the mean value and standard deviation were calculated for each item. An ABC analysis was also carried out to categorize and simplify the interpretation of the results (Schawel & Billing, 2018). The next step involved a more differentiated analysis of the success factors. In the course of a cluster analysis, the 33 items in which the respondents were asked to rate the importance of certain factors using the five-point Likert scale were included as evaluation fields. Based on the available data, two clear cluster patterns have emerged. For an in-depth analysis of the differences between the clusters with regard to the success factors, some items were analyzed using cross-tabulations. The aim of the analysis was to enable a detailed description of the clusters in terms of their personal success factors.

Note: The cluster analysis followed an exploratory approach, aiming to identify potential target group structures rather than deriving statistically generalizable segments. This aligns with the exploratory nature of the study, which seeks not to establish confirmatory segmentation but rather to provide an initial structure for a phenomenon that has received little research attention to date. Consequently, the identified clusters should be interpreted as indicative rather than definitive segments, and further research is needed to psychometrically validate and refine the segmentation results. In line with exploratory segmentation approaches in novel research contexts, the focus was on interpretability and practical relevance rather than formal model optimization and evaluation.

4 Results and discussion

This paper examines the potential target groups for festival cruises and the success factors for establishing this hybrid format. A total of 833 people took part in the online survey. 254 participants (30.49 %) were removed from the data set by means of a filter question and excluded from the evaluation of the success factors. The sample relevant for this analysis comprises $n = 579$ people.

4.1 Target group potential for festival cruises

The results of the two-step cluster analysis make it clear that two clearly distinguishable target group segments can be formed among the respondents.

The clusters are differentiated both in terms of demographic and travel behavior-related characteristics (see Table 1). The two most important items for cluster formation were age with an importance of 1.00, followed by occupation (0.99). Income, travel intensity, cruise experience and marital status played a moderate role in cluster formation, while festival experience contributed less to differentiation. Cluster 1 comprises 39.7% of the sample ($n = 230$). Cluster 2 forms a slightly larger group with 60.3% ($n = 349$). The differences in size should be taken into account when interpreting the data, although this is only relevant to a limited extent, as the analysis relies primarily on percentage values.

Cluster 1 consists mainly of younger people. 87.4% of respondents in this cluster were born between 1995 and 2004 and a large proportion of them are single and students. The cluster has a low net household income of less than 1,000 euros and tends to travel once or twice a year. Almost 60% of respondents in the cluster have already been to a music festival. What is striking, however, is that most people in Cluster 1 have no cruise experience, but are interested

in doing so (40%). The combination of relatively low income, high affinity with music festivals and a lack of cruise experience suggests that the people in Cluster 1 are a young, open and potentially receptive target group segment that is likely to be responsive to the music festival context (Bauer et. al., 2025a).

Cluster 2 represents the demographically older opposite pole. 30.4% were born between 1965 and 1974 and 21.8% between 1955 and 1964, which means that this cluster is primarily composed of active seniors (Maas, 2023). The target group is characterized by being predominantly employed and married. For the most part, respondents have a medium income of 2,000 to 2,999 euros per month, although a closer look at the results shows that the distribution of income in higher income brackets is relatively balanced. People in this cluster tend to travel slightly more often, typically three to four times a year. There is a major difference from Cluster 1 in terms of cruise experience, as 83.7% in Cluster 2 have already taken part in a cruise. In addition, 60.7% already have music festival experience—and are therefore not festival ‘virgins’ (Cashman 2019). This target group segment tends to comprise experienced, higher-income people with an affinity for cruises. They are more likely to find the format interesting in the cruise context, but also have an affinity for festivals.

Table 1. Results of the cluster analysis on demographic and travel behavior-related characteristics (own illustration)

	Cluster 1			Cluster 2		
	Cluster size 39,7 % (n=230)			Cluster size 60,3 % (n=349)		
Item	Most frequent category	Percentage within the cluster	Importance	Most frequent category	Percentage within the cluster	Importance
Item 1: Age group (birth year)	1995-2004	87.4%	1	1965-1974	30.4%	1
Item 3: Marital status	Single	52.2%	0.47	Married	50.1%	0.47
Item 6: Profession	Student	77.4%	0.99	Employed	61.9%	0.99
Item 7: Income	Below €1,000	37.8%	0.59	€2,000 to €2,999	16.6%	0.59
Item 8: Travel frequency	1-2 times per year	51.3%	0.41	3-4 times a year	36.7%	0.41
Item 9: Cruise experience	No, but interested	40.0%	0.55	Yes	83.7%	0.55
Item 10: Festival experience	Yes	59.1%	0.03	Yes	60.7%	0.03

4.2 Success factor analysis for the establishment of festival cruises in general

The evaluation of success factors enables an assessment of which attributes potential participants in festival cruises rated as particularly relevant and which they rated as less

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important. An ABC analysis was carried out for categorization, in which items with a mean value from 4.00 upwards were rated as particularly important (A), those with a mean value of 3.00–3.99 as neutral (B) and those with a mean value below 3.00 as comparatively unimportant (C) (see appendix A).

The analysis of all respondents shows that five factors in particular were rated as especially important and were therefore classified as Category A. The most important success factor is the preferred musical genre during the cruise, with the highest mean value (4.43) and the lowest standard deviation (0.81). Pop dominates as the preferred musical genre (69%), followed by rock and EDM. The second most important success factor ($M = 4.29$) is that there are quiet areas away from the festival action, followed by an uncomplicated booking process via the internet. Long and flexible restaurant opening hours are also a Category A factor for the respondents, as is provision of a large selection of non-alcoholic and alcoholic drinks on board.

4.3 Success factor analysis for the establishment of festival cruises in general by cluster

For a more detailed analysis of the preferences within the target group segments identified, the mean values and associated ABC categorizations of the success factors were considered within the cluster analysis. A general analysis of the relevance of success factors within all those interested in festival cruises, conducted independently of the clusters, already showed that individual aspects such as the preferred musical genre, the opportunity to withdraw to a quiet space, long restaurant opening hours, a large selection of drinks and an uncomplicated online booking process are of above-average importance.

This assessment is also largely shared by both target group segments. In both Cluster 1 and Cluster 2, the preferred musical genre was rated as one of the most important success factors. In addition, both clusters cite an unsuitable music genre as a possible obstacle to booking. However, the clusters differ in terms of the preferred musical genre. Although both segments prefer pop music, Cluster 1 tends more towards electronic music, hip-hop and indie, while Cluster 2 prefers music genres such as rock and pop.

Clusters 1 and 2 also agree on some other attributes, such as quiet areas on board, long restaurant opening hours and an uncomplicated booking process via the internet, and rate these as A factors. This indicates that these are the core requirements for festival cruises, which can be regarded as necessary basic conditions regardless of age, travel experience and income. Only the aspect of beverage selection is evaluated slightly differently by the clusters: Cluster 2 rates this aspect with a lower relevance, assigning it to the B category, while Cluster 1 gives it a higher relevance and classifies it as an A factor. Overall, however, these factors should definitely be considered relevant requirements when designing the offer.

However, a detailed examination of both target group clusters also reveals differences in the importance of some success factors (see Appendix B). In Cluster 1, for example, the festival atmosphere on board is classified as an A factor, while in Cluster 2 this aspect is only rated as a B factor. Similar differences in prioritization can also be seen in the long opening hours of the bars or the selection of drinks on board. In contrast to Cluster 2, both items are also rated as an A factor in Cluster 1. In addition to the items relating to the festival experience, other aspects are also valued more highly in Cluster 1 than in Cluster 2. Among other things, it is more important to respondents in Cluster 1 that the trip takes place in warmer weather. The sustainability aspect is also rated as an A factor in Cluster 1 but not in Cluster 2, which only classified it in category B—unlike at regular open-air festivals, where the issue of sustainability plays only a minimal role for all guests (Bauer et. al., 2025a; Bauer et. al., 2024). The difference in the importance of the provision of diet choices such as vegetarian and vegan food is

particularly striking. While this variable was classified as an A factor in cluster 1, it is rated as unimportant in cluster 2 and falls into Category C.

Considering the overall picture, the question of potential booking obstacles also arises. In addition to financial aspects, environmental and sustainability concerns, fundamental reservations about cruises and a different preferred form of vacation play an important role for Cluster 1. Cluster 1 prefers social media as a communication channel. This can be explained by the age structure of the cluster (ARD & ZDF, 2024). The other preferred communication channels, such as festival websites and online advertising, also show the cluster's affinity for online communication. In addition, value is also placed on interpersonal recommendations.

Cluster 2, on the other hand, has a different profile. The average age of the people assigned to cluster 2 tends to be that of active seniors. Respondents in this cluster tend to be employed, have a higher income and to be very experienced cruise passengers. They rate traditional comfort and quality aspects more highly than Cluster 1 and, in terms of gastronomy, also rate onboard à la carte restaurants as more important. However, respondents in Cluster 2 are not enthusiastic about typical festival snacks, which they categorize as a C factor. These are rated more highly in Cluster 1. Cluster 2 also differs from Cluster 1 in terms of the selection of additional services, in that it has a significantly higher affinity for booking specialty restaurants as an additional service. This indicates that Cluster 2 respondents place more value on gastronomic quality and service. With regard to the choice of cabin category, Cluster 2 also opts for higher and more expensive cabin categories than Cluster 1. Balcony cabins tend to be booked in Cluster 2, while inside and outside cabins are preferred in Cluster 1. Ship size is also more relevant in Cluster 2 than in Cluster 1. As is typical for mass tourism (Georgsdottir & Oskarsson, 2017), both clusters are most likely to opt for normal to large ocean-going vessels; however, the choice of ship size and type was evaluated as a B factor in Cluster 2, while in Cluster 1 it was considered rather unimportant and subsequently placed in the C category, here.

Cluster 2 is also more open to festival cruises for which a flight to join the cruise would be necessary. This may be partly due to the higher income within the cluster. Shore excursions on the festival theme, on the other hand, are rated as unimportant in Cluster 2, in contrast to Cluster 1. With regard to factors which would dissuade them from booking, Cluster 2, like Cluster 1, cites financial aspects as the biggest obstacle. Additionally, an unsuitable musical genre and a lack of time or vacation days are also important factors. Cluster 2 also differs from Cluster 1 in terms of communication channels, with the official websites of cruise operators being mentioned most frequently, which can be explained by the high affinity for cruises. Cluster 2 is also most likely to be reached via traditional online channels such as social media and email marketing. The cluster also attaches importance to interpersonal recommendations.

With regard to willingness to pay for festival cruises, despite the differences in income between the clusters, it can be seen that both clusters indicated a preferred upper price limit of 150–199 euros per night. However, differences can be seen in the upper price levels, as these were almost exclusively indicated by Cluster 2. This indicates a higher willingness to pay, but only to a small extent (Klein et al., 2017).

In summary, the differentiated cluster analysis with regard to success factors shows that both target group segments have some similarities in terms of their rating of individual factors, but also have different preferences: The similarities in the A factors suggest common core requirements that should be considered mandatory for festival cruises offerings in general. Unanimously rated C factors can be disregarded when designing the offer. The differing preferences of the clusters offer potential for target group-specific offer differentiation, for example in the basic design of the trip, the program content or the choice of communication channels for marketing.

4.4 Practical implications

The findings have practical implications for both cruise operators and festival organizers. For cruise operators, the results indicate that festival cruises should not be marketed as conventional cruises with added music entertainment, but as experience-oriented hybrid products requiring differentiated programming, pricing and communication strategies. For festival organizers, the findings suggest that the cruise setting offers opportunities to extend festival brands into tourism contexts, but also requires adaptation to the expectations of cruise-oriented audiences, particularly with regard to comfort, gastronomy and service quality.

The segmentation results further suggest that a one-size-fits-all approach is unlikely to address the full market potential of festival cruises. Younger, event-oriented participants may respond more strongly to music programming, atmosphere and accessible pricing, whereas older, cruise-oriented participants may place greater emphasis on comfort, service quality and the overall travel experience.

5. Conclusions: Limitations and outlook

The present study is subject to several limitations that must be taken into account when evaluating the results.

One central limitation results from the innovative nature of the subject of the study. Festival cruises represent a hybrid tourism format that remains largely under-explored to date and for which there is neither an established theoretical definition nor reliable empirical preliminary work. The design of the online questionnaire was therefore based on existing literature on the two established reference formats of festival and cruise tourism (see above, chapters 2.1 to 2.3.). This provided a preliminary framework to identify the relevant dimensions, but was necessarily limited by the fact that features specific to festival cruises are only indirectly observable.

The sample is subject to self-selection effects, as the survey was distributed through snowball sampling and social media channels. Consequently, the sample cannot be considered representative of the German population or of all potential participants in festival cruises. The survey was conducted in German and focused on the German market. Therefore, the findings should not be generalized to other national source markets without further comparative research.

A further limitation concerns the design of the survey instrument. The success factors were evaluated using a five-point Likert scale for subjective assessment, a standard method for eliciting opinions (Ritschl et al., 2023). Due to the odd-numbered scale format, however, there is the possibility that the middle category is used as a so-called escape choice, for example in cases where the respondent has not formulated an opinion. This can lead to a reduction in selectivity and thus to inaccuracies in the results (Porst, 2014).

Further limitations result from the cluster analysis carried out. The segmentation was carried out exclusively on the basis of selected demographic characteristics. Consequently, it is possible that different cluster configurations would have resulted if other variables or alternative analytical methods had been included. The identified target group segments should therefore be seen as an exploratory first attempt to determine the target group. In addition, the economic, organizational and legal framework conditions of the providers were not systematically taken into account when deriving the recommendations for action. The success factors identified therefore primarily reflect the perspective of potential participants, while aspects such as cost structures, logistical feasibility or regulatory requirements were not included.

Furthermore, the cluster analysis revealed age as a particularly influential segmentation variable. While this reflects meaningful differences in life stage, travel experience and cruise

familiarity, it also limits the interpretation of the clusters as purely behavior-based segments. The identified clusters should therefore be understood as socio-demographically anchored target group profiles.

The aforementioned limitations provide several starting points for future research. Qualitative methods, in particular semi-structured interviews with people interested in festival cruises, could help to capture motivations, expectations and needs in greater depth (Reinders et al., 2022). In addition, the inclusion of the provider perspective appears to be a sensible next step, for example through expert interviews with product and program managers, in order to gain additional insights into the development and implementation of the product concept. Due to the exclusive use of the German language and the distribution of the questionnaire, this study focuses on the German market. Future studies could examine the international marketability of festival cruises through comparative analyses with data from other source markets and analyze cultural differences in the relevance of individual success factors. Overall, the study makes an initial scientific contribution to research into the hybrid format of festival cruises and thus creates a starting point for further empirical and conceptual work.

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Appendix

Table A.1. *Results of the mean value analysis of the success factors in relation to all interested persons from important to unimportant (own illustration).*

Item	Average	Standard deviation	Category
Item 23: How important would your preferred music genre be during the festival cruise?	4.43	0.811	A
Item 36: How important is it to you that there are quiet areas on board away from the festival activities for relaxation?	4.29	0.98	A
Item 47: How important would a straightforward booking process via the internet be to you?	4.23	1.038	A
Item 45: How important would it be to you that restaurants have long and flexible opening hours so that you can also eat out during the festival program?	4.18	0.937	A
Item 39: How important would a large selection of drinks on board be to you?	4.08	0.992	A
Item 29: How important would it be to you to have a strong festival atmosphere?	3.97	1.016	B
Item 46: How important would it be to you that bars are open until late at night?	3.95	1.179	B
Item 40: How important would the option to book an all-inclusive upgrade with drinks in advance or on board be to you?	3.84	1.262	B
Item 20: How important would it be to you that the cruise operator is already established and has a good reputation?	3.82	1.132	B
Item 17: How important would it be to you that the trip takes place in warm temperatures?	3.78	1.083	B
Item 24: How important would it be to you that well-known headliners and artists from the music genre perform?	3.75	0.99	B
Item 30: How important would it be to you that the ports and destinations are attractive?	3.75	1.064	B
Item 21: How important would it be to you that the cruise operator places great emphasis on sustainability and environmental protection?	3.68	1.277	B
Item 35: How important is the choice of cabin category to you?	3.64	1.186	B
Item 33: How important would it be to you that there is sufficient time in the port (no stops that are too short)?	3.62	1.171	B
Item 26: How important would it be to you to have multiple stages or venues on board?	3.58	1.138	B

Item 13: How important would the optimal duration of a festival cruise be to you?	3.54	1.007	B
Item 42: How important would it be to you to have buffet restaurants?	3.48	1.199	B
Item 15: How important would it be to you to be able to book a travel package (train/flight) through the provider?	3.27	1.437	B
Item 43: How important is it to you that individual dietary needs are taken into account?	3.18	1.549	B
Item 27: How important would it be to you that, in addition to the main concerts, there is a varied daily program with additional entertainment?	3.17	1.246	B
Item 19: How important would the preferred size of the ship be to you?	3.13	1.149	B
Item 31: How important would it be to you to have shore excursions related to the festival theme?	3.05	1.166	B
Item 44: How important is it to you that festival-typical snack food is also offered?	3.05	1.344	B
Item 41: How important would it be to you to have à la carte restaurants?	3.03	1.304	B
Item 14: How important would it be to you that you don't have to fly for the trip?	2.98	1.529	C
Item 37: How important would it be to you to have a wellness/spa area?	2.94	1.383	C
Item 28: How important would it be to you that additional activities with the artists are offered?	2.74	1.267	C
Item 25: How important would it be to you that niche genres are also presented?	2.62	1.134	C
Item 38: How important would it be to you to have a fitness area?	2.6	1.342	C
Item 48: How important would detailed advice from a travel agency be to you?	2.55	1.391	C
Item 32: How important would it be to you to have as few sea days as possible on the trip?	2.42	1.244	C
Item 16: How important would it be to you that the trip takes place during holiday periods or over public holidays?	2.17	1.433	C

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Table A.2. *Results of the mean value analysis of the success factors in relation to the two cluster groups formed (own illustration)*

	Cluster 1			Cluster 2		
	Cluster size 39,7 % (n=230)			Cluster size 60,3 % (n=349)		
Item	Average	Importance	Category	Average	Importance	Category
Item 13: How important would the optimal duration of a festival cruise be to you?	3,57	0	B	3,52	0	B
Item 14: How important would it be to you that you don't have to fly for the trip?	3,38	0,07	B	2,72	0,07	C
Item 15: How important would it be to you to be able to book a travel package (train/flight) through the provider?	3,51	0,03	B	3,11	0,03	B
Item 16: How important would it be to you that the trip takes place during holiday periods or over public holidays?	2,85	0,23	C	1,73	0,23	C
Item 17: How important would it be to you that the trip takes place in warm temperatures?	4	0,05	A	3,63	0,05	B
Item 19: How important would the preferred size of the ship be to you?	2,93	0,04	C	3,27	0,04	B
Item 20: How important would it be to you that the cruise operator is already established and has a good reputation?	3,67	0,02	B	3,91	0,02	B
Item 21: How important would it be to you that the cruise operator places great emphasis on sustainability and environmental protection?	4,01	0,07	A	3,46	0,07	B
Item 23: How important would your preferred music genre be during the festival cruise?	4,54	0,02	A	4,36	0,02	A
Item 24: How important would it be to you that well-known headliners and artists from the music genre perform?	3,75	1,34 E-4	B	3,75	1,34 E-4	B

Item 25: How important would it be to you that niche genres are also presented?	2,71	0,01	C	2,55	0,01	C
Item 26: How important would it be to you to have multiple stages or venues on board?	3,88	0,07	B	3,38	0,07	B
Item 27: How important would it be to you that, in addition to the main concerts, there is a varied daily program with additional entertainment?	3,4	0,04	B	3,01	0,04	B
Item 28: How important would it be to you that additional activities with the artists are offered?	2,5	0,04	C	2,91	0,04	C
Item 29: How important would it be to you to have a strong festival atmosphere?	4,34	0,14	A	3,73	0,14	B
Item 30: How important would it be to you that the ports and destinations are attractive?	3,63	0,02	B	3,83	0,02	B
Item 31: How important would it be to you to have shore excursions related to the festival theme?	3,22	0,03	B	2,93	0,03	C
Item 32: How important would it be to you to have as few sea days as possible on the trip?	2,37	0	C	2,45	0	C
Item 33: How important would it be to you that there is sufficient time in the port (no stops that are too short)?	3,57	0,01	B	3,66	0,01	B
Item 35: How important is the choice of cabin category to you?	3,18	0,16	B	3,94	0,16	B
Item 36: How important is it to you that there are quiet areas on board away from the festival activities for relaxation?	4,42	0,02	A	4,2	0,02	A
Item 37: How important would it be to you to have a wellness/spa area?	2,87	0,01	C	2,99	0,01	C
Item 38: How important would it be to you to have a fitness area?	2,55	0	C	2,64	0	C

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Item 39: How important would a large selection of drinks on board be to you?	4,3	0,06	A	3,93	0,06	B
Item 40: How important would the option to book an all-inclusive upgrade with drinks in advance or on board be to you?	3,92	0,01	B	3,79	0,01	B
Item 41: How important would it be to you to have à la carte restaurants?	2,69	0,08	C	3,26	0,08	B
Item 42: How important would it be to you to have buffet restaurants?	3,72	0,05	B	3,32	0,05	B
Item 43: How important is it to you that individual dietary needs are taken into account?	4,09	0,37	A	2,58	0,37	C
Item 44: How important is it to you that festival-typical snack food is also offered?	3,4	0,07	B	2,83	0,07	C
Item 45: How important would it be to you that restaurants have long and flexible opening hours so that you can also eat out during the festival program?	4,38	0,05	A	4,05	0,05	A
Item 46: How important would it be to you that bars are open until late at night?	4,29	0,09	A	3,72	0,09	B
Item 47: How important would a straightforward booking process via the internet be to you?	4,56	0,1	A	4,01	0,1	A
Item 48: How important would detailed advice from a travel agency be to you?	2,4	0,02	C	2,65	0,02	C

DIGITAL BUSINESS TRANSFORMATION IS PRIMARILY A HUMAN CHALLENGE, NOT A DIGITAL ONE

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Abstract: *Digital transformation (DX) failures are more often rooted in organizational and human factors than in technological inadequacy. This paper shows that the frequently cited 70% failure rate of DX initiatives is closely related to insufficient attention to shared vision, stakeholder alignment, change leadership, continuous learning, and organizational culture. The paper integrates David Rogers' digital transformation roadmap, John Kotter's change leadership framework, Peter Senge's learning organization principles, and Nigel Vaz's emphasis on learning, unlearning, and relearning. To complement this conceptual synthesis, the paper includes an exploratory descriptive analysis of four course-based analytical tasks completed by master's-level students with substantial professional experience. The descriptive findings are consistent with the theoretical emphasis on strategic coherence, psychological safety, problem validation, learning capability, and structural alignment. The paper therefore frames digital business transformation primarily as an organizational challenge in which technology functions as an enabler rather than the primary determinant of success.*

Keywords: *digital transformation, organizational change, shared vision, learning organization, change leadership.*

1 Introduction

Over the last three decades, advances in computer hardware, software, and networks have produced a sequence of related concepts. Digitization refers to the conversion of analogue information into digital form, while digitalization refers to the broader reorganization of social and organizational life around digital communication and media infrastructures. Digital transformation goes further and can be understood as an attempt to improve an entity by triggering significant changes through combinations of information, computing, communication, and connectivity technologies (Brennen & Kreiss, 2014; Vial, 2019).

In practice, however, transformation rarely fails because organizations cannot buy or deploy technology. The more persistent problem is that new technologies unsettle established processes, governance structures, and cultural assumptions. This pattern suggests that digital transformation should be treated as a combination of digital strategy and organizational change rather than as a technology implementation project (Rogers, 2023). This broader view is consistent with review-based evidence showing that digital transformation research in business and management increasingly emphasizes strategy, change management, dynamic capabilities, and value creation rather than technology adoption alone (Kraus et al., 2022).

Many organizations are redesigning communication channels, customer interfaces, internal workflows, and business models in response to changing customer expectations and intensified competition. Although such initiatives often promise gains in speed, quality, and productivity, they also generate resistance, coordination problems, and uncertainty. As Rogers (2023) emphasizes, transformation unfolds in a turbulent environment where customer needs, competitive dynamics, and organizational structures all change simultaneously.

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The purpose of this paper is to show that digital business transformation is primarily a human and organizational challenge. The paper integrates Rogers' roadmap with Kotter's change leadership framework, Senge's learning-organization perspective, and Vaz's emphasis on continuous learning and unlearning. To complement this theoretical foundation, it also uses an exploratory descriptive analysis of assignment-based data from experienced master's students to identify recurring organizational themes related to digital transformation failure, experimentation, strategic vision, and idea evaluation. The empirical material is used as a bounded descriptive supplement rather than as a basis for broad statistical generalization.

2 Theoretical Framework: Integrating Change Leadership with Digital Transformation

Rogers (2023) proposes a five-step digital transformation roadmap: define shared vision, pick problems that matter, validate new ventures, manage growth at scale, and grow technology, talent, and culture. This roadmap is valuable because it connects strategy with execution. At the same time, it assumes organizational conditions that must be created deliberately through leadership and culture.

Kotter's (2012) change leadership framework explains how these conditions emerge. His work emphasizes urgency, guiding coalitions, communication of vision, empowerment, short-term wins, consolidation, and cultural anchoring. For digital transformation, Rogers clarifies what should be changed, while Kotter explains how change should be led.

Senge (1990) adds a third dimension by showing that sustainable change requires learning capability. A learning organization is built on systems thinking, personal mastery, mental models, shared vision, and team learning. Vaz (2021) extends this logic to digital environments by emphasizing that established organizations must develop the capacity to learn, unlearn, and relearn continuously.

The human and organizational dimensions that these frameworks address are what distinguish transformation successes from failures. Technology is necessary but insufficient. This conclusion is also consistent with evidence from the HRM domain, where digital transformation effectiveness depends not only on technology adoption but also on the human capacity to interpret, adapt, and act upon digital opportunities (Aškerc Zadavec, Weis & Gorenc, 2025). Transformation success therefore requires leaders who establish urgency and clear vision, build coalitions with psychological safety enabling action, empower experimentation and learning, and cultivate cultures where continuous learning and intellectual humility are normalized.

This interpretation is also consistent with Vial's (2019) review, which conceptualizes digital transformation as a process in which digital technologies create disruptions that trigger strategic responses, while outcomes depend on how organizations manage structural changes and organizational barriers.

Taken together, these perspectives provide the conceptual lens for the exploratory empirical supplement presented in the next section. Table 1 summarizes how the four authors contribute to this integrated perspective.

Table 1. *Integrated contribution of the four frameworks to digital business transformation*

Framework / author	Primary focus	Contribution to DX as a human and organizational challenge
Rogers (2023)	Transformation roadmap and strategic sequencing	Defines the transformation agenda and links strategy with execution across vision, validation, scaling, and capability growth.

Kotter (2012)	Change leadership and mobilization	Explains how urgency, coalitions, communication, and short-term wins translate transformation intent into coordinated organizational action.
Senge (1990)	Learning organization capability	Shows that sustainable change depends on systems thinking, shared vision, team learning, and the ability to challenge entrenched mental models.
Vaz (2021)	Continuous learning, unlearning, and relearning	Highlights the cultural and behavioral conditions required for established firms to remain adaptive in digitally turbulent environments.

3 Method

3.1 Research design and setting

This study combines a conceptual synthesis with an exploratory descriptive analysis of course-based empirical material. The conceptual part integrates the digital transformation perspectives of Rogers, Kotter, Senge, and Vaz in order to explain why transformation success depends on leadership, learning, and organizational alignment as much as on technology choices. The empirical part complements this synthesis with descriptive evidence from four structured course-based analytical tasks completed within a master's-level course.

The purpose of the empirical component is not to test causality or to validate the framework statistically. Rather, it is used to identify recurring perceptions that can illustrate whether the organizational themes emphasized in the literature also appear in the reflections of participants with substantial professional experience.

3.2 Participants

The participants were master's-level students with substantial professional experience. The available single-response items indicate a cohort size in the mid-thirties (35 students), while higher totals in some questions reflect multiple-response formats. The responses were collected in October and November 2025. This profile is important because the respondents were not full-time students without practice; they were experienced adult learners able to reflect on transformation challenges from both academic and workplace perspectives.

The sample should nevertheless be understood as a convenience sample from an educational setting rather than as a representative population of managers or firms.

3.3 Instrument and procedure

The empirical material consisted of four course-based analytical tasks, each containing two to three structured questions. The assignments addressed perceived reasons for digital transformation failure, barriers to innovating outside the core business, properties and limitations of strategic vision, symptoms of successful experimentation, critical questions for evaluating new ideas, signals for abandoning projects, and the business value of a solution.

Responses were aggregated into thematic categories and summarized in frequency counts. Some items required one response, whereas others allowed multiple selections or asked respondents to identify the two most important options. As a result, total coded responses vary across questions.

3.4 Data analysis

The analysis relied on descriptive statistics only, primarily frequencies and percentages. For single-response items, the totals approximate the number of participants who answered the question. For multiple-response items, percentages represent the share of total coded responses within a question rather than the share of individual participants.

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The descriptive findings were then compared with the conceptual framework to assess whether the participant responses were consistent with the proposed emphasis on shared vision, psychological safety, problem validation, learning capability, and structural alignment.

3.5 Limitations of the empirical component

The empirical component is presented in Table 2 and has several limitations. The sample was non-random and drawn from one educational context. The findings therefore cannot be generalized to all organizations, sectors, or leadership teams.

In addition, the data derive from structured assignment responses and descriptive aggregation rather than validated psychometric instruments or inferential testing. For this reason, the empirical material should be interpreted as a bounded descriptive supplement to the theoretical argument.

Table 2. Overview of the empirical component used as a descriptive supplement

Course-based task	Main question focus	Response format	Dominant themes
Task 1	DX failure reasons; two most important failure causes	Multiple response and forced-choice priority selection	Fear of experimenting; absence of shared vision; capability gaps
Task 2	Innovation outside the core business; properties and limits of vision	Single-response categorical items	Silos; core-business resource lock-in; legal and ownership constraints
Task 3	Bad decisions without vision; experimentation success; idea evaluation	Single and multiple-response categorical items	Technology hype; disconnected goals; customer signals; parallel testing; safe-to-fail conditions; customer/problem definition
Task 4	Most important added value of a solution	Single-response categorical item	Savings; risk reduction; new revenue

4 Exploratory Descriptive Findings

The descriptive findings reveal a pattern that aligns closely with the literature reviewed above. In Task 1, fear of experimenting was the most frequently cited reason for digital transformation failure (46.2%). When participants were asked to identify the two most important failure reasons, the most common responses were absence of shared vision (30.0%) and lack of capability upgrade (28.6%). These patterns place organizational clarity, learning, and willingness to experiment ahead of technology itself as perceived determinants of failure.

Task 2 focused on innovation outside the core business and on strategic vision. Organizational silos were the most frequently cited barrier to innovation outside the core business (35.9%), followed by resource dedication to the core business only (20.5%). When participants described the properties of vision, the strongest emphasis was placed on connectivity with vision (51.4%), ahead of inspiration (28.6%). They also identified legal environment (38.9%) and ownership structure (30.6%) as major constraints on feasible vision. Together, these findings suggest that vision is valued not only as a motivational statement, but as an integrative device shaped by structural realities.

Task 3 further reinforced the business-led and learning-oriented character of the responses. The most common bad decision associated with poor understanding of vision was following technology hype (38.0%), while disconnected departmental goals ranked second (24.0%). Successful experimentation was associated most strongly with decisions based on customer signals (26.3%), parallel testing of multiple ideas (23.2%), and safe-to-fail conditions

in which failure is not expensive (21.2%). In the evaluation of new ideas, the two most frequent questions were “Who is my client?” (21.0%) and “Are we solving the right problem?” (18.1%).

Task 4 asked about the most important added value of a solution. The dominant response was savings (48.6%), followed by risk reduction (22.9%) and new revenue (14.3%). Although this question is less central to the present framework, it still indicates that participants associated successful digital initiatives with concrete business value rather than with novelty for its own sake. Table 3 summarizes the key descriptive findings across the four course-based tasks.

Table 3. *Descriptive findings across the four course-based tasks*

Tasks	Main focus	Key descriptive findings
Task 1	DX failure reasons	Fear of experimenting was the most frequently cited failure reason (46.2%).
Task 2	Innovation outside the core business; strategic vision	Organizational silos were the most frequently cited barrier to innovation outside the core business (35.9%). Vision was associated primarily with connectivity/coherence (51.4%).
Task 3	Vision-related decisions; experimentation; idea evaluation	Following technology hype (38.0%). In idea evaluation, the most frequent question was “Who is my client?” (21.0%).
Task 4	Added value of a solution	The dominant response was savings (48.6%).

When we rearrange the findings from a perspective of five critical success factors, these descriptive findings show that the participants repeatedly emphasized strategic coherence, experimentation, customer problem definition, learning, and structural conditions. These recurring themes are consistent with the argument that digital business transformation is primarily a human and organizational challenge. Summary of findings is presented in Table 4.

Table 4. *Five critical success factors and indicative descriptive findings*

Critical success factor	Theoretical meaning	Indicative descriptive findings
Shared vision and strategic coherence	A coherent transformation direction that connects units, priorities, and decisions.	No shared vision (30.0%); vision connectivity/coherence (51.4%); following technology hype without clear direction (38.0%).
Psychological safety and coalition action	Conditions in which people can experiment, question assumptions, and act across boundaries.	Fear of experimenting (46.2%); successful experimentation linked to safe-to-fail conditions (21.2%); silos highlighted as a barrier (35.9%).
Problem validation before solution building	Clarifying customer, problem, and value logic before scaling solutions.	Most frequent evaluation questions were “Who is my client?” (21.0%) and “Are we solving the right problem?” (18.1%).
Learning organization capability	Evidence-based adaptation through experimentation, feedback, and revision of assumptions.	Successful experimentation linked to customer signals (26.3%), parallel testing (23.2%), and flexible problem solving (14.1%).
Structural alignment and cultural anchoring	Governance, resources, and culture aligned with the transformation direction.	Resource dedication to core business (20.5%), legal environment (38.9%), and ownership structure (30.6%) shaped perceived feasibility.

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5 Discussion: Five Critical Success Factors for Digital Business Transformation

Against this background, the discussion highlights five critical success factors for digital business transformation. Each factor is conceptually grounded in the literature and descriptively supported by recurring response patterns in the empirical material.

5.1 Shared vision and strategic coherence

The first critical factor is shared vision supported by strategic coherence. Kotter (2012) highlights the importance of urgency and communicated direction, while Rogers (2023) emphasizes the need for a transformation vision grounded in future developments and the organization's right to win. The descriptive findings reinforce this point. Participants most frequently identified absence of shared vision as a central cause of failure and described connectivity or coherence as the most important property of vision.

This suggests that vision should not be treated as a symbolic statement alone. Its practical function is to align priorities, interpret external change, and connect departmental activity to a common transformation direction. When this coherence is missing, organizations become more vulnerable to hype-driven projects, duplicated initiatives, and conflicting priorities.

5.2 Psychological safety and coalition action

The second factor is psychological safety enabling coalition action. Kotter's notion of a guiding coalition explains why transformation must be carried by actors with credibility across organizational boundaries. Yet such coalitions are unlikely to emerge if people perceive experimentation as dangerous or career threatening.

The empirical material is highly consistent with this interpretation. Fear of experimenting was the most frequently cited failure reason, and successful experimentation was associated with safe-to-fail conditions. These patterns suggest that coalition building is not only a matter of formal leadership alignment, but also of creating environments in which people can report weak results honestly, question assumptions, and act across silos without punitive consequences.

5.3 Problem validation before solution building

The third factor is disciplined problem validation before solution building. Rogers' staged validation logic points in this direction, but the descriptive findings sharpen the point further: participants consistently prioritized identifying the customer and clarifying the right problem before considering other business or technical questions.

This emphasis is important because digital transformation initiatives often begin with enthusiasm for tools or platforms rather than with validated customer problems. The finding that technology hype was the most frequent example of a bad decision further supports the need to begin with problem definition, customer relevance, and value logic rather than with premature solution design.

5.4 Learning organization capability

The fourth factor is learning organization capability. Senge (1990) provides the broad conceptual foundation, while Vaz (2021) translates it into a digital context by emphasizing learning, unlearning, and relearning. The descriptive findings mirror this logic in practical terms: participants associated successful experimentation with customer signals, parallel testing, safe failure, and flexible adaptation.

These patterns point to a specific organizational capability rather than to isolated tactics. Learning organizations do not simply collect information; they embed routines for testing

assumptions, interpreting feedback, revising direction, and abandoning weak ideas. This capability becomes especially important after initial pilots, when sustained transformation depends on continuous adjustment rather than on a single implementation event.

5.5 Structural alignment and cultural anchoring

The fifth factor is structural alignment anchored in culture. The literature makes clear that transformation fails when governance, incentives, resource allocation, and capability-building remain tied to the logic of the legacy business. This point is reinforced by review-based evidence showing that digital transformation reshapes firms across multiple organizational layers and that transformation success depends in part on how firms manage structural redesign, boundary changes, and tensions between centralization and decentralization (Plekhanov, Franke & Netland, 2022). The assignment-based findings are consistent with this view: participants emphasized silos, core-business resource concentration, legal constraints, and ownership structures as factors that shape what organizations can realistically do.

This factor links structural design with cultural change. Structures determine whether collaboration, experimentation, and investment are possible in practice, while culture determines whether people accept, normalize, and sustain the new way of working. For this reason, structural reform and cultural anchoring should be treated as mutually reinforcing rather than as separate streams of work.

6 Implications for Organizational Leaders

For organizational leaders, the central implication is that digital transformation should be governed as a business and organizational change process rather than as a sequence of technology projects. Table 5 summarizes the main leadership priorities emerging from the combined theoretical and descriptive analysis.

Table 5. *Leadership implications for digital business transformation*

Leadership priority	What leaders should do	Expected organizational effect
Create strategic coherence	Communicate why change is necessary, define a realistic transformation direction, and connect every major unit to that direction.	Higher alignment, fewer disconnected projects, and better decision consistency.
Build safe-to-act coalitions	Form coalitions across formal and informal leadership networks and legitimize experimentation without punitive reactions to failure.	Greater initiative, honest reporting, and stronger cross-functional collaboration.
Validate real problems	Invest in customer and stakeholder research before committing to solution design or scaling decisions.	Better resource allocation and lower risk of expensive but irrelevant initiatives.
Institutionalize learning	Use post-mortems, decision reviews, experimentation routines, and evidence-based governance.	Faster adaptation and stronger capacity to adjust when assumptions prove incorrect.
Remove structural barriers	Redesign governance, funding, incentives, and capability development to ensure transformation work is protected from core business pressures.	Improved execution capacity and greater durability of change.
Anchor change in culture	Reinforce desired behaviors through hiring, promotion, evaluation, and leadership role-modeling.	Transformation becomes part of organizational identity rather than a temporary program.

7 Conclusions

This paper shows that digital business transformation is primarily a human and organizational challenge, not a technological one. The conceptual synthesis indicates that transformation success depends on shared vision, change leadership, learning capability, and structural alignment. The exploratory descriptive evidence from assignment-based data points in the same direction by repeatedly highlighting fear of experimentation, lack of shared vision, silos, customer-problem definition, and the need for safe learning conditions.

The contribution of the paper lies in combining a theoretical framework with a clearly bounded empirical supplement. Rather than presenting the descriptive statistics as generalizable proof, the paper uses them to illustrate how experienced master's-level participants interpret recurrent transformation problems. This strengthens the paper methodologically by making the empirical basis transparent and proportionate to the claims being made.

For practice, the message is direct. Organizations that invest in strategic coherence, psychological safety, disciplined problem validation, learning capability, and structural alignment will be better positioned to achieve sustained digital transformation. Future research should test the proposed framework in broader organizational samples and with more formal empirical designs.

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THE ROLE OF ARTIFICIAL INTELLIGENCE IN ASSESSING THE REVENUE MANAGEMENT EFFECTIVENESS

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Abstract: *This paper develops and evaluates an organizational mechanism for AI-enhanced revenue management (RM) in hospitality that combines monitoring and analytics, machine-learning-driven dynamic pricing, advanced AI segmentation, strategic partnerships, and staff motivation programs. The main objective is to propose and validate a dual-metric assessment framework that enables holistic optimization of RM subsystems by linking quantitative financial, HR, and resource indicators with complementary qualitative marketing, environmental, and digital metrics. Methodologically, the study uses mixed methods: quantitative modelling and metric definition (CostPar—average cost per occupied room, Occ—average occupancy rate, staff labor productivity, and Market Penetration Index) are paired with qualitative socio-economic evaluation (ecological activity cost coefficient and digitalization cost coefficient); these metrics are tested through scenario analyses and comparative assessment to demonstrate their integrative capability. Results show that (1) combining AI-driven pricing and segmentation with real-time monitoring improves revenue capture and occupancy efficiency; (2) the dual-metric framework more accurately reflects subsystem performance than single-dimension measures, revealing trade-offs between short-term financial gains and longer-term marketing, ecological, and digital investments; and (3) specific metrics (CostPar, Occ, staff productivity, MPI, ecological and digital cost coefficients) provide actionable insights for targeted interventions. The discussion highlights practical implications: hospitality managers should adopt the proposed framework to balance revenue maximization with sustainability and digital transformation goals; AI tools must be embedded within organizational processes and staff incentive systems; and multi-indicator evaluation is necessary for justified, generalized RM assessments. The framework supports data-driven decision-making and offers a roadmap for implementing AI-enabled, sustainable RM in hospitality.*

Keywords: *Revenue management, artificial intelligence, revenue management effectiveness, digital revenue management technologies, synchronization coefficient.*

INTRODUCTION

The significant impact of methodological approach to evaluating revenue management metrics based on a balanced scorecard framework, especially for AI-enhanced hospitality operations small and independent facilities, due to limited economic and investment opportunities, deteriorating competitiveness and revenue shortfalls. To define the key concepts of revenue management effectiveness, a structured methodology for their assessment has been proposed. In the hotel industry, revenue management (RM) increasingly utilises artificial intelligence-based tools—such as dynamic pricing using machine learning, advanced market segmentation via AI algorithms, and real-time monitoring of key performance indicators—with

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the aim of boosting revenue generation and operational efficiency. However, the prevailing methodological approaches to evaluating RM effectiveness remain predominantly financial and one-dimensional, focusing on individual metrics such as revenue per available room or average occupancy rate. This narrow focus creates a critical gap in the literature: there is a limited number of empirical and theoretical recommendations on how to evaluate RM subsystems holistically, considering the trade-offs between short-term financial benefits and long-term investments in marketing, sustainability, digitalisation and human capital. For small and independent hotels — constrained by limited economic and investment capacity, reduced competitiveness and a persistent revenue shortfall — this gap is particularly problematic, as single-metric evaluation can lead to the misallocation of scarce resources and undermine the strategic value of AI implementation.

Theoretical concepts from the fields of management and organisational sciences offer promising avenues, but they have not yet been systematically integrated into the methodology for evaluating resource management. The Balanced Scorecard (Kaplan & Norton, 1996) rethinks performance evaluation by going beyond financial results to include aspects related to customers, internal processes and learning/development, yet its application to AI-based resource management in the hospitality sector remains under-researched. The theory of dynamic capabilities (Teece, 2007) emphasises the capabilities of perception, utilisation and reconfiguration, which are critical for adaptive resilience, but empirical studies linking AI-based resource management to the development of dynamic capabilities in small hotels are few and far between. Similarly, the theory of external control of organizations (Pfeffer & Salancik, 2015) and agency theory (Meckling & Jensen, 1976) suggest that multi-dimensional metrics are necessary for strategic prioritisation and mitigating myopic optimisation; yet the literature on revenue management in the hospitality sector has not empirically confirmed how balanced multi-indicator frameworks improve the consistency of decisions or the accuracy of their implementation under resource constraints.

Assessing the performance of subsystems — financial, human resources, resource management, marketing, environmental and digital — using a standardised scale allows for the consolidation and systematisation of data, revealing patterns in resource utilisation and the dynamics of indicators as factors influencing revenue across different hotel categories (e.g., 3*, 4*, 5*).

The development of integration profiles for indicators, derived from the financial reports of Ukrainian hotels and expert surveys, highlights imbalances in 3-star hotels, indicating a dispersion of resources and vulnerability to market risks.

The assessment process consists of three stages: scaling qualitative/quantitative indicators, calculating integrated indices of subsystems, and constructing integration profiles to track interdependencies and forecast adjustments.

From an organisational perspective, such balanced integration facilitates the coordination of revenue centres, targeted budgeting and resource optimisation; from a methodological perspective, it enables the identification of system characteristics, cause-and-effect relationships and the monitoring of imbalances for proactive revenue forecasting.

AI-driven digital metrics act as catalysts for balance in the digital economy, identifying revenue reserves through intelligent data integration.

Efficiency concepts focus on maximising revenue by utilising resource potential whilst minimising financial risks, relying on booking systems that track key performance indicators (KPIs). The evaluation process involves three stages: scaling qualitative/quantitative metrics, computing subsystem integral indices, and constructing integration profiles to track interdependencies and forecast adjustments. In organizational terms, this balanced integration fosters revenue center coordination, targeted budgeting, and resource optimization;

methodologically, it yields temporal system characteristics, causal links, and imbalance monitoring for proactive revenue forecasting.

Digital metrics, powered by AI, serve as catalysts for balance in the digital economy by identifying revenue reserves through intelligent data integration in different spheres (Mikava & Mamulaidze, 2023; Weis & Vukasović, 2025).

Effectiveness concepts emphasize maximizing income via resource potential while minimizing financial risks, drawing from booking systems tracking core KPIs like Occupancy Rate, RevPAR, ADR, MPI, and extended ones (HRPar, ECPAr, DCPAr).

Strategic partnerships, tech access, and stakeholder feedback enhance external cores (marketing, ecological, digital), though challenges persist in metric misalignment and skill gaps—addressed via corporate/regional outsourcing for scalable, objective gains.

The methodology sequences analytical steps to optimize resource use, demand satisfaction, cost control, and dynamic pricing in AI-driven revenue management. for AI-enhanced hospitality operations. It defines key concepts of revenue management effectiveness and proposes a structured methodology for their assessment.

Evaluation of subsystem metrics—financial, HR, resource, marketing, environmental, and digital—using a unified scale enables generalization and systematization, revealing resource utilization patterns and metric dynamics as revenue drivers across hotel categories.

In organizational terms, this balanced integration fosters revenue center coordination, targeted budgeting, and resource optimization; methodologically, it yields temporal system characteristics, causal links, and imbalance monitoring for proactive revenue forecasting.

The main objective of the article is to develop and empirically test a methodology that combines quantitative financial, human resources and resource indicators (CostPar, Occ, staff productivity, MPI) with complementary qualitative marketing, environmental and digital indicators (environmental activity cost ratio, digitalisation cost ratio) to ensure the holistic optimisation of resource management subsystems using artificial intelligence. Using a mixed-methods approach — quantitative modelling of indicators combined with qualitative socio-economic assessment and scenario-based comparative testing — the aim is to investigate how this system improves revenue generation, identifies trade-offs in performance and helps allocate the limited resources of hotel operators.

METHOD

I.1. Sample and population

Data collection and interviews with hotel managers took place between February and May 2024 and covered the data collection period from 2012 to 2023, using the CAWI (computer-assisted web interview) method. Hotel managers from Ukraine were invited to participate in the survey (senior management and/or heads of departments – sales, marketing and reservations).

I.2. Data Collection Process and Methods

To operationalize the methodological approach for evaluating revenue management metrics, detailed justification focuses on metric content within the context of its empirical testing across a sample of hotels varying by star category. Hotel category serves as the primary grouping criterion, as survey results indicate that revenue management systems—whether comprehensive or partial—are predominantly implemented in 3* and higher establishments, making it a stable, time-invariant indicator immune to inflation and foundational to all financial and operational metrics.

Sample selection criteria included observation volume (economic analyses often rely on small samples of 5–30 units); location; ownership form; enterprise size; and market

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saturation. The diversity of economic phenomena, research objectives, and heterogeneous data necessitated grouping techniques, forming homogeneous clusters from the statistical population based on typical features. Group homogeneity was assessed via variation coefficients ranging from 41–42%, confirming sufficient uniformity for analyzing factor impacts on hotel operations and development. Hotels were then stratified into three groups by category: Group 1 (5* hotels, n=3); Group 2 (4* hotels, n=9); Group 3 (3* hotels, n=6). Groupings ensured comparable economic conditions, competitive markets, locations, customer bases, service levels, categories, and service volumes, with "proximity" or "similarity" across attributes as the homogeneity benchmark.

RESULTS

In accordance with the established methodological framework for the use of artificial intelligence in revenue management, we propose the following three-stage sequence for its application (Boiko et al., 2025), assessment of qualitative and quantitative metrics based on a standardised scale; determination and calculation of an integrated metric indicator for each subsystem; construction of revenue management metric integration profiles.

This is the general logic for evaluating revenue management metrics based on a balanced approach, which can be used in practical settings, albeit with some refinements, as the academic literature presents evaluation methods only for financial revenue management metrics, namely indicators of gross revenue, pre-tax profit and cost reduction, which have a quantitative representation (Remy et al., 2023; Boo et al., 2025; Ismail et al., 2002). At the same time, experts from the American consulting firm Allied Market Research, in their report ‘Revenue Management: Global Opportunity Analysis and Industry Forecast 2023–2032’ have identified the need to consider human resources and marketing metrics that determine the strategic ability to maximise revenue (Schwartz et al., 2017).

A revenue management methodology based on a balanced approach utilising artificial intelligence at the methodological, instrumental and organisational levels establishes a systematic foundation for the optimal combination of operational and strategic objectives based on quantitative and qualitative metrics, as outlined in the report by the consulting firm Allied Market Research. The quantitative indicators of the ‘financial subsystem’ metric reflect the status and effectiveness of financial resources in terms of financial stability, liquidity, profitability and financial performance, and their impact on revenue management in the hospitality industry (Kazmi, 2026; Ballani, 2025; Salami, 2025; Vasconcelos, 2025).

For the quantitative indicators under the ‘human resources subsystem’ metric, it is proposed to use those that enable the assessment of how the effectiveness of human resources policy influences revenue generation (Kumar et al., 2024; Sun, 2025; Vasconcelos, 2025).

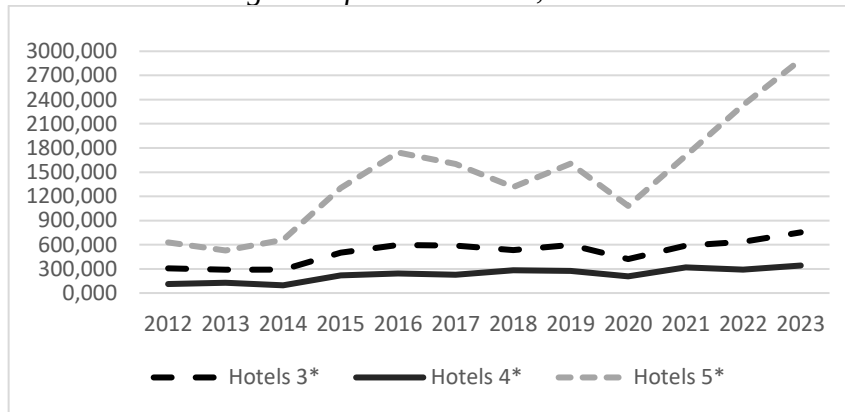
The resource metric is formed by quantitative indicators that are important for assessing the effectiveness of operational activities as a whole and serve as the basis for decision-making regarding room inventory management, business diversification, service expansion, prioritisation of revenue centres, and the use of chatbots (Hossain, 2026; Kühn, 2024; Kilanko, 2023; Coman et al., 2023). The marketing subsystem of revenue management comprises a set of quantitative (monitoring and measuring the financial results of marketing campaigns and operational efficiency) and qualitative indicators, (which form the basis for monitoring consumer behaviour, activities related to distribution channels, and customer satisfaction levels) (Karunakaran et al., 2024; Kavita et al., 2024; Smrutirekha et al., 2022).

The rationale we have established for incorporating quantitative and qualitative indicators of environmental metrics is aimed at enhancing the environmental sustainability and energy efficiency of a hospitality enterprise, which, through cost optimisation and the identification of new revenue streams, will enable the expansion of the target segment and the

maximisation of revenue. The scope of digital metrics comprises both quantitative indicators (the financial efficiency of digitalisation and the optimisation of cost structures) and qualitative indicators (improved service quality, accelerated operational and business processes, and the capabilities of artificial intelligence).

To assess financial metrics, the ‘average cost per room (CostPar)’ indicator was analysed; its trend indicates growth, with five-star hotels dominating the average figure. The rise in hotel costs is a consequence of rising utility and energy prices, increases in the minimum wage and staff social security costs; growing competition in the hospitality sector is forcing businesses to invest in service improvements as a key factor influencing their financial performance. Average costs per room rose steadily between 2012 and 2023 (Figure 1).

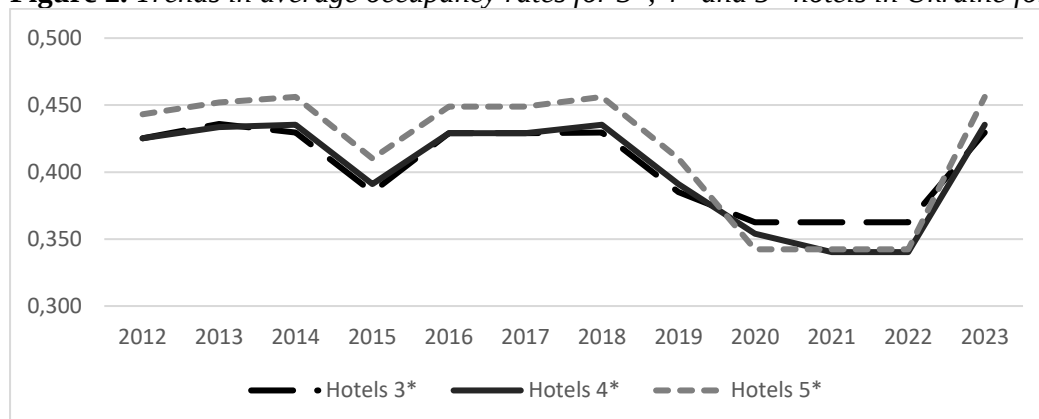
Figure 1. Trends in average cost per room in 3*, 4* and 5* hotels in Ukraine for 2012–2023



Source: Design of authors

In order to assess resource metrics, the quantitative indicator ‘average occupancy rate (Occ)’ was analysed; its trend shows significant fluctuations, particularly due to the impact of the war and economic factors. In 2021, the average occupancy rate for hotels in Ukraine stood at around 37%, which is an improvement compared to 34% in 2020, but still below pre-war levels (approximately 44% in 2013). Following the start of the full-scale invasion in February 2022, many hotels closed or experienced very low occupancy rates (10–20%). However, a gradual recovery began as early as September 2022, and occupancy began to rise thanks to the hosting of events and the accommodation of small groups. In 2023, the average occupancy rate in Ukraine’s hotel market reached 45.19%, which is 10.45% higher than the previous year (Figure 2).

Figure 2. Trends in average occupancy rates for 3*, 4* and 5* hotels in Ukraine for 2012–2023

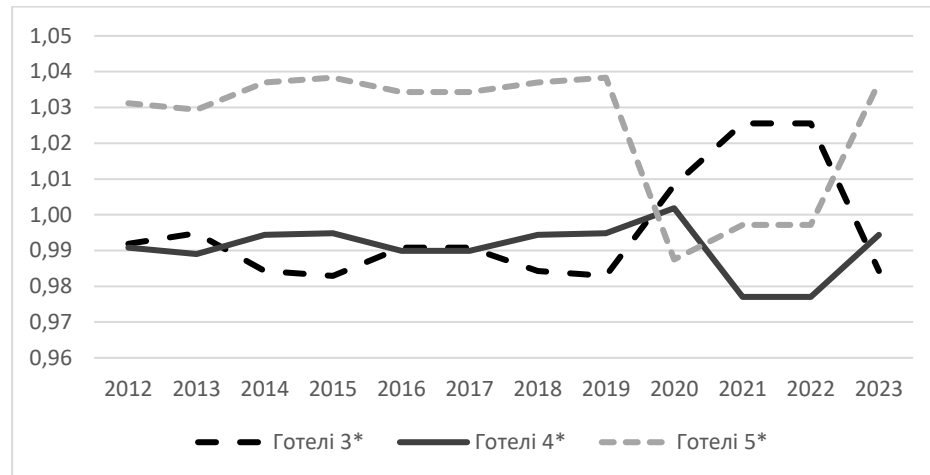


Source: Design of authors

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To assess marketing metrics, the ‘market share (MPI)’ indicator was examined; trends in this indicator suggest that the war and economic changes have significantly affected all categories of the hotel industry. Three-star hotels are facing the greatest difficulties due to a decline in demand, whilst four-star and five-star hotels continue to adapt to the new conditions and are showing signs of recovery (Figure 3).

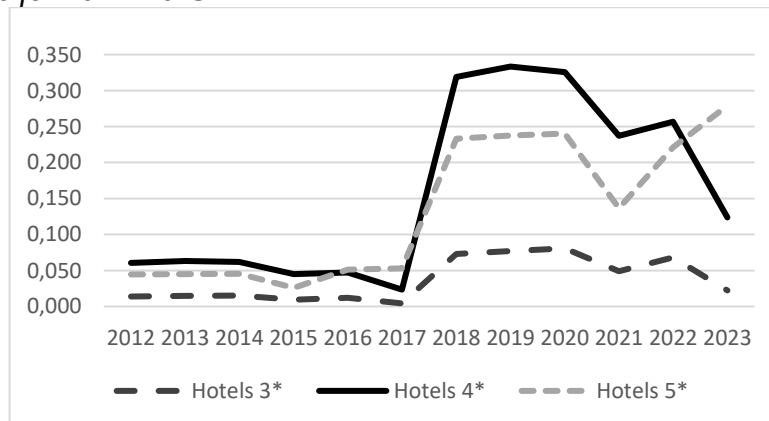
Figure 3. Dynamics of the average market share of 3*, 4* and 5* hotels in Ukraine for 2012–2023



Source: Design of authors

To assess staffing metrics, the ‘staff productivity’ indicator for three-star, four-star and five-star hotels in Ukraine was analysed from the start of martial law in 2022, reflecting the significant impact of military operations on the hotel industry (Figure 4).

Figure 4. Dynamics of the labour productivity indicator for staff at 3*, 4* and 5* hotels in Ukraine for 2012–2023



Source: Design of authors

Due to the war, many hotels suffered significant staff losses. Some staff left their jobs, migrated or joined the armed forces. This led to staff reductions, which had a negative impact on overall labour productivity. The remaining staff often face the need to perform additional duties due to staff shortages. This can lead to an increased workload for employees and a decline in service quality.

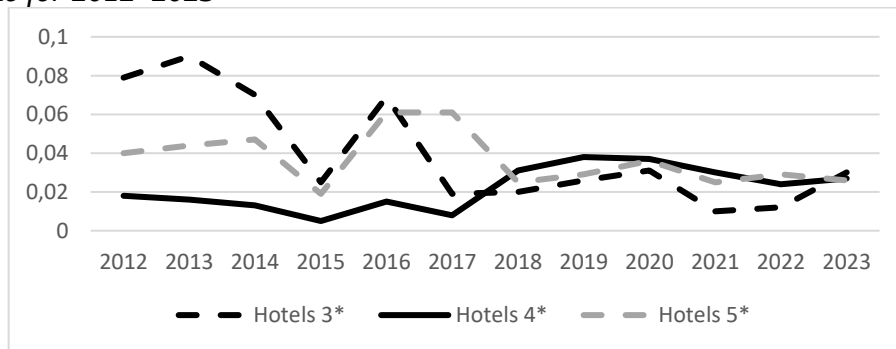
Hotels are being forced to adapt their processes to the new reality, including the introduction of safety measures for staff and guests. This may involve training staff on how to respond to emergencies and providing shelters in the event of air raid alerts.

In three-star hotels, productivity has fallen due to lower levels of automation and limited resources. These establishments often target the budget segment, making them more vulnerable to changes in demand. Four-star hotels have suffered fewer productivity losses compared to three-star hotels thanks to greater resources and better organisation. They have been able to adapt more quickly to the new conditions. Five-star hotels demonstrated the greatest resilience thanks to their high level of service and investment in staff training. They were able to retain some of their skilled staff and adapt their work to the new conditions.

To assess environmental metrics, the ‘environmental expenditure ratio’ was analysed, the dynamics of which indicate an environmental focus and activities aimed at reducing their negative impact on the environment by reducing water and energy consumption through the introduction of energy-saving technologies and the use of alternative energy sources, which is more characteristic of five-star hotels. The dynamics of these costs reflect the overall stability and specific characteristics of each hotel category (Figure 5). To assess digital metrics, the ‘digitalisation cost ratio’ of three-star, four-star and five-star hotels in Ukraine was analysed. The trend in this indicator reflects the overall digitalisation of each hotel category (Figure 6).

As a result of hostilities, hotel property in Ukraine was destroyed or damaged, leading to the loss of infrastructure and resources necessary for operations.

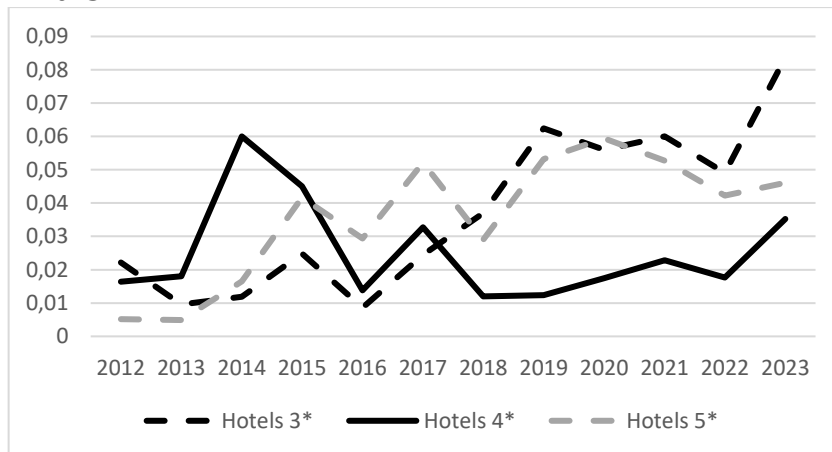
Figure 5. Trends in the cost ratio for environmental activities of 3*, 4* and 5* hotels in Ukraine for 2012–2023



Source: Design of authors

This applies to all categories of hotels, but those located in active combat zones have been hit hardest. Due to the war, the number of tourists has fallen, leading to a reduction in revenue and, consequently, in resources for the digitalisation of hotels. Hotels were forced to invest in security measures, such as shelters and warning systems, which further reduced opportunities for digitalisation.

Figure 6. Dynamics of the digitalisation expenditure ratio for 3*, 4* and 5* hotels in Ukraine for 2012–2023



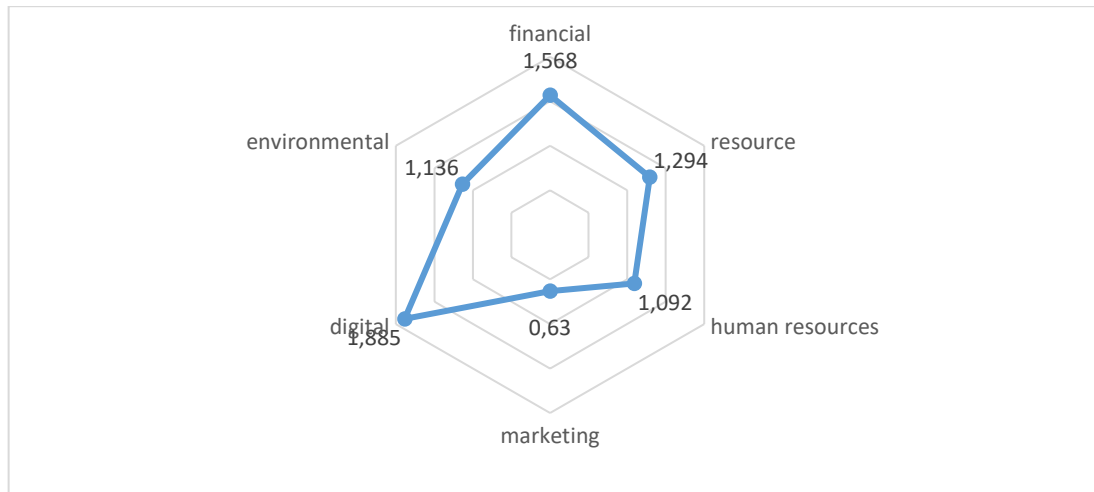
Source: Design of authors

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To compare and standardise the quantitative and qualitative revenue metrics to uniform values, growth rates reflecting their average annual growth rates were used. It has been established that the metrics of different subsystems are interrelated; their assessment and monitoring have made it possible to track how changes in one subsystem can affect other subsystems.

To visualise the results, integration profiles of revenue management metrics have been modelled. (Figure 7-9).

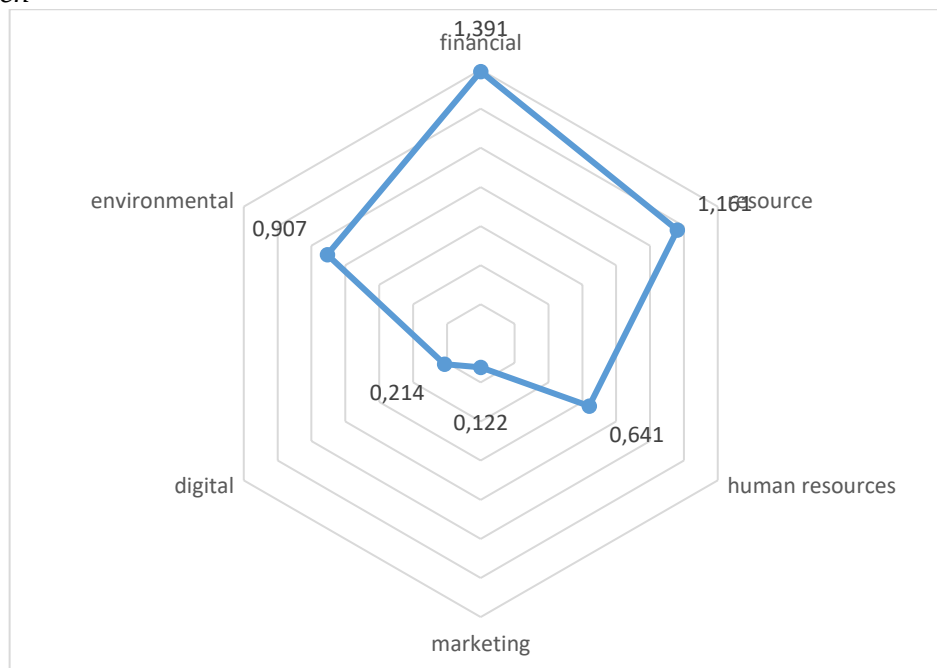
Figure 7. Profile of revenue management metric integration in 3* hotels based on a balanced approach



Source: compiled by the authors using data from the financial statements of Ukrainian hotel enterprises and the results of an expert survey of a sample

In 3* hotels, an imbalance has been identified between digital and marketing revenue management metrics (the range between metric values is 1.26).

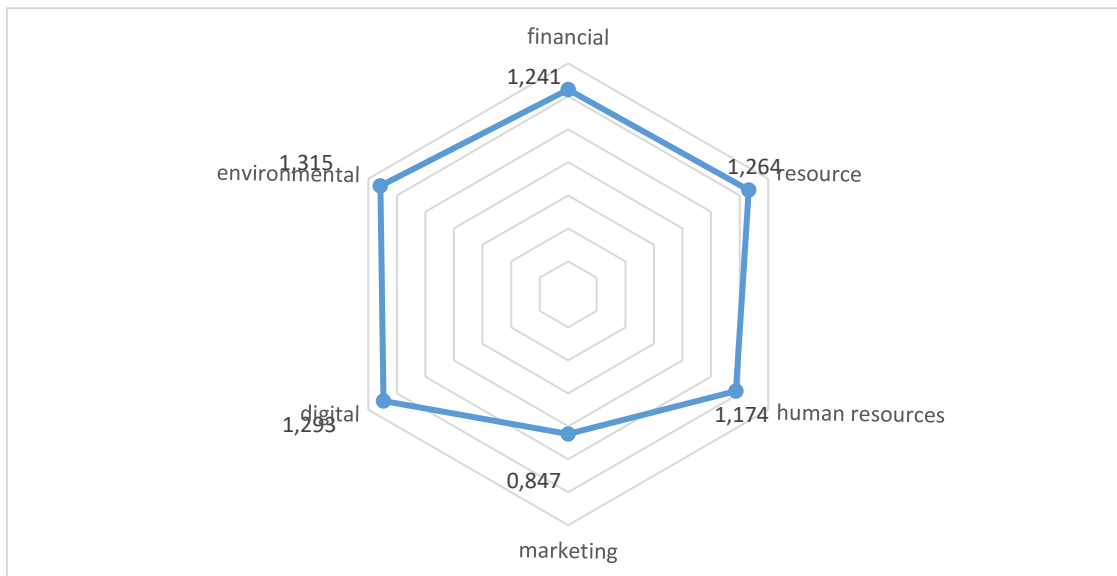
Figure 8. Profile of revenue management metric integration in 4* hotels based on a balanced approach



Source: compiled by the authors using data from the financial statements of Ukrainian hotel enterprises and the results of an expert survey of a sample

In 4* hotels, an imbalance has been identified between financial and marketing metrics (range – 1.27); and between digital and human resources metrics (ranges – 1.18 and 0.75 respectively). A high range between revenue management metrics indicates a dissipation of resources and serves as an indicator of increased risks in the event of market fluctuations; it points to problems in revenue planning and the development of staff digital competencies, leading to stagnation and a decline in revenue in the future.

Figure 9. Profile of the integration of revenue management metrics for 5* hotels based on a balanced approach



Source: compiled by the authors using data from the financial statements of Ukrainian hotel enterprises and the results of an expert survey of a sample

The congruence of revenue management metrics in 5-star hotels (low range from 0 to 0.59) indicates their positive impact on the flexibility and adaptability of revenue management. The balance of revenue management metrics across subsystems facilitates the achievement of revenue management objectives, as adherence to revenue management principles ensures that focusing solely on maximising short-term profits during peak seasons does not compromise the achievement of long-term financial stability. It is precisely the integration and balance of metrics in 5-star hotels that positively influence the flexibility and adaptability of revenue management tools.

Thus, the proposed methodological approach to evaluating revenue management metrics based on a balanced approach makes it possible, depending on the category of the hotel enterprise, to determine the utilisation of resource potential in terms of the dynamics of changes and the consistency of metrics as a source of revenue generation.

The evaluation of revenue management subsystem metrics for hotel enterprises based on a balanced approach, followed by their generalisation and systematisation, has made it possible, depending on the category of the hotel enterprise, to determine the utilisation and deployment of resource potential in relation to the dynamics of change and the alignment of metrics as a source of revenue generation.

DISCUSSION/CONCLUSION

In order to assess the impact of artificial intelligence in hotel revenue management, the quantitative metrics of the ‘financial subsystem’, ‘human resources subsystem’ and ‘resource

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subsystem' have been characterised and assigned threshold values, along with the quantitative and qualitative metrics of the 'digital subsystem', 'marketing subsystem' and 'environmental subsystem' in the context of testing a methodological approach to evaluating revenue management metrics based on a sample comprising hotels of various categories. To evaluate the metrics, the indicators of three-star, four-star and five-star hotels in Ukraine were analysed.

It has been established that Ukrainian hotels exhibit an imbalance between digital and marketing, financial and marketing, and digital and HR revenue management metrics, indicating a significant increase in risks in the event of market fluctuations, which necessitates prompt adjustments to revenue planning. A methodology has been developed for assessing revenue management metrics by subsystems of balance, with a graphical representation of the integration profile in the form of a hexagon, which has been tested in the hotel industry and enables the congruence of metrics to be assessed and areas for revenue maximisation and cost optimisation to be identified. The balance of revenue management metrics across subsystems in 5-star hotels has been identified, which facilitates the achievement of revenue management objectives due to compliance with revenue management principles, the flexibility and adaptability of revenue management tools, and the integration of business processes.

This study analyzed existing approaches to evaluating revenue management (RM) metrics and concluded that a justified, generalized assessment can only be achieved through a comprehensive, multi-indicator approach. The analysis encompassed six key metrics: (1) average cost per occupied room (CostPar) – a financial metric; (2) average occupancy rate (Occ) – a resource metric; (3) staff labor productivity – an HR metric; (4) market penetration index (MPI) – a marketing metric; (5) ecological activity cost coefficient – an environmental metric; and (6) digitalization cost coefficient – a digital metric. These metrics were evaluated using data from three-star, four-star, and five-star hotels in Ukraine. The findings reveal a significant imbalance in Ukrainian hotels between digital and marketing metrics, financial and marketing metrics, and digital and HR metrics. This disbalance indicates substantial vulnerability to market fluctuations and underscores the need for timely adjustments in revenue planning.

To address these challenges, we developed a methodology for evaluating RM metrics across balanced subsystems, featuring a graphical representation of the integration profile in the form of a hexagon. This methodology was applied to hotel enterprises and enables the assessment of metric congruence, identification of areas for revenue maximization, and optimization of costs. The analysis revealed that RM metrics are balanced across subsystems in five-star hotels, which facilitates the achievement of RM goals. This balance is attributable to adherence to RM principles, flexibility and adaptability of RM tools, and the integration of business processes. These findings align with balanced scorecard theory, which posits that multi-dimensional performance measurement enhances strategic alignment and decision coherence.

The conceptual framework of RM effectiveness defines a hotel enterprise's capacity to maximize revenue while optimally utilizing its resource potential and minimizing financial risks. We identified and analyzed outcome indicators generated by the enterprise's resource potential as concepts of the internal and external core of hotel effectiveness. Graphically modeled curves depict the relationship between hotel revenue and average room rate (ARI), MPI, investments in personnel development, and investments in digital, energy-saving, and ecological technologies. The study demonstrates that an adequate representation of RM effectiveness concepts is achieved through the enterprise's resource capabilities, which create an internal leverage effect for revenue formation and growth. This finding supports dynamic capabilities theory, suggesting that resource-based capabilities enable hotels to sense market opportunities, seize revenue potentials, and reconfigure operations for sustained performance.

These results carry important implications for small and independent hospitality operators facing investment constraints. The hexagon-based balanced assessment framework provides a practical tool for identifying metric imbalances, prioritizing investments, and aligning AI-driven RM tools with organizational capabilities. For Ukrainian hotels – particularly those in the three- and four-star categories – the identified imbalances suggest that operational adjustments in digitalization, marketing, and HR development are necessary to mitigate market volatility risks. The demonstrated effectiveness in five-star hotels offers a benchmark for best practices, indicating that integrated business processes and flexible RM toolkits are critical for achieving RM objectives. Future research should examine how these metric imbalances evolve under different market conditions and test the hexagon methodology in international hospitality contexts.

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THE IMPACT OF INNOVATION STRATEGIES ON BUSINESS PERFORMANCE: EVIDENCE FROM SUPERMARKET CHAINS IN ALBANIA

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Abstract: *Innovation is a key driver of competitiveness and business performance, particularly in the retail sector. This study examines the impact of innovation strategies on supermarket chains in Albania, focusing on product, organizational, technological, and digital business model innovations. A quantitative methodology is employed through structured questionnaires administered to supermarket managers and consumers, enabling a comparative analysis of perceptions regarding innovation effectiveness and its influence on performance and customer experience. The findings reveal a strong positive relationship between innovation and business performance. Specifically, 95% of consumers reported improved convenience from online ordering and delivery, 90% were attracted by regularly updated product assortments, and 70% of managers confirmed a positive impact of innovation on performance. Technological and customer-oriented innovations have the greatest effect on customer satisfaction and competitive differentiation, while organizational innovations enhance operational efficiency and long-term sustainability. The results provide practical insights for managers and policymakers in transitional economies.*

Keywords: *innovation strategies, business performance, technological innovation, customer experience, supermarkets, Albania.*

1 Introduction

In today's rapidly evolving business environment, innovation is critical in determining the success and competitiveness of businesses across industries. This study investigates the impact of innovation initiatives on the performance of supermarkets in the Albanian market, specifically exploring how creative approaches to product offerings, marketing techniques, and customer experiences influence consumer behavior, satisfaction, and ultimately corporate performance. Schumpeter (1934) defines innovation as the creation of new production methods or products, while Davila et al. (2013) frame it as a structured strategy for creating value through change. In a globalized competitive landscape, companies must prioritize innovation to remain competitive and adapt to changing dynamics, with Pisano (2015) noting that the absence of a defined innovation strategy is among the most significant barriers to sustained performance improvement.

The retail sector in Albania is undergoing a significant transformation driven by technological advancements, shifting consumer tastes, and intensifying competition. Supermarkets must implement creative strategies to remain relevant and survive in the market. This study, which examines the relationship between innovation strategies and business success, provides important insights for Albanian supermarkets seeking to improve their strategic decision-making. Additionally, the findings can help policymakers, industry

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stakeholders, and business leaders understand the need to cultivate an innovative culture and invest in technology to support retail growth and competitiveness. The study aims to address gaps in the literature on the impact of innovation on business performance in Albanian supermarkets, with the expectation that the findings will offer practical implications for supermarkets navigating the complexities of the modern market landscape.

Research Question: *How do innovation strategies such as self-payment systems, expanded product assortments, reverse vending machines, marketing strategies, and improved customer experience influence the performance of supermarkets in Albania?*

Hypothesis: *Supermarkets in Albania that adopt innovative practices such as self-checkout systems, expanded product assortments, bottle recycling machinery, innovative marketing strategies, and improved customer experiences will perform better financially.*

2 Literature review

2.1 Innovation strategy: conceptual framework

Research within the field reveals considerable disparities in innovation strategies among firms, visible both within specific sectors and over time. An innovation strategy can be understood as a structured plan comprising consistent policies and actions aimed at achieving specific competitive objectives, as articulated by Davila et al. (2013). Sheth and Sinfield (2022) further elaborate that an innovation strategy consists of context-dependent options that serve as management levers for innovation within an industry. These strategies are essential for companies to remain relevant, adapt to market changes, and capitalize on emerging opportunities, encompassing a broad spectrum of activities from product development to process improvement and business model innovation.

Without a defined innovation strategy, companies often rely on a mix of recognized best practices without considering how well they align with broader business objectives. Pisano (2015) underlines the challenge companies face in improving innovation due to the lack of such strategies. Research by Karlsson and Tavassoli (2015) highlights the performance benefits of adopting complex innovation strategies that encompass multiple aspects, such as product, process, organizational, and marketing innovations. They found that companies employing such comprehensive strategies outperform those without innovation initiatives or with simpler strategies focused on individual aspects.

2.2 Innovation in retail and food stores

A growing body of literature highlights the central role of innovation in the retail and food industry. Supermarket retailers rely primarily on three areas of innovation: multi-channel sales, supply chain efficiency, and information management. Retailers predominantly pursue incremental rather than radical innovation, favoring non-technological approaches such as online shopping, electronic shelf labels, and automated checkout systems (Pantano & Vannucci, 2019). Dynamic capabilities — the ability to integrate, build, and reconfigure internal competencies in response to market changes — have been identified as critical for sustaining this innovation trajectory, particularly in the food retail context (Teece, 2018). Recent research published in AIJES highlights that intelligent packaging technologies are increasingly reshaping retail product communication and supply chain sustainability, a trend directly relevant to supermarket innovation strategies (Gigauri & Palazzo, 2023). Similarly, augmented reality and AI-driven personalization tools are emerging as next-generation retail innovations with significant implications for customer engagement (Zimmermann et al., 2023). At the macroeconomic level, Abbes (2025) demonstrates that innovation has a statistically significant positive effect on economic growth in developing economies, reinforcing the strategic importance of innovation adoption in markets such as Albania.

Digital business model innovation in the food retail sector has traditionally been dominated by brick-and-mortar models, which have remained largely untouched by digital disruption until recent years. However, there has been a notable shift towards integrating digital technologies into traditional business models, leading to a closer integration between physical and digital channels. The COVID-19 pandemic further accelerated the adoption of digital technologies in food retail, as retailers were forced to rapidly reorganize their in-store and online operations to minimize physical contact and manage panic buying. The adoption of a genuine digital culture within organizations has been identified as a key enabler of sustainable competitive advantage, linking innovation capacity directly to human capital and talent management practices (Serafimova & Vasilev, 2024).

The Balkan supermarket market is one of the most significant sectors in the services and trade industry of the Western Balkans, encompassing Albania, Kosovo, North Macedonia, Montenegro, Bosnia and Herzegovina, Croatia, and Serbia. Supermarket chains were established late in Albania because, unlike the rest of Yugoslavia, which had a mixed economy, Albania's economy was rigorously planned. Only in the mid-2000s did supermarket chains emerge, with two of the main chains being multinationals (Spar and Conad) (Gërdoçi et al., 2016).

2.3 Barriers to innovation and the Albanian business environment

Supermarkets in Albania face various challenges and barriers in implementing innovation strategies. These include limited access to financing, as many supermarkets — particularly small and medium enterprises — struggle to secure sufficient funds to invest in new technologies, equipment, and research and development. Regulatory constraints also pose significant challenges, as Albania's regulatory environment is complex and bureaucratic, imposing heavy compliance requirements and administrative procedures. Cultural resistance to change is another barrier, as traditional attitudes and norms within the workforce may resist changes to established practices and routines (Albanian Institute of Statistics, 2020).

Furthermore, limited infrastructure and technological capabilities present challenges for supermarkets seeking to innovate. Insufficient access to reliable electricity, internet connectivity, and transport infrastructure in some regions of the country can hinder the adoption of advanced technologies and digital solutions. The Albanian government has recognized the importance of innovation in driving economic growth, implementing initiatives such as the National Strategy for Science, Technology, and Innovation (2014-2020) and the Albanian Investment Development Agency (AIDA) to support businesses in overcoming barriers to innovation (Council of Ministers of Albania, 2014).

2.4 Consumer behavior and innovation adoption

Consumer behavior and preferences play a significant role in shaping the retail landscape in Albania. A prominent trend in the Albanian retail market is the growing demand for convenience. Consumers increasingly value time-saving solutions and seamless shopping experiences, leading to innovations such as online shopping platforms, click-and-collect services, and mobile payment options. Sustainability has also become an important consideration for Albanian consumers, with growing awareness of environmental issues prompting demand for eco-friendly products and sustainable retail practices (European Commission, 2021). The growing influence of digital and social media marketing on consumer decision-making further reinforces this trend, with recent evidence confirming that digital channels significantly shape purchasing behaviour in retail contexts (Kaur, 2023).

Examining Irish food shopping habits and their potential implications for the Albanian market reveals considerable connections and illuminating insights. The shift in consumer

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behavior in Ireland from weekly or monthly grocery trips to more frequent, smaller shopping excursions, driven by changing food consumption patterns and a growing preference for fresh and nutritious items (Turčínková & Stávková, 2009), implies a complex reconfiguration of consumer behavior that may resonate in the Albanian context. Albanian retailers could benefit by prioritizing easy store navigation and quick checkout processes to meet the growing demand for convenient shopping options.

3 Methodology

This study employs a quantitative research approach to investigate the relationship between innovation strategy and business performance in supermarkets and markets in Albania. Data collection was carried out during the period November–December 2023. The target population comprised (i) supermarket executives and managers employed in Albanian supermarket chains that had recently undertaken innovation initiatives — including self-checkout deployment, product assortment expansion, digital marketing campaigns, or installation of reverse vending machines — and (ii) adult consumers who regularly shop at Albanian supermarket chains. Structured survey questionnaires were designed for each respondent group to collect quantitative data using 5-point Likert-scale items (1 = Strongly Disagree, 5 = Strongly Agree) and one open-ended question per questionnaire to capture qualitative insights.

Two distinct questionnaires were administered: one targeting business executives and managers (n=30) from supermarket companies that had recently undergone innovation, and a second targeting consumers (n=100). The business leaders sample comprised respondents holding roles such as Business Leader (50%), Manager (40%), and Market Development Responsible (10%), drawn from small (27%), medium (50%), and large (23%) supermarket companies. The consumer sample was predominantly female (70%), with the 33–44 age cohort being the largest (35%), and 60% holding a university degree. The business questionnaire covered demographic information (role, years of experience, company size), innovation strategy assessment, and financial management practices. The consumer questionnaire examined demographics, perceptions of innovation strategies in supermarkets, and experiences with shopping innovations, including loyalty programs, store design, pricing strategies, and digital platforms. Data were analyzed through descriptive statistics and thematic analysis of open-ended responses.

To test the research hypothesis inferentially, composite scores were calculated for each respondent by averaging their responses across the relevant Likert items. For business leaders, two subscales were constructed: an innovation strategy subscale (5 items) and a financial management subscale (3 items), yielding a full composite of 8 items. For consumers, an innovation strategy perception subscale (6 items) and a shopping experience subscale (5 items) were aggregated into an 11-item composite. Internal consistency was assessed using Cronbach's alpha (α). One-sample t-tests were conducted to determine whether each composite mean was significantly above the neutral midpoint ($\mu_0 = 3.0$), corresponding to a rejection of the null hypothesis that perceptions of innovation are neutral or negative. Effect size was reported as Cohen's d. Spearman rank-order correlations were computed among subscales to examine relationships within the construct. A significance threshold of $\alpha = 0.05$ was applied throughout.

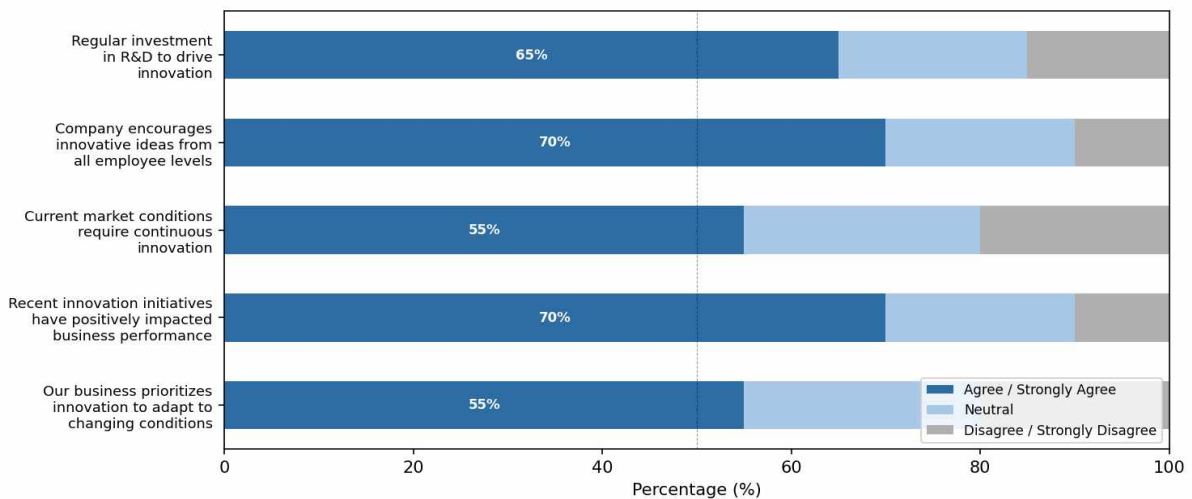
4 Results

4.1 Business Leaders' Perceptions

The innovation strategy assessment among business leaders revealed strong positive perceptions of innovation adoption. Key findings included: 55% agreed or strongly agreed that

their business prioritizes innovation to adapt to changing socio-economic conditions; 70% agreed that recent innovation initiatives positively impacted business performance; 70% indicated that their company actively encourages innovative ideas from all employee levels; and 65% reported regular resource investments in research and development. Regarding financial management practices, 70% effectively tracked the ROI of innovation projects; 65% had financial resources specifically allocated to innovation; and 70% reported close cross-departmental collaboration to ensure innovation projects were adequately funded. Figure 1 presents business leaders' perceptions of innovation strategy and financial management dimensions. A particularly notable qualitative finding emerged from the open-ended question regarding Reverse Vending Machines (RVMs) for bottle recycling. Opinions ranged from enthusiastic approval to cautious skepticism. One manager noted: "From a managerial perspective, I believe that implementing bottle recycling machines is a strategic move that can differentiate our supermarket from competitors and attract environmentally conscious customers. While presenting some initial obstacles, the long-term benefits in terms of sustainability and customer loyalty outweigh the challenges." Another expressed concerns about practicality: "I am somewhat skeptical about implementing bottle recycling machines. While I understand the importance of recycling and sustainability, I am concerned about the practicality and effectiveness of these machines in the Albanian context."

Figure 1. Business leaders' perceptions of innovation strategy and financial management (n=30)



Source: Authors' own elaboration.

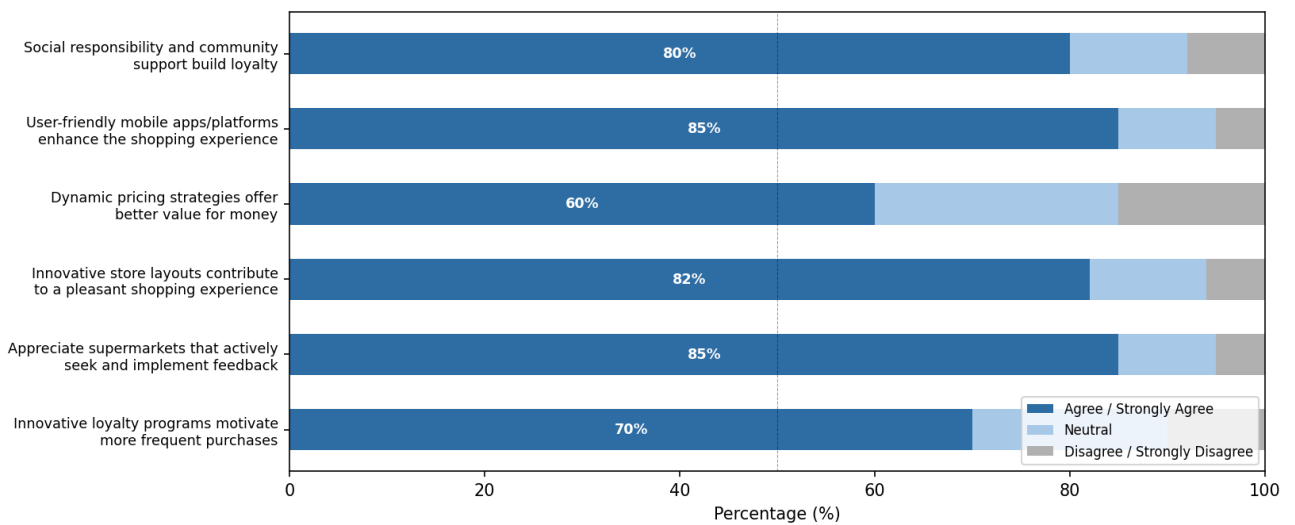
4.2 Consumer perceptions

Figure 2 presents consumer perceptions across shopping experience and innovation dimensions. Regarding shopping experiences and innovations: 70% reported that innovative loyalty programmes motivate them to shop more frequently; 85% appreciated supermarkets that actively seek and implement customer feedback; 82% agreed that innovative store layouts contribute to a more pleasant shopping experience; 85% valued supermarkets with user-friendly mobile applications and online platforms; and 80% showed appreciation for supermarkets that demonstrate social responsibility and support for local communities.

Regarding RVMs, consumer responses were predominantly positive, with the majority expressing a willingness to shop more at supermarkets equipped with these machines. One consumer stated: "Absolutely! I am all for sustainability, and knowing that a supermarket has reverse vending machines makes me more likely to choose it over others. Plus, earning points that I can convert into discounts or products? It is a win-win!"

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Figure 2. Consumer perceptions of shopping experiences and innovation (n=100)



Source: Authors' own elaboration.

Table 1 provides a consolidated overview of the key survey findings across both respondent groups, summarising the percentage of respondents who agreed or strongly agreed with each innovation-related statement.

Table 1. Summary of key survey findings (business leaders n=30; consumers n=100)

Category	Key Indicator	% Agree / Strongly Agree
Business Leaders: Innovation Strategy	Prioritizes innovation to adapt to changing conditions	55%
	Recent innovations positively impacted business performance	70%
	Encourages innovative ideas from all employee levels	70%
	Regular investment in R&D to drive innovation	65%
Business Leaders: Financial Management	Effectively tracks the ROI of innovation projects	70%
	Dedicated financial resources allocated for innovation	65%
	Cross-departmental collaboration for innovation funding	70%
Consumer Perceptions: Innovation Strategy	New products/services improve the shopping experience	70%
	Innovative marketing raises awareness of products & promotions	80%
	Online ordering/delivery services improve convenience	95%
	Eco-friendly packaging positively influences purchase decisions	80%
	Regular product range updates attract customer attention	90%
	Technology investment in checkout processes is valued	80%
Consumer Perceptions: Shopping Experience	Innovative loyalty programs motivate more frequent purchases	70%
	Supermarkets that actively seek and implement feedback are valued	85%
	Innovative store layouts contribute to a pleasant experience	82%
	User-friendly mobile apps/platforms enhance shopping	85%
	Social responsibility & community support build loyalty	80%

Source: Authors' own elaboration.

4.3 Statistical test of hypothesis

To test the research hypothesis inferentially, one-sample t-tests were conducted for each composite scale against the neutral midpoint ($\mu_0 = 3.0$). The results are presented in Table 2.

Table 2. Statistical test results: one-sample t-tests vs neutral midpoint ($\mu_0 = 3.0$)

Scale	n	M	SD	95% CI	t (df)	d
Manager: innovation strategy (5 items)	30	3.61	0.69	[3.36, 3.87]	4.88 (29)***	0.89
Manager: financial management (3 items)	30	3.82	0.61	[3.60, 4.05]	7.45 (29)***	1.36
Manager: full composite (8 items)	30	3.69	0.50	[3.50, 3.88]	7.52 (29)***	1.37
Consumer: innovation strategy (6 items)	100	4.16	0.56	[4.05, 4.27]	20.60 (99)***	2.06
Consumer: shopping experience (5 items)	100	4.19	0.58	[4.08, 4.31]	20.73 (99)***	2.07
Consumer: full composite (11 items)	100	4.18	0.40	[4.10, 4.25]	29.64 (99)***	2.96

Source: Authors' own elaboration.

Note. *** $p < 0.001$. Cronbach's α : manager full scale = 0.700; consumer full scale = 0.726. All means are significantly above the neutral midpoint ($\mu_0 = 3.0$), confirming the hypothesis.

One-sample t-tests were conducted for each composite scale to test whether the mean significantly exceeded the neutral midpoint ($\mu_0 = 3.0$). All tests were statistically significant ($p < 0.001$) with large effect sizes. The manager full composite yielded $M = 3.69$, $SD = 0.50$, $t(29) = 7.52$, $p < 0.001$, Cohen's $d = 1.37$; the consumer full composite yielded $M = 4.18$, $SD = 0.40$, $t(99) = 29.64$, $p < 0.001$, Cohen's $d = 2.96$. Subscale results are reported in Table 2. Cronbach's alpha indicated acceptable to good internal consistency across all scales: manager innovation subscale $\alpha = 0.816$, manager full scale $\alpha = 0.700$, consumer innovation subscale $\alpha = 0.828$, consumer shopping experience subscale $\alpha = 0.807$, and consumer full scale $\alpha = 0.726$. These results provide inferential statistical support for the hypothesis that Albanian supermarkets adopting innovation strategies are perceived as performing significantly above neutral across both managerial and consumer perspectives.

5 Discussion

The study provides inferential statistical evidence confirming that innovation strategies are positively and significantly associated with perceptions of business performance in Albanian supermarkets. This finding aligns with Karlsson and Tavassoli (2015), who demonstrated that firms employing comprehensive multi-dimensional innovation strategies consistently outperform those with narrower or absent approaches. The present study extends this evidence to a transitional Balkan market context where such empirical validation has previously been limited. Consumer perceptions of innovation were particularly strong ($M = 4.18$, $d = 2.96$), suggesting that customer-facing innovations yield the most visible returns — a pattern consistent with Hristov and Reynolds (2015), who found that non-technological, customer-oriented innovations deliver the most immediate competitive benefits in retail. This

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is further supported by Varis and Littunen (2010), who found that organizations introducing more new products consistently attract higher customer engagement.

The near-universal agreement (95%) among consumers that online ordering and delivery services improve convenience is the most striking single finding of this study. This substantially exceeds equivalent figures reported in comparable Central European retail studies, suggesting that latent demand for digital services in Albanian retail is higher than previously recognized. This finding diverges from Pantano and Vannucci (2019), who found that technology diffusion in retail tends to be gradual and heterogeneous; the Albanian consumer data suggest a readiness for rapid digital adoption that may leapfrog the incremental patterns observed in more developed markets. This has direct implications for investment prioritization: digital infrastructure and online platforms should be treated as urgent rather than aspirational investments.

The strong consumer receptiveness to sustainability initiatives (80% for eco-friendly packaging) aligns with broader European consumer trends and is particularly significant in the context of Albania's EU accession aspirations. This corroborates Dabija et al. (2019), who identified sustainability-driven retail innovations as a key driver of loyalty in Central and Eastern European markets, and Ankiel et al. (2020), who documented similar convergence trends in EU-candidate food retail markets. What is new here is that this preference appears to have already taken root in a market with significantly lower average incomes than those of established EU members, suggesting values-driven purchasing behavior decoupled from constraints on disposable income.

The mixed but predominantly positive managerial perceptions of Reverse Vending Machines illustrate the tension between strategic vision and operational feasibility that characterizes the adoption of innovation in developing retail markets. This echoes Pantano (2016), who showed that early retail innovators face higher risks but achieve competitive advantages; however, the Albanian context introduces additional barriers — infrastructure limitations, maintenance capacity, and consumer education — that are less pronounced in Western European settings. This is a novel contribution: the study identifies a gap between consumer enthusiasm for sustainability innovations and managerial skepticism, which policymakers and retailers must bridge through targeted support mechanisms. Teece (2018) notes that dynamic capabilities require not only the ability to sense opportunities but also the capacity to reconfigure resources accordingly; the RVM findings suggest that Albanian supermarkets are sensing the opportunity but have not yet fully developed the capacity to reconfigure resources.

Taken together, these findings confirm that innovation strategies — spanning digital adoption, product diversification, sustainability, and customer experience — constitute a coherent and measurable driver of business performance in the Albanian supermarket sector. The results corroborate Sheth and Sinfield (2022), who argue that innovation strategy must be embedded as a systemic management lever. They also advance the evidence base for transitional-economy retail contexts documented by Abbes (2025), who found a statistically significant link between innovation investment and economic growth at the national level, thereby complementing the firm-level evidence presented here. This study's contribution is therefore twofold: it provides the first inferential statistical validation of the innovation–performance link in Albanian food retail, and it identifies digital and sustainability innovations as the highest-priority investment domains for Albanian supermarket managers.

6 Conclusions

This study underscores the transformative capacity of innovation to drive business performance and customer satisfaction in the supermarket industry. The findings confirm the

hypothesis that Albanian supermarkets adopting innovation strategies achieve superior performance outcomes, consistent with Karlsson and Tavassoli (2015), who demonstrated that firms employing comprehensive multi-dimensional innovation strategies outperform those pursuing narrower approaches. The centrality of digital and customer-oriented innovations in driving satisfaction aligns with Hristov and Reynolds (2015), who found that non-technological and customer-facing innovations yield the most immediate competitive benefits in retail. Furthermore, the positive consumer receptivity to sustainability initiatives reflects the growing alignment with EU market norms, echoing findings by Dabija et al. (2019), who identified sustainability-driven retail innovations as a key driver of loyalty in Central and Eastern European markets. In contrast to Pantano (2016), who noted that early retail innovators face disproportionate risk, the Albanian supermarkets in this study appear to have mitigated risk through incremental adoption — confirming that gradual digital integration is a viable strategy in transitional economies.

Investments in technology, such as self-payment systems, online ordering platforms, and mobile loyalty applications, emerge as key drivers of operational efficiency and customer satisfaction. This corroborates Sheth and Sinfield (2022), who argue that innovation strategy must be embedded as a systemic management lever rather than an ad hoc initiative. Additionally, the growing consumer preference for eco-friendly packaging and recycling programs signals convergence with broader European sustainability standards, a finding supported by Ankiel et al. (2020), who documented similar trends across emerging EU-candidate food retail markets. By embracing innovation and adapting to changing market dynamics, supermarkets can position themselves for sustainable growth and competitiveness in Albania's evolving retail landscape.

Practical Recommendations

- 1 Integration of digital technologies, such as self-payment systems and mobile applications, should be prioritized across all supermarket branches, incorporating features such as online ordering, personalized recommendations, and loyalty program management.
- 2 Supermarkets should actively adopt sustainability initiatives to minimize environmental impact and connect with the values of environmentally conscious consumers, including reducing plastic use, sourcing from local, eco-friendly suppliers, and implementing in-store recycling programs.
- 3 Supermarkets should develop innovative loyalty programs tailored to individual customer preferences and shopping behaviors, leveraging customer data analytics to create personalized experiences, targeted promotions, and exclusive loyalty rewards.
- 4 Policymakers should strengthen support mechanisms for retail innovation through financial incentives, streamlined regulatory processes, and investment in digital infrastructure, particularly in regions with limited connectivity.

The study's main limitation is the quantitative nature of the data collection method, which may limit the depth of understanding regarding the underlying motivations and contextual factors driving business innovation strategies. Future research could employ mixed-methods approaches to provide richer insights into the mechanisms by which innovation strategies translate into business performance outcomes in the Albanian retail context.

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WHY STARTUPS LEAVE: DELAWARE INCORPORATION AS AN INSTITUTIONAL SIGNAL IN EMERGING STARTUP ECOSYSTEMS

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Abstract: *Small developing startup ecosystems frequently lack the legal infrastructure required to attract international venture investment, placing domestically incorporated companies at a structural disadvantage relative to counterparts registered in established legal jurisdictions. The study examines the Delaware Flip phenomenon - the practice whereby startups incorporate in Delaware, USA, rather than in their home country - as a measurable indicator of legal framework inadequacy within small, developing startup ecosystems, with an empirical focus on the case of Georgia. This study employs documentary profiling of 28 Georgian tech startups alongside semi-structured interviews with founders, legal practitioners, and ecosystem actors, applying North's institutional theory and the Triple Helix framework as analytical lenses to interpret structural patterns of offshore incorporation. The results reveal that more than a third of sampled startups with international investor engagement have undergone full or partial Delaware incorporation, driven by four structural legal gaps: the absence of SAFE note legislation, inadequate employee stock ownership plan frameworks, the lack of specialized commercial dispute resolution mechanisms, and exclusion from global payment infrastructure incompatible with domestic incorporation. The results further show that these deficiencies collectively render foreign incorporation a functional necessity rather than a voluntary strategic preference, affecting the regulatory anchoring of the startup cohort. The findings of this study suggest that the Delaware Flip represents a loss not only of tax revenue but of legal identity, institutional capital, and ecosystem anchoring, and that a state simultaneously funding startup development while maintaining structural conditions that necessitate foreign incorporation produces outcomes contrary to its own developmental objectives.*

Keywords: *Delaware Flip; institutional framework; startup ecosystem; Georgia; legal infrastructure*

1. INTRODUCTION

At some point in nearly every Georgian startup's growth trajectory, the same conversation happens. An international investor is interested, due diligence begins, and then comes the question - not about the product, nor the team, but the legal structure: "Are you incorporated in Delaware?" If the answer is no, investors lose enthusiasm.

This paper is about what that moment reveals. The practice of reincorporating in Delaware - commonly called the "Delaware Flip" - is well known among startup practitioners but poorly understood as a policy problem. Most treatments of the phenomenon focus on the mechanics: how to structure the flip, what the tax implications are, how long it takes. What receives far less attention is what the flip actually signals about the legal system being left behind. Georgia's startup ecosystem has grown considerably since GITA's (Georgia's Innovation and Technology Agency) establishment in 2014. Investment volumes reached \$180 million by 2024. The 500 Global partnership brought international methodology and connections. StartupBlink's rankings improved. On paper, the ecosystem is moving in the right direction. Yet we observe the pattern: the more successful a Georgian startup becomes

internationally, the more likely it is to legally exit Georgia. The paradox runs deeper than it first appears. GITA - the state agency whose mandate is to develop the Georgian startup ecosystem - runs its flagship accelerator program in partnership with 500 Global, one of the world's most active early-stage funds. 500 Global's standard investment terms require Delaware incorporation. This means that Georgia's primary public instrument for startup development is, in practice, a pipeline to Delaware. The state is simultaneously building the ecosystem and funding the mechanism that extracts value from it. It is a structural consequence of a legal framework that was not built with venture-backed companies in mind. Broader institutional reform efforts in Georgia's business environment, including ongoing changes to audit and accounting frameworks, suggest a moment of regulatory transition that extends beyond startup law alone (Kalatozishvili & Gegeshidze, 2025).

The argument this paper makes is straightforward. Delaware Flip is not a preference. Founders do not sit down and weigh the merits of Georgian versus Delaware corporate law and conclude that Delaware is superior. They flip because their investors require it, and their investors require it because Georgian law lacks the instruments that international venture capital transactions depend on - SAFE notes, enforceable ESOP structures, predictable IP assignment mechanisms, and courts with the expertise to handle disputes that arise from these arrangements. When these instruments do not exist in local law, the transaction migrates to a jurisdiction where they do. Delaware has been refining these instruments for over a century. Georgia has been building its startup ecosystem for ten years. The gap is not surprising. But it is costly.

Profiling of Georgian tech startups, combined with interviews conducted with founders and other ecosystem stakeholders between 2022 and 2025, shows that more than a third of startups with international investor engagement have undergone full or partial Delaware incorporation. The aim of this study is to identify and document the structural legal factors driving Delaware incorporation among Georgian tech startups and to assess their cumulative impact on ecosystem development. To achieve this aim, the study addresses three intermediate problems: (1) identifying the specific legal instruments absent from Georgian corporate law that international investors require as standard; (2) quantifying the prevalence of Delaware incorporation among internationally active Georgian startups; and (3) evaluating the systemic consequences of this pattern for ecosystem anchoring and institutional development.

The study is guided by the following research question: *What structural legal gaps in Georgia's corporate framework drive Delaware incorporation among internationally active tech startups, and what are the cumulative consequences of this pattern for startup ecosystem development?* Three subsidiary questions follow: (1) Which specific legal instruments absent from Georgian law do founders and investors identify as drivers of reincorporation? (2) How prevalent is Delaware incorporation among internationally active Georgian startups? (3) What are the ecosystem-level consequences of this pattern at scale?

2. LITERATURE REVIEW

Delaware's corporate law has been developing since 1899. That date matters not symbolically but practically: 125 years of continuous refinement through court decisions, legislative amendments, and market feedback has produced a system whose predictability simply does not exist elsewhere. Daines (2001) shows that Delaware's dominance is a network effect - investors, lawyers, and judges all operate within the same system, and deviation from it is expensive for every party involved. This is not about Delaware being objectively superior in some abstract legal sense. It is about coordination: when everyone expects Delaware, the cost of proposing something different falls entirely on whoever proposes it.

Black and Gilson (1998) are more direct: venture capital market depth correlates with corporate law sophistication. Their argument is not that good law produces good startups, but

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that without adequate legal infrastructure, the financial instruments that venture capital depends on - convertible notes, equity compensation, liquidation preferences - cannot be executed with the speed and standardization that investors require. The legal framework is not background. It is the operating system. Delaware's adaptive capacity compounds this advantage. The 2025 SB 21 reform, that clarified director liability standards in response to activist shareholder litigation, illustrates that Delaware does not just exist, it responds (Harvard Law School Forum on Corporate Governance, 2025). Most national legislatures revising startup law are working from scratch, without the institutional memory or judicial precedent that makes Delaware's adjustments incremental rather than foundational.

2.1 Institutional Theory, the Entrepreneurial State, and the Triple Helix

North (1990) defines institutions as the rules of the game - the formal and informal constraints that structure economic interaction. The distinction between formal and informal matters here. Informal institutions - trust, reputation, cultural attitudes toward risk and failure - can do a great deal of work in early-stage ecosystems. A founder and an angel investor who know each other can close a deal on a handshake. But informal trust does not scale. When a Georgian startup seeks capital from a US fund whose partners have never met the founders, never visited Tbilisi, and are accountable to their own limited partners for every investment decision, they need formal instruments: a legal structure they recognize, documents their lawyers can review without a week of orientation, and courts they can access if something goes wrong. Informal institutions cannot provide any of that.

Williamson (2000) adds a temporal dimension that is often overlooked. Informal institutions change slowly - over decades or generations. Formal rules can change quickly, if there is political will. This asymmetry is relevant for policy: a government that wants to reduce Delaware Flip rates cannot wait for cultural change. It can, however, pass legislation. The instruments required are not novel - SAFE notes, ESOP frameworks, IP assignment mechanisms, specialized commercial dispute resolution. Other countries have written this legislation. The question is whether Georgia will.

DiMaggio and Powell's (1983) concept of institutional isomorphism explains the social dimension of the flip decision. Startups do not incorporate in Delaware because they have independently evaluated all available jurisdictions. They do it because incorporation in Delaware signals to investors that the founding team understands professional norms. It is a legitimacy mechanism as much as a legal one. This means that even if Georgian law were improved tomorrow, some period of reputation-building would be required before international investors began treating Georgian incorporation as equivalent. Legal reform is necessary but not immediately sufficient - which makes the delay in pursuing it more costly, not less.

Mazzucato (2013) rounds out the theoretical picture. Her argument that the state should function as an active institutional builder - not merely removing barriers but constructing the infrastructure that markets cannot build for themselves - applies directly here. The legal instruments that Georgian startups need do not emerge spontaneously from market activity. They require legislative action. Framing this as government interference misses the point: Delaware's corporate law is itself the product of sustained state effort over more than a century. Georgia needs a compressed version of that effort.

Etzkowitz and Leydesdorff's (2000) Triple Helix model provides a complementary structural lens. The framework conceptualizes innovation ecosystems as the product of dynamic interaction among three institutional spheres: government, industry, and academia. In a well-functioning ecosystem, these spheres overlap and reinforce each other. Government constructs the regulatory and financial conditions, industry applies and scales innovation, and academic institutions supply knowledge and talent. The model's central insight for this study is that government's role is not passive: it must actively build the institutional infrastructure

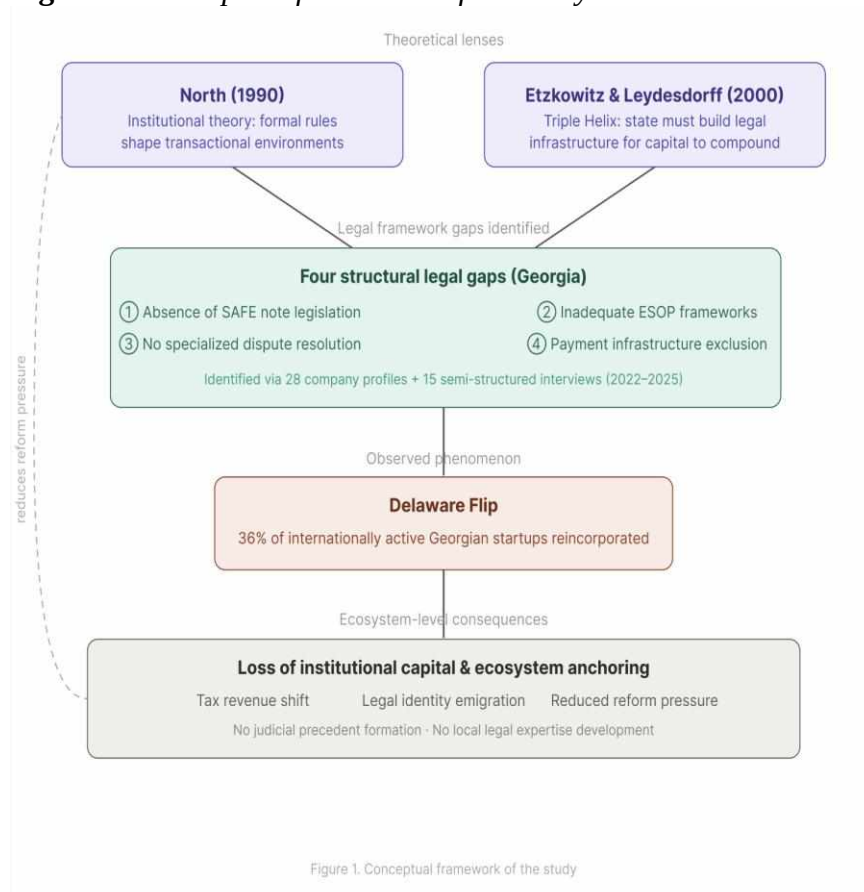
within which private capital and entrepreneurial activity can combine productively. A government that invests in financial ecosystem instruments, such as grants, accelerators, co-investment programs, while neglecting the legal infrastructure those instruments depend on produces a structurally incomplete Helix. State investment cannot compound into durable ecosystem outcomes.

2.2 What the Literature Has Missed

Documentation of Delaware Flip in academic literature is thin. Practitioner sources - notably Rest of World (2021) - describe the mechanics: how to structure the transaction, what the tax implications are, how long it takes. What they do not examine is what happens to the ecosystem being left behind. When one startup flips, the consequence is primarily financial - tax revenue and legal fees go to Delaware rather than the home country. When more than a third of internationally active startups flip, something more significant is happening. The domestic legal system is being systematically bypassed by the most dynamic segment of the business population. This creates a feedback loop: as successful startups flip, the local legal ecosystem receives less pressure to reform, less revenue from sophisticated transactions, and less talent with experience in growth-stage legal work. The gap widens.

The legal framework limitations driving Delaware Flip are not newly discovered. The authors first documented them in 2020, noting that Georgian support organizations were structurally misaligned with the practical legal needs of growth-stage companies (Chachanidze et al., 2020). Five years later, the legislative gaps identified then remain unaddressed - while the number of startups affected has grown. This study is partly a response to that inaction: a more systematic quantification of a problem that practitioners have named, and policymakers have not yet solved.

Figure 1. *Conceptual framework of the study*



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Comparative evidence makes the structural argument stronger. Israel's Yozma program succeeded partly because legal reforms accompanied financial intervention - domestic incorporation became viable for venture-backed companies at the same time that capital became available (Avnimelech & Teubal, 2006). Estonia's EU-harmonized corporate framework reduced the incentive to flip by making local incorporation internationally credible (Startup Estonia, 2024). Both cases support the same conclusion: financial ecosystem investment without corresponding legal reform produces exactly the dynamic Georgia is experiencing - startups that grow successful enough to leave. Romania offers a high-profile illustration of the same dynamic: UiPath, founded in Bucharest and now one of the world's most valuable enterprise software companies, reincorporated in the United States prior to its 2021 IPO. Figure 1 presents the conceptual framework of the study, illustrating how the two theoretical lenses jointly identify the structural legal gaps driving the Delaware Flip and its consequences for ecosystem development.

As the framework indicates, the legal gaps identified in the literature require empirical verification through primary data. The following section describes the methodological approach used to examine these gaps within the Georgian startup ecosystem.

3. METHODOLOGY

There is no public database of Delaware Flips. Georgian startups that reincorporate in Delaware do not announce it - most treat the decision as routine paperwork. This created the first methodological problem: how do you study a phenomenon that the people experiencing it have little incentive to disclose?

Qualitative research methods are particularly well-suited to investigative contexts where the aim is to understand how and why actors make decisions within specific institutional environments, rather than to quantify outcomes across large populations (Creswell & Poth, 2018; Denzin & Lincoln, 2018). In entrepreneurship research specifically, qualitative approaches are recognized as appropriate for examining the interpretive processes behind founder decisions, particularly in nascent or understudied ecosystems where standardized instruments do not yet exist (Gartner & Birley, 2002; Neergaard & Ulhøi, 2007). The decision to employ a qualitative design in this study reflects both the nature of the research question: why founders reincorporate in Delaware rather than simply how many do, and the absence of any existing dataset from which a representative sample could be drawn.

Semi-structured interviews were selected as the primary instrument for gathering founder and practitioner perspectives. This format allows respondents to address theoretically relevant themes while retaining flexibility to introduce dimensions not anticipated in the original guide, a property particularly valuable in exploratory institutional research (Brinkmann & Kvale, 2015; Merriam & Tisdell, 2016). Interview data were analyzed using inductive thematic analysis, in which codes were developed from the data rather than applied from a predetermined framework (Braun & Clarke, 2006).

The researcher's twelve-year engagement in Georgia's startup ecosystem as an accelerator operator at MediaLab and jury member at startup competitions constitutes a form of insider access that qualitative research has recognized as analytically valuable when made transparent (Dwyer & Buckle, 2009). This position enabled triangulation of public records against contextual knowledge of companies' actual incorporation status and investor relationships. Several companies profiled had previously engaged with MediaLab as program participants; where prior professional contact may have shaped respondents' willingness to disclose, this is noted in the relevant sections. The dual role of practitioner and researcher is treated here not as a methodological liability but as a documented source of contextual access, consistent with established practice in interpretivist inquiry (Patton, 2015).

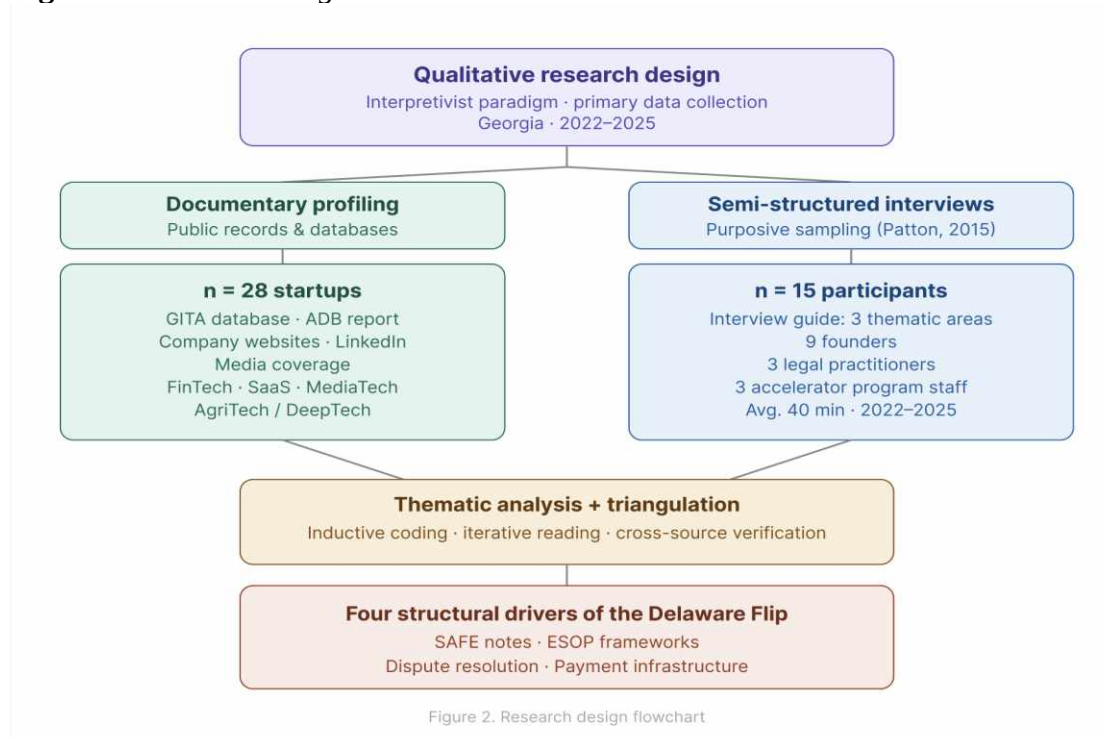
This study draws on two distinct sources of evidence. The research process began with an initial screening of 88 Georgian startups that had successfully secured either the 100,000 GEL or 150,000 GEL startup grants from GITA. Following this comprehensive baseline mapping, 28 startups were selected based on criteria of international investment readiness and cross-border commercial activity. After, systematic documentary profiling of 28 Georgian tech startups was performed. Company-level data was assembled from publicly available sources: GITA's startup database, the ADB ecosystem report by Nanitashvili and Vandenberg (2023), company websites, LinkedIn profiles, Facebook pages, and media coverage. Where public records were incomplete or ambiguous - particularly on incorporation status and cap table structure - the researcher's professional network was used for verification, not as a primary data source. The second source is fifteen semi-structured interviews with founders, legal practitioners, and accelerator staff, conducted between 2022 and 2025.

3.1 Why these companies

The sample was constructed to match the scope of the research question, which concerns the internationally active segment of the Georgian startup ecosystem, not startups as a whole. The sample was built purposefully, not randomly. Purposive sampling is appropriate when the objective is to examine a specific institutional phenomenon within a defined population rather than to produce statistically representative results (Patton, 2015). Random sampling of Georgian startups would have produced mostly companies that have never spoken to an international investor - and the incorporation question simply does not arise for them. The research question concerns the internationally active segment: companies that have sought or received external investment, participated in accelerator programs, or made documented attempts to raise capital beyond Georgia's borders. All 28 companies met at least one of these criteria. They operated between 2018 and 2024, spanning FinTech, MediaTech, AgriTech, and SaaS - roughly consistent with GITA's grant distribution over the same period (GITA, 2024).

Figure 2 presents the research design as a sequential flowchart, illustrating the two parallel data collection streams and their convergence through thematic analysis toward the study's findings.

Figure 2. Research design



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As the flowchart indicates, the two data streams were not treated as independent sources but as complementary evidence: company profiles established whether and in what form reincorporation had occurred, while interview data identified the structural reasoning behind each decision.

3.2 The interviews

Fifteen people were interviewed - nine founders, two lawyers and an accountant who work with startups, and three accelerator program staff. Conversations averaged 40 minutes. A portion was recorded on video with participant consent; for the remaining interviews, key themes and responses were documented following each conversation. All participants consented to the use of their input for research purposes. Three - one lawyer and two founders - asked not to be identified and appear throughout as Founder A, Founder B, and Legal Practitioner 1.

The interview structure had three parts. First: when did the incorporation question come up, and who raised it? Second: what specifically did the investor require, and what did they say Georgian law could not provide? Third - and this was the most revealing question - what would Georgian law have needed to look like for the flip to have been unnecessary?

Interview material was analyzed thematically. Responses were coded inductively across the three interview themes, with recurring patterns - SAFE note requirements, ESOP concerns, dispute resolution preferences, payment infrastructure constraints - identified through iterative reading rather than applied in advance. Documentary and interview evidence were then triangulated: the profiles established whether incorporation had occurred and in what form; the coded interview material explained why.

4. RESULTS

The interview data produced four findings that came up repeatedly enough to be treated as structural rather than anecdotal.

The first was SAFE notes. Eleven of the fifteen founders interviewed had encountered a situation where an investor proposed a SAFE - Simple Agreement for Future Equity - as the instrument for an early-stage round. In every case, the investor's legal team flagged that SAFE notes are not a recognized instrument under Georgian corporate law (Coyle & Green, 2018). The options were: restructure the deal using instruments Georgian law does recognize, which investors found unfamiliar and their lawyers found time-consuming, or reincorporate in a jurisdiction where the SAFE is standard. Most chose the latter. Several described the decision as taking less than a week once the legal issue was identified.

The second was ESOP structures. Eight founders raised employee stock option plans as a driver of the reincorporation decision, not always as the primary driver but consistently as a contributing one. The problem is specific: founders and employees face risks of 'dead equity' and unfavorable tax treatment. Georgian tax law and corporate law do not provide a framework for granting options that vest over time, are forfeited upon departure, and are taxed at grant rather than exercise - the opposite of market standard. Building an ESOP under Georgian law requires bespoke legal architecture that is expensive, unfamiliar to employees, and not recognized by international investors reviewing a cap table. Three founders described situations where a senior hire - a CTO or VP of Product recruited from outside Georgia - conditioned their acceptance on receiving equity in a structure they understood. Delaware provided that structure. Georgia did not.

The third was dispute resolution. This came up less frequently in the initial interview questions but emerged consistently when founders were asked about investor concerns during due diligence. International investors, particularly US-based funds, expressed discomfort with the prospect of resolving disputes in Georgian courts, because Georgian courts have no track

record with startup-specific disputes, no established body of case law on convertible instruments or IP ownership, and no specialized commercial bench. The Court of Chancery in Delaware has over a century of exactly this precedent. Founders reported that several investors explicitly named court jurisdiction as a condition of investment.

A fourth driver emerged consistently but was rarely named in policy discussions: payment infrastructure. Stripe, the dominant payment processing platform for international software sales, does not support Georgian-registered companies. The workaround is the same as the flip itself: incorporate in the US. Without a Delaware or other US entity, a Georgian SaaS startup cannot open a Stripe account, cannot process international card payments through the platform their customers expect, and cannot credibly sell software to global markets. For founders building B2B SaaS products, this is often the most immediate and operational reason for the flip - more pressing in the short term than investor requirements or legal instruments. Delaware incorporation does not just satisfy investors. It turns on the revenue tap.

The pattern was most pronounced among AI and FinTech companies, where US investor networks and payment infrastructure constraints make reincorporation functionally unavoidable; it was absent among Agro/DeepTech firms, whose investor base remains more regionally oriented and less likely to require Delaware documentation as a condition of investment.

Figure 3 consolidates the results of the documentary profiling and interview analysis, presenting the key finding, the four structural drivers with their interview frequencies, the sectoral distribution of the Delaware Flip, and the resulting ecosystem-level consequences.

Figure 3. Results

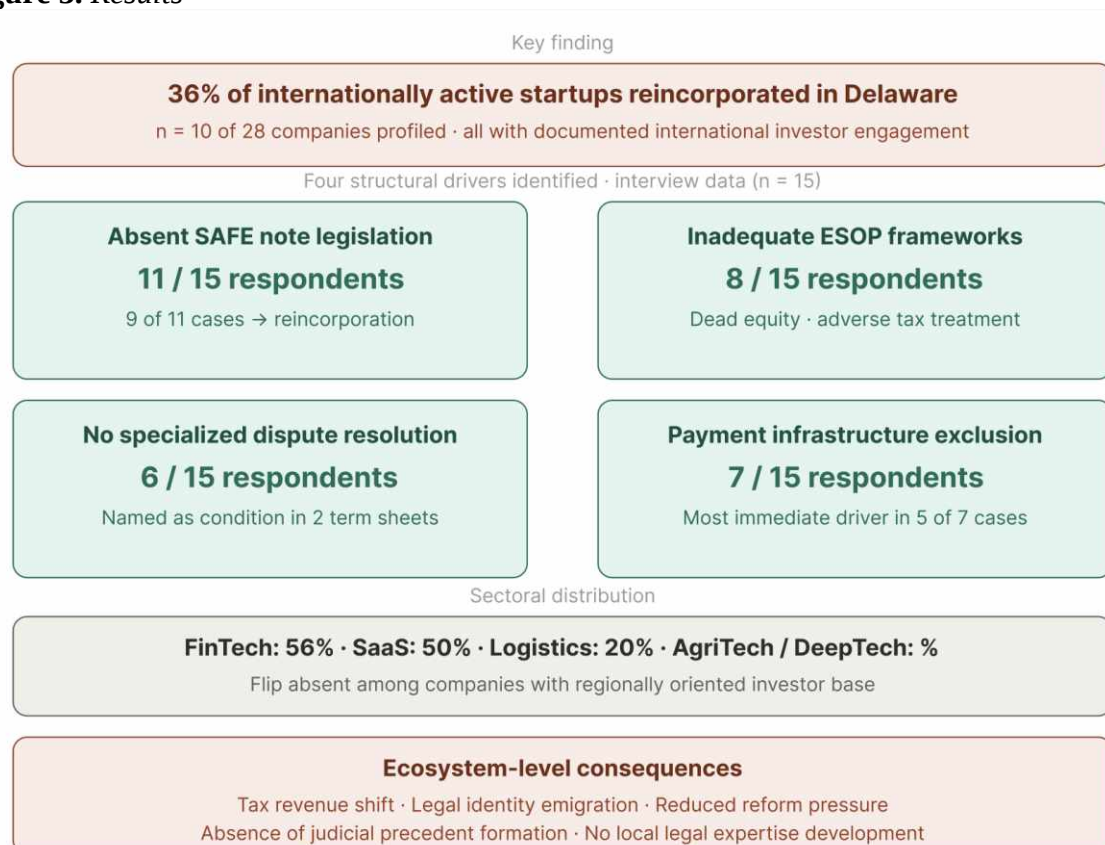


Figure 3. Summary of results

Taken together, these findings indicate that Delaware incorporation among Georgian tech startups is not distributed randomly across the ecosystem but is concentrated precisely where legal gaps and US investor networks intersect most directly.

5. DISCUSSION

The costs of Delaware Flip are partly visible and partly not. The visible costs are straightforward: legal fees for the reincorporation process, amount depending on the complexity of the existing cap table. Tax obligations in Georgia do not disappear upon reincorporation - founders retain personal tax residency and operational tax obligations - but the corporate tax relationship shifts. Over time, as the company grows, the value accretion occurs in the Delaware entity rather than the Georgian one.

The less visible costs are harder to quantify but arguably more significant. When a company reincorporates in Delaware, its legal identity becomes American. Its cap table is governed by Delaware law. Its disputes are resolved in Delaware courts. Its future investors will expect Delaware documentation. The company may continue to employ people in Tbilisi and pay Georgian payroll taxes, but its institutional relationship with Georgia becomes increasingly thin. The startup that was building Georgian ecosystem capital - employing Georgian lawyers, using Georgian accountants, establishing precedents in Georgian courts - is now building American institutional capital instead.

At scale, this is not a tax problem. It is an ecosystem development problem. Every sophisticated legal transaction that migrates to Delaware is a transaction that does not develop Georgian legal expertise, Georgian judicial precedent, or Georgian investor familiarity with growth-stage instruments. The ecosystem's legal infrastructure does not improve through disuse. North's (1990) framework predicts exactly this dynamic. When formal institutions fail to provide the transactional environment that economic actors require, those actors find workarounds - and in doing so, they reduce the pressure on institutions to reform. Delaware Flip is a workaround. It solves the individual founder's problem efficiently. It does nothing for the system that produced the problem.

The Triple Helix interpretation adds a layer. The state sphere in Georgia has invested heavily in the financial dimension of ecosystem development - grants, accelerators, co-investment programs. What it has not invested in is the legal dimension. The result is a Triple Helix with one arm built and two underdeveloped: a government that can write checks but cannot provide the institutional infrastructure that makes those checks compound into durable companies. Mazzucato's (2013) entrepreneurial state argument is blunt on this point: financial intervention without institutional construction produces dependency, not development. GITA grants have created a generation of Georgian startups capable of reaching international investors. The legal framework has ensured that a significant proportion of those startups, upon reaching that milestone, leave. A natural policy response to high Delaware Flip rates is to make staying financially attractive - tax breaks for domestic incorporation and grants contingent on Georgian legal domicile. Several Georgian founders were aware of such proposals. None found them compelling.

The reason is clear. They are making a judgment about whether Georgian incorporation will make their next funding round easier or harder. If the answer is harder - because the next investor will also require SAFE notes, also want Delaware documentation, and also prefer Court of Chancery jurisdiction - then the subsidy delays the flip by one round at most. It does not change the underlying calculation.

6. LIMITATIONS

The sample is not statistically representative of all Georgian startups. It was designed to represent the companies for whom the incorporation question is live, which is the only population relevant to this research. Because founders are sometimes reluctant to discuss decisions that implicitly criticize the local system and occasionally reluctant to discuss them with someone they know professionally, some responses were incomplete. Where that was apparent, it is noted in the relevant sections rather than treated as absent data.

7. CONCLUSIONS

This study set out to identify the structural legal factors driving Delaware incorporation among Georgian tech startups and to assess their cumulative impact on ecosystem development. The results establish that four specific legal gaps - absent SAFE note legislation, inadequate ESOP frameworks, no specialized commercial dispute resolution, and exclusion from global payment infrastructure - collectively make reincorporation functionally unavoidable for internationally active startups. More than a third of the sampled companies with international investor engagement had undergone full or partial Delaware incorporation, concentrated in FinTech and SaaS and absent among regionally oriented sectors.

The study's principal contribution is reframing the Delaware Flip as a measurable institutional signal rather than a founder preference, shifting analytical focus from individual behavior to legal structure. It is the first study to quantify this prevalence among Georgian startups through primary data and to identify payment infrastructure exclusion as an independent, often more immediate driver than investor documentation requirements, a finding not previously documented in the literature.

The instruments this study identifies are not theoretical. They exist in other jurisdictions, they have been introduced by governments smaller and less resourced than Georgia's, and their absence here has a measurable cost, not just in tax revenue, but in the institutional capital that leaves every time a startup's legal identity moves to Delaware. Grants and subsidies cannot fill that gap. The solution is legislative and policymakers who want to understand what legislation is needed have, in this study, a starting point.

What this study cannot do is track what happens next. Whether Georgia introduces the relevant reforms, and whether those reforms actually reduce reincorporation rates, are questions that require longitudinal data this study does not yet have. The same framework applied to other small economies facing comparable legal infrastructure gaps would test whether the four drivers identified here are specific to Georgia or symptoms of a wider pattern - Romania, where UiPath's reincorporation in the United States prior to its 2021 IPO offers perhaps the most prominent European illustration of the same institutional logic, is a natural starting point for that comparison. The question of what sustained Delaware Flip does to local legal talent, to judicial development, to the long-term capacity of a legal system to handle sophisticated transactions remains largely unexamined, and worth examining.

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ARTIFICIAL INTELLIGENCE AND LABOR DEMAND IN ROMANIA: EARLY EVIDENCE FROM ONLINE JOB POSTINGS

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Abstract: *The rapid diffusion of artificial intelligence (AI) technologies is expected to reshape labour demand, yet empirical evidence for emerging European economies remains limited. This paper examines short-run trends in AI-related labour demand in Romania using a high-frequency dataset of 1,874 online job postings from October 2025 to March 2026. Adopting Web Labour Market Information (LMI) approach, the study aims to elucidate the structural characteristics and professional archetypes of AI diffusion in Romanian economy. Results highlight increasing concentration of AI-related labour demand in service sector (35,8%) and a transition towards standardized production phase characterized by a robust technical middle class. Evidence reveals a shift toward skills-based hiring behaviour, where 54% of vacancies do not require a formal degree. Furthermore, the market exhibits signs of opportunistic upskilling, where employers are raising entry barriers. Hard skills were found to be the strongest predictor of the number of years of professional experience required for a position, whereas soft skills showed no statistically significant impact on the seniority level. The objective of the paper is to deliver a quantitative assessment of the impact of AI transformation on the Romanian labour market. By providing early empirical evidence from a high-frequency vacancy dataset, the paper contributes to the literature on AI, labour markets, and technological diffusion in emerging EU economies.*

Keywords: *Artificial Intelligence, Labour Market, Web Labour Market Intelligence, Occupational Analysis, Emerging European Economies*

1 Introduction

Technological progress arises not solely from capital accumulation, but also from the cultivation of a culture that values the accumulation of meaningful knowledge and upholds principles such as work ethic, discipline, and innovation (Mokyr, 2017). The labour market, the legitimisation of work and the pursuit of practical knowledge are essential mechanisms through which cultural values interact with economic factors to drive technological advancement. These dynamics illustrate how cultural values and institutional frameworks complement capital accumulation to foster sustained technological development. Social acceleration is driven by technological advancements, which quicken the pace of life. This faster rhythm, in turn, stimulates further technological innovation, creating a self-reinforcing cycle of acceleration (Rosa & Trejo-Mathys, 2013). From the perspective of the labour market, its dynamics are incompatible with the accelerated pace. While it is unable to react quickly to accelerated technological change, it can itself be an obstacle to accelerated development.

In the case of the Romanian labour market, we identified four structural barriers that undermine the large-scale diffusion of AI: demography, economics, education, and socio-political factors. Demography refers to the aging workforce and population decline, which limits the adoption of new technologies (OECD, 2025). Economic constraints include limited investment in digital infrastructure, hindering the development and integration of AI solutions. Educational gaps result from low level of digital literacy, low tertiary education participation and outdated curricula that do not adequately prepare workers for AI-related skills (European

Commission. Directorate General for Research and Innovation., 2024). Central and Eastern European labor markets often manifests an acute mismatch between emerging digital demands and existing workforce competencies (Aškerc Zadavec et al., 2025). Socio-political factors involve resistance to change and policy reluctance to adress technology related reglementations, both of which can slow the implementation of innovative technologies (Tugwell, 1931). AI-exposed businesses may hire more non-AI workers if AI either boosts worker productivity through task complementarity or, by replacing some roles, increases overall productivity enough to create new demand for non-automated tasks (Acemoglu & Restrepo, 2019). In emerging economies like Romania, AI tend to be treated as an infrastructure for outsourcing rather than a driver of domestic innovation, treatening with the trap of middle-income (Eichengreen et al., 2013). The asymmetrical nature of AI implementation depends on a country's existing labour market composition and its level of capabilities (Guarascio & Reljic, 2025). Countries with highly skilled workforces may experience different patterns of AI adoption compared to those with predominantly low-skilled labour, which in turn affects both economic outcomes and social dynamics.

The ability of an economy to capitalize on AI technologies largely depends on the configuration of its human capital. In a pyramidal structure, the higher levels (research and development specialists, machine learning researchers, algorithm engineers, cloud and accelerated hardware experts) cannot perform their function without a broad base of workforce with complementary basic digital skills and general digital competencies (OECD, 2023). At the intermediate level, we identify two distinct groups, one of the applied engineering, which translates solutions into scalable products (data engineers, developers, system architects, data security and governance specialists), and the second group, consisting of domain translators and transformation managers: professionals with dual expertise, both technological and sector-specific (finance, health, industry), who redesign processes and ensure system compatibility with a specific domain. They are capable of operating AI systems and collaborate in multidisciplinary teams and generate endogenous technological advantage and determine the rate at which proprietary solutions can be exported (Brynjolfsson et al., 2021). Focusing on such roles reduces the gap between concept and industry-level adoption (Cohen & Levinthal, 1990). The emergence of AI-related vacancies indicates a paradigm shift where firms with high R&D intensity and digital literacy grow more rapidly than non-adopters, signaling the intrinsic value of specialized technical human capital as a catalyst for innovation-led growth (Acemoglu et al., 2022).

A significant portion of labour market demand is communicated through specialised online portals. The accelerated pace of AI deployment necessitates a shift from traditional, time-lagged labour market surveys to real-time web-based Labour Market Information (LMI) systems that utilise machine learning techniques (Boselli et al., 2018). These systems analyse data from online job portals to provide up-to-date insights into labour market demand. Online job advertisement main provocation derive from the fact that they are not using standard taxonomy and the classification needed for extracting useful knowledge from unstructured text (Boselli et al., 2018). Combining online AI postings with AI exposure index (Felten et al., 2021), resulted in a conclusion, that greater exposure to AI has no significant employment impact (Acemoglu et al., 2022). While the labour displacement remains a central concern for the future of work, contemporary recruitment data indicates no substantial divergence in hiring trends strictly based on role's level of AI exposure. Roles characterized as augmented have consistently outpaced broader market hiring growth since mid-2024 (LinkedIn, 2026). AI job postings have been used to define distinct job categories within AI domain. They have also helped to identify the specific hard and soft skills required across these categories (Nakash & Peretz, 2025). Adopting a multidimensional Web Labour Market Intelligence (LMI) approach allows for a granular analysis of AI related jobs, confirming that AI is a transformative

technology that penetrates almost all sectors of the economy, with varying degrees of intensity (Demand for AI Skills in Jobs, 2021). In addition to automating tasks, the successful integration of AI in the workplace requires adaptive strategies that emphasize the ongoing development of human skills to ensure alignment with AI-supported workflows. (Babashahi et al., 2024). Employees should possess not only the capability to utilize AI tools, but also the expertise to incorporate them into business processes through effective teamwork. Communication, problem-solving, management skills form the foundation of the soft-skill package required for AI jobs (Lightcast, 2025). Skill-based hiring is often present for AI related jobs, lowering the reward for degrees and suggesting alternative skill-oriented education (Bone et al., 2025). This emergent skill-based paradigm invigorates Becker's human capital accumulation theory (Becker, 1964), shifting the focus from formal educational credentials back to the intrinsic value of specialized, technical human capital, a dynamic portfolio that must be continuously updated.

The AI labour market increasingly values soft skills and creativity. The co-occurrence of AI expertise and creativity has become more pronounced since the introduction of large language models (Wang et al., 2025). The opportunistic upskilling (Modestino et al., 2020) refers to employers taking advantage of periods of high competitiveness to raise technical and experience requirements, even for entry-level positions. This practice often results in increased barriers for new entrants to the workforce, making it more difficult for recent graduates and those seeking career changes to secure entry-level roles. Following the framework of Web LMI (Boselli et al., 2018), this study moves beyond traditional surveys to provide a multidimensional view of the Romanian AI market. This approach allows for a granular representation of knowledge across sectors and territories.

The purpose of this study is to capture the current state of AI-driven changes, such as sector concentration or evolving skill requirements, on the Romanian labour market. Specifically, the research aims to examine whether global trends, including increased demand for digital and soft skills, are evident within Romania. To achieve this, we employ quantitative analysis, providing a comprehensive assessment of both the impact of AI transformation and the presence of international patterns in the local context.

2 Methodology

2.1 Data collection

The data collection was based on AI-related job postings for Romania sourced from LinkedIn. To comply with strict scrapping policy of the company, but to avoid manually gathering process, we used LLM-based data collection (RapidAPI). Conducted in March 2026, the research utilised a RapidAI subscription granting access to the active LinkedIn jobs that were posted during the last six months. To transform unstructured text into ordinal and categorical variables, we first identified relevant keywords based on industry trends and the specific requirements of AI-related roles. We used the keywords 'AI', 'Artificial Intelligence', 'Machine Learning', 'Data Engineer or Developer or Scientist or Analyst', 'Software' and 'Intelligence', together with the location filter 'Romania', to extract detailed job descriptions. This workflow ensures data gathering by automating both the identification and content extraction steps. Covering a six-month period (October 2025-March 2026), we gathered publicly available data from 6,551 AI vacancies.

2.2 Data pre-processing

Queries were constructed using Phyton to mark jobs as AI relevant based on a predefined AI lexicon, resulting 1,958 relevant postings. To verify the results, we labelled each job with its corresponding term from the lexicon. Entity extraction queries (automated searches used to identify specific skill keywords within each job description) were employed to isolate

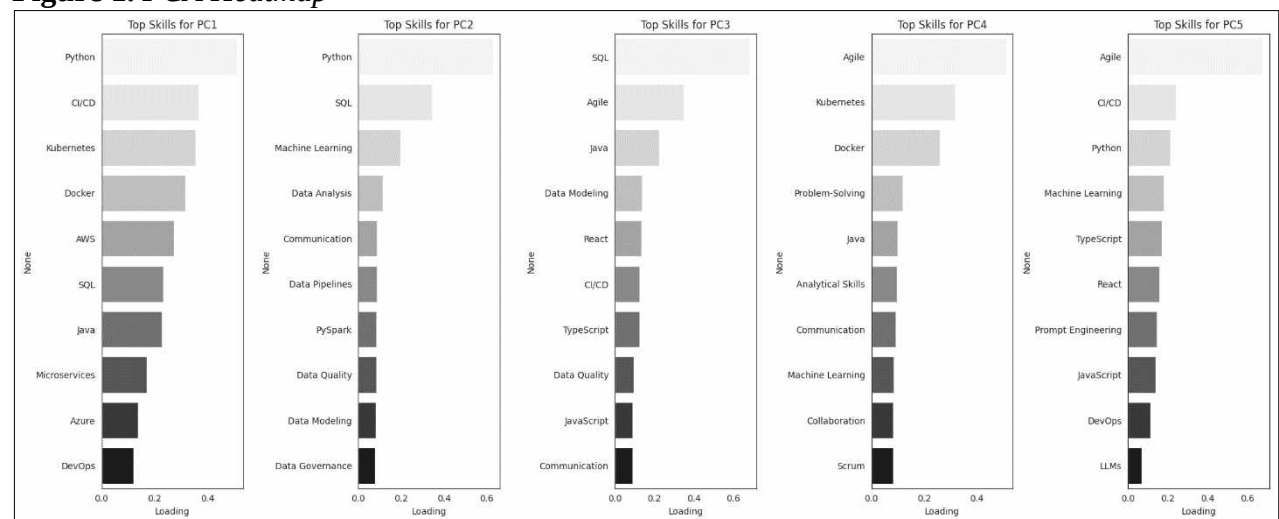
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relevant skills from lengthy text. Following this, normalisation was carried out by standardising variations in terminology, while the categorisation process involved grouping similar skills into predefined categories such as technical or interpersonal competencies. To ensure accuracy, sample extracted skill was checked against the lexicon manually, and any discrepancies were resolved. Python was used to mitigate the ambiguity of requirement language and to transform raw descriptions into structured dataset suitable for statistical analysis. A ruled-based Natural Language Processing (NLP) approach was utilized to convert qualitative descriptions into quantitative variables: to capture numerical years of experience, to map educational level by defining a four-tier hierarchy (Bachelor's, Master's, PhD and Not Specified) and scanning for academic terminology. To address the high variance in technical terminology (e.g. "LLM" vs "Large Language Models"), Semantic Dictionary strategies were implemented. A Semantic Dictionary is a tool that standardises different terms referring to similar concepts. This resulted in the consolidation of specific technologies into broader professional domains; for example, Docker, Kubernetes, and CI/CD were grouped under MLOps /Infrastructure. To address the high number of skills and job titles, Principal Component Analysis (PCA) was performed on a binary matrix of the top frequent 50 hard and 20 soft skills. This reduction generated five distinct skill clusters, representing professional archetypes. After the statistical extraction of clusters, a qualitative labelling process was performed. The core skill categories defined through the PCA are presented in Table 1 and its component skills in Figure 1.

Table 1. Skills categories defined by PCA

Category Name	Key Skills (High Positive Loadings)	Defining Logic
PC1. MLOps & Cloud Infrastructure	Python, CI/CD, Kubernetes, Docker, AWS	Focuses on the deployment and scaling of AI. These are roles that ensure models run reliably in production environments.
PC2. Data Science & ML Research	Machine Learning, PyTorch, TensorFlow, SQL	Focuses on modeling and insight. These roles require heavy statistical and mathematical foundations.
PC3. Enterprise Backend Engineering	Java, Microservices, Spring, SQL	Focuses on integration. This represents AI being built into large-scale, corporate software architectures.
PC4. AI Interface & Web Development	React, TypeScript, JavaScript, Node.js	Focuses on the user experience. These roles build the front-end tools and web-apps that allow users to interact with AI.
PC5. Agile Project Delivery	Agile, Scrum, Communication, Problem-Solving	Focuses on methodology. This category represents the "soft" layer of the market—how AI projects are managed and delivered in teams.

Figure 1. PCA Heatmap



2.3 Data analysis

Descriptive statistics were used to identify general patterns and tendencies and to check if variables are biased. On a second level, we focused on identifying and verifying the strength of relationships between our primary variables. We used Spearman correlation matrix analysis because, for variables such as Experience, Degree, Skills, or Seniority, it uses ranks rather than raw values. Spearman correlation is particularly suitable because these variables are often ordinal and may not follow a normal distribution, making rank-based analysis more appropriate than methods relying on raw values. Variables such as education and experience were converted into ordinal scales based on predefined levels (education was ranked as not mentioned = 0, bachelor's = 1, master's = 2, and PhD = 3). Experience was similarly categorised according to numerical years or specified ranges, from 1 to 4. The number of hard and soft skills was counted separately for each category, ensuring a clear distinction between technical and interpersonal competencies. To determine how much one or more independent variables contribute to a dependent variable we used linear regression analysis. The synthesized skills components were utilised as independent variables in the OLS regression model. Finally, inferential statistics (Kruskal-Wallis) was used to test if observed differences between groups are statistically significant.

3 Results

3.1 Descriptive Statistics

Within our database, we identified 1,958 valid AI job listings. After removing agency postings to avoid duplicates and ensure data integrity, we obtained 1,874 unique job listings. Sectors with less than 10 postings, representing 9.66%, were aggregated in Other Sectors categories. Distributions presented in Table 2 shows an IT dominance (services, consulting and software development), with more than 50% of total.

Table 2. Job Postings Distribution by Sectors

Sector	Job Count	Percentage (%)
IT Services and IT Consulting	575	30,68%
Software Development	490	26,15%
Other Sectors (< 10)	181	9,66%
Automotive & Manufacturing	174	9,28%
FinTech & Finance	172	9,18%
Technology, Information and Internet	93	4,96%
Professional Services	71	3,79%
Telecom & Media	69	3,68%
Engineering Services	25	1,33%
Internet Marketplace Platforms	14	0,75%
Computer and Network Security	10	0,53%

Service type AI jobs represent 35,8% of total, confirming that Romanian AI market is primarily an outsourcing and service market. Most AI engineers are hired to work for other clients rather than developing internal products in sectors like Automotive & manufacturing (9,28%) and FinTech & Finance (9,18%). The high share of Other Sectors (9,66%), gathering sectors with less than 10 postings, suggest that AI is widely spread across industries, rather than being a niche. Analysis of AI jobs by categories reveals a clear market leader of Data Engine (16.3%) that build the AI infrastructure. Presence of software engineers (SE) MLOps on second position (13,4%) suggest that market is focused on deployment in production, also. Data Scientist (6.2%) represent the specialised core that designs the logic needed for further product implementation. The presence of 176 Management & Tech Lead (9,4%) indicates that market is maturing into structured teams with dedicated leadership. Based on their prevalence,

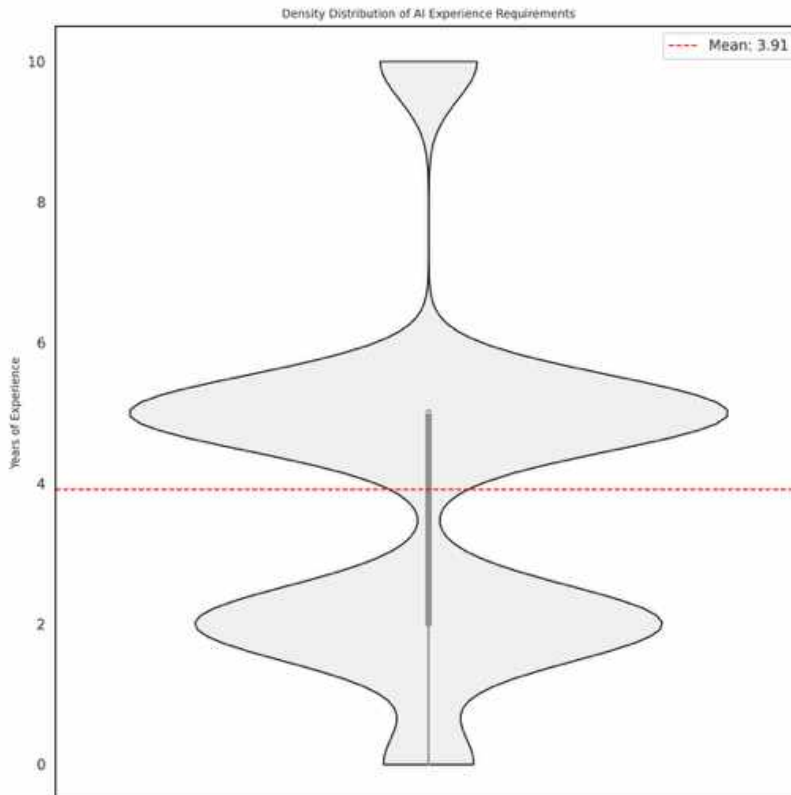
dominant technical skills are Python being present in 43,7% of all jobs, followed by SQL (24,3%), CI/CD (18,5%), Java (16,7%), Kubernetes (15,7%), Docker (13,1%), AWS (13,3%) and Machine Learning (11,4%). On soft skills, there are a set of competencies that appeared consistently across the job descriptions: Agile (18,4%), Communication (15,8%), Management/ Leadership (7,8%), Problem Solving (6,5%) and Collaboration (6,5%). Almost 16% of all job listings do not specify a seniority level, suggesting a high degree of flexibility from companies which are hiring based on a skills approach rather than traditional experience-based levels, as presented in Table 3. The most present seniority level is Mid-level (64,4%) followed by Associate (9,7%) and Entry Level (7,6%).

Table 3. *Job Postings Distribution by Seniority Levels*

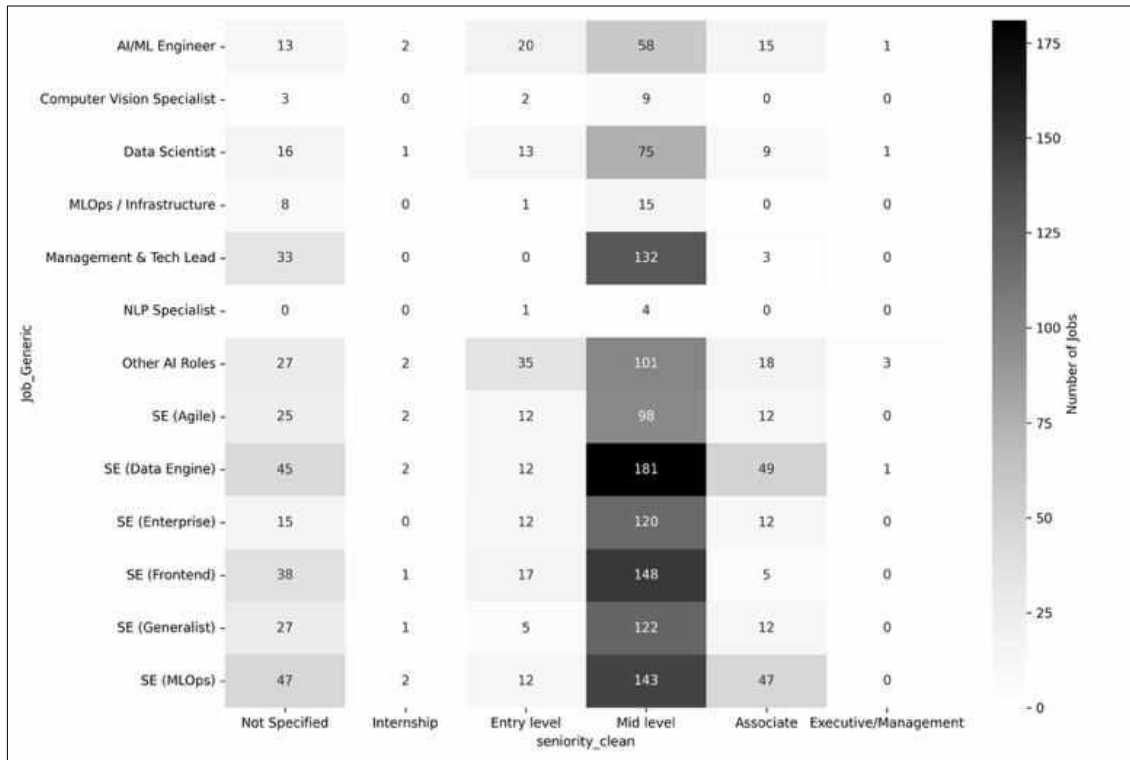
Seniority Level	Average experience (years)	Job Count	Percentage (%)
Not Specified	3,88	297	15,8%
Internship	0,00	13	0,7%
Entry level	0,99	142	7,6%
Associate	3,54	182	9,7%
Mid level	4,34	1206	64,4%
Executive/Management	4,68	34	1,8%

Mapping the average years of experience required for each level, we encounter more than 3 years difference between entry level and mid-level, while from mid to executive level the difference is less than half year. The average required experience is 3,91 years (Figure 2).

Figure 2. *Density Distribution of AI Experience Requirements*



When we mapped Seniority vs Job Category in Figure 3, we can identify which roles are more likely to be Seniority-heavy.

Figure 3. Seniority vs Job Category Heatmap Analysis

The industry is heavily middle-weighted, focused on people who can deliver immediately rather than those who need training. Numbers of Entry Level, especially for AI/ML Engineer, or Not Specified (SE MLOps, Data Engine, Management, Agile), suggests that companies are open to various levels of expertise as long as the core data skill is present. Internship row is almost completely white. Dominance of Mid-level and Associate in SE MLOps prove a high level of maturity of the market, companies looking for competent workforce to run already standardized engineering processes. The analysis of educational requirements in the dataset reveals that formal education is often secondary to demonstrate technical proficiency. Most job listings do not explicitly specify degree requirements (54%). When specified, bachelor's degree is most often requested (31%) over a master or PhD degree (14%). The regional distribution of AI job postings reveals a highly concentrated market. Bucharest and the three main university centres (Cluj-Napoca, Iasi, and Timisoara) account for 68% of jobs, with a substantial remote component (20%).

3.2 Correlation Analysis

For identifying the inter-relationships between our primary variables, we used a correlation matrix presented in Tabel 4.

Table 4. Spearman Correlation Matrix of AI Job Requirements (ρ)

	Seniority_Nu m	Exp_Nu m	Education_Nu m	Hard_Skills_Coun t	Soft_Skills_Coun t
Seniority_Nu m	1	0,645	0,090	0,346	-0,163
Exp_Nu m	0,645	1	0,131	0,353	-0,210
Education_Nu m	0,090	0,131	1	-0,082	0,061
Hard_Skills_Coun t	0,346	0,353	-0,082	1	-0,821
Soft_Skills_Coun t	-0,163	-0,210	0,061	-0,821	1

The strongest observed correlation in the analysis is between Soft Skills and Hard Skills, with a coefficient of -0.821. This value indicates a strong negative relationship, meaning that highly technical roles mention fewer soft skills. This is a clear differentiation between AI professionals and facilitators. On positive side, there is a strong correlation between Seniority and Experience (0,645), meaning that as seniority level increase, the required year of experience moves up. The analysis shows that education has a low correlation with all measured parameters, variables being relatively independent. Specifically, holding a higher degree does not predict seniority, and the skills required for roles are not closely tied to educational degrees. Both Seniority (0.346) and Experience (0.353) have a moderate positive correlation with the Hard Skills. As you move up on seniority, you are expected to know more tools and as candidates accumulate more professional experience, they are likely to possess a wider and more diverse technical skillset. It demonstrates a clear trend without being so strong as to suggest that experience is associated with technical capability.

3.3 Regression Analysis

Using OLS regression analysis, we identify the answer for how much each additional skill or degree add to the required years of experience. While the total database comprises 1874 job postings, the regression models were performed on a subset of 337 cases that provided explicit data for all variables analysed: Seniority Level, Education level, Soft Skills and Hard Skills, as independent variables, and Years of Experience as dependent variable. The model is highly explanatory ($R^2 = 0.425$) for the variance in required years of experience, highly significant ($F = 9.83e^{-39}$) and the Durbin-Watson (1.3) indicates no significant autocorrelation in residuals. Results are presented in Table 5.

Table 5. OLS Regression Results

Variable	Coefficient (Beta)	Std, Error	t-Statistic	p-Value	Conf, Interval Lower (0.025)	Conf, Interval Upper (0.975)
const	-0,6855	0,271	-2,53	0,012	-1,219	-0,153
Education_Num	0,1508	0,055	2,729	0,007	0,042	0,26
Hard_Skills_Count	0,0361	0,018	2,032	0,043	0,001	0,071
Soft_Skills_Count	-0,0074	0,034	-0,218	0,827	-0,074	0,059
Seniority_Num	0,8242	0,064	12,873	0	0,698	0,95

The negative value of Intercept suggests a certain entry barrier, a baseline experience requirement. The most powerful predictors are Seniority (0,82) and Education (0,15). Every increase in education adds 0,15 years to the expected experience level. Hard Skills accumulation remain significant ($p = 0,043$), but Soft Skills has no statistical impact on required experience.

3.4 Inferential Statistics

Given the non-normal distribution of skill counts, we employed the Kruskal-Wallis H-test to compare technical requirements across groups. The null hypothesis states that the median skills count is the same across all job categories. Rejecting it ($p < 0.0001$) means that there is a statistically significant difference in the median number of hard skills requested among the various AI job categories. The test resulted an H-statistic of 160,76, indicating that job categories are defined by distinct level of skills.

Table 6. Kruskal-Wallis H-test Results

Job_Generic	Mean Hard Skills Count	Median Hard Skills Count	Std Dev Hard Skills Count	N sample	Mean Rank
SE (MLOps)	15,1	16	1,586	251	1169,789
MLOps / Infrastructure	15,0	16	1,805	24	1156,917
SE (Enterprise)	15,0	16	1,639	159	1136,579
SE (Frontend)	14,7	16	1,866	210	1053,626
SE (Data Engine)	14,4	15	1,879	305	941,390
SE (Agile)	14,1	15	2,249	150	854,693
Data Scientist	14,1	15	2,034	116	853,845
Management & Tech Lead	14,1	15	1,971	176	852,097
AI/ML Engineer	14,0	15	2,400	110	845,882
Computer Vision Specialist	13,7	14	2,673	14	828,143
SE (Generalist)	14,0	14	2,022	167	809,446
Other AI Roles	13,2	14	2,600	187	672,497

All generic roles require between 13,2 and 15,1 mean hard skills. Engineering roles, such as MLOps, Infrastructure and Enterprise, related with AI integration and scale, demand a broader technical skill set (mean >15), highlighting the value placed on versatility in these roles. Data Scientist and AI/ML Engineer positions have an average number of required skills of 14.1 and 14.0, respectively. This relatively lower skill complexity suggests that these roles prioritize specialized expertise in a few key areas, rather than a broad range of skills. In other words, candidates are expected to possess deeper knowledge in core competencies, such as advanced statistical modeling or machine learning techniques, instead of being familiar with many unrelated tools. For example, a Data Scientist may be expected to demonstrate a high level of proficiency in data analysis and statistical methods, while an AI/ML Engineer might focus on mastering machine learning algorithms and frameworks. Relative to median required skills, all job categories exhibit a low standard deviation, suggesting that these has a high level of standardization.

4 Discussion

The empirical investigation into the Romanian AI labour market reveals a landscape characterized by a transition toward a skill-based hiring paradigm, where competence often outweighs formal credentials (Bone et al., 2025). This is typical of high-growth tech hubs where the speed of innovation outpaces formal university curricula. Bachelor's remains the most common academic requirement. The Spearman correlation analysis reveals a labour market characterized by technical pragmatism. While required years of experience predictably align with seniority levels, formal education shows a negligible relationship with career advancement, suggesting that the Romanian AI sector prioritizes accumulated professional expertise over academic credentials.

By synthesizing the results from 1,874 unique job postings, this study confirms that Romania serves primarily as an outsourcing and service-oriented hub, with 35.8% of roles explicitly categorized as service-type AI positions. This finding aligns with the theoretical framework of Guarascio and Reljic (2025), which affirm that AI implementation is asymmetrical and dependent on a country's existing labour market composition and baseline capabilities. The analysis of hiring criteria provides a contemporary validation of Becker's (1964) human capital accumulation theory, showing a shift where technical proficiency often supersedes formal educational credentials: 54% of job listings omit degree requirements. The middle-weighted nature of the market, where 64.4% of vacancies target mid-level

professionals, indicates a preference for immediate delivery over long-term talent cultivation. This preference potentially exacerbates the opportunistic upskilling trend described by Modestino et al. (2020), where high competitiveness allows employers to raise experience barriers, further marginalizing recent graduates. Employers' average requirement of 3.91 years of experience is raising entry barriers, as shown by few internships (0.7%) and a large gap between entry- and mid-level jobs.

While sectorial analysis shows high service sector concentration, the distribution of job categories suggests a more nuanced, cross-sectorial implementation hub architecture, with deployment specialists (SE MLOps 13,4%) and structured teams with dedicated leadership (Management & Tech Lead 9,4%). The presence of Associate-level positions (9,7%) signifies that the Romanian AI sector is transitioning into a standardized production phase. The market is no longer seeking pioneers (Entry Level 7,6%) to define the field, but rather a robust technical middle class capable of independent execution in scaling and maintaining AI systems within established corporate frameworks. Romania's AI labour market continues to be remote friendly (20%) and concentrated in cities that host major universities (68%), underscoring the crucial role that academic centres play in attracting this sector.

The empirical results of this study concerning soft skills within the Romanian AI labour market provide a compelling counter-narrative to international trends, revealing a sector currently defined by a separation between technical and human skills. While global literature, such as that by Nakash and Peretz (2025), identifies communication (50.93%) as the most in-demand AI skill and emphasizes a strong connection between leadership and technical competencies, the Romanian market exhibits a sharp negative correlation (-0.821) between hard and soft skills. The regression analysis in this study further underscores this structural rigidity: while seniority and technical human capital are significant predictors of professional experience requirements ($p = 0.043$), soft skills have no statistical impact on the required years of experience ($p = 0.827$). This highlights a significant differentiation between technical professionals and organizational facilitators. This disconnect suggests that while Romanian firms are successfully adopting AI at a technical level, they may face the skill transformation challenges noted by Babashahi et al. (2024), where the integration of AI tools into business processes requires more effective teamwork and management skills. As demonstrated by Aškerc Zadavec et al. (2025), when organizations navigate technological disruptions, critical competency shortages rapidly emerge in strategic HRM and employee development. However, by ignoring soft skills at the recruitment level, the Romanian AI ecosystem risks exacerbating these exact shortages, constructing highly technical but structurally isolated teams that lack the relational framework required to manage the complex, ethical, and human-centric dimensions of AI transformation.

A primary strength of this study is the application of real-time, high-frequency Web Labour Market Information (LMI) systems, which offer a more granular view than traditional, lagged surveys. By utilizing LLM-based data collection and Principal Component Analysis (PCA), the research identifies five distinct professional archetypes that define the market's technical core. However, a notable weakness is the six-month temporal window (October 2025–March 2026), which may not capture long-term cyclical shifts or the full impact of technology. While these findings are highly representative of the Romanian AI sector, generalization to other emerging European economies should be approached with caution, because its specificity.

A critical direction for future research lies in performing a comprehensive gap analysis between academic curricula and the industry demanded skill sets identified in this study. The existing literature underscores a profound mismatch between the pace of evolution in formal education and the requirements of the labour market (Dwivedi et al., 2024), often resulting in a significant disconnect between academic training and industry priorities. To address the

already identified structural barriers (demography, economics, education, and socio-political factors), policy interventions must modernize educational curricula to align with the requirements of the industry. Specifically, there is a need for specialized training in MLOps and Data Engineering, which currently demand the broadest technical skill sets. To address a possible skills gap and mitigate the structural barriers, it is imperative to enlarge formal education opportunities to systematically provide the specialized technical and hybrid competencies demanded by the industry, particularly as increasing attention is being paid to candidates' skills acquired outside formal education (Fuller et al., 2022). For the private sector, it is recommended to move away from mid-heavy hiring, to loose the entry barriers and invest in entry-level pipelines to ensure long-term workforce sustainability and counter the effects of an aging workforce. Further research is needed to determine if this implementation hub status evolves into domestic product innovation or remains a service-oriented niche. Within the Romanian context, which is already constrained by outdated curricula and low tertiary education participation, the risk of a skills gap is particularly acute, where academic programs may fail to provide the specialized technical capital required for the modern AI workforce.

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THE INFLUENCE OF LEADER-MEMBER EXCHANGE (LMX) ON EMPLOYEE JOB SATISFACTION IN THE HOSPITALITY INDUSTRY: EVIDENCE FROM GEORGIA

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Abstract: *In the Georgian hospitality sector, which is frequently marked by labor shortages and poor levels of work satisfaction, this study investigates the link between leader-follower exchange (LMX) and employee job satisfaction. A substantial positive connection between LMX and job satisfaction was found in data gathered from a survey of 155 employees ($r = 0.715$, $p = 0.001$). 52% of the observed variation in satisfaction was explained by the proposed model ($R^2 = 0.520$). Experience sharing and a collaborative work environment served as mediators in this connection, whereas communication ($= 0.513$) and support ($= 0.233$) were shown to be significant predictors. These results have significant ramifications for management approaches to leadership in the hotel industry as well as theoretical advancement.*

Keywords: *LMX; Job satisfaction; hospitality; relational leadership.*

1. INTRODUCTION

Solid manager-employee connections are fundamental to hospitality operations, directly influencing service quality and organizational competitiveness (Edgar & Nisbet, 1996; Schneider, 2003). The issue is especially pronounced in Georgia's hospitality industry. Georgia's tourist sector had a 20.1% growth in output in the third quarter of 2022, exceeding pre-pandemic figures; nonetheless, the business faced ongoing challenges with labor retention. Meladze et al. (2022) and the Georgian National Tourism Administration (2023) recognized inadequate working conditions and strained interpersonal connections as the primary factors for staff attrition. These aspects are highly significant, since job satisfaction has been consistently associated with absenteeism, employee turnover, and the quality of customer service (Diaz-Serrano, 2013; Norman et al., 2015). The Leader-Member Exchange theory elucidates why certain managers excel in fostering employee satisfaction, whilst others fail, as seen by the discontent among employees in Georgia's tourism sector. Determining the elements that influence employee satisfaction is a critical issue for the Georgian hospitality sector. Fundamentally, LMX posits that the strength of the connection between a leader and each team member is a crucial determinant of employees' thoughts, emotions, and behaviors in the workplace. While international research on LMX is abundant and comprehensive, studies within the Georgian hospitality context have been virtually nonexistent. This study sought to fill that gap. Data from 155 hotel employees in Georgia were examined to assess the impact of LMX quality, supervisors sharing their professional experiences, and a collaborative work environment on job satisfaction.

2. Theoretical Framework

2.1 LMX Theory: Foundations and Development

The theoretical foundations of LMX stem from Dansereau et al. (1975), who proposed the Vertical Dyad Linkage structure to challenge a widely held assumption: that leaders treat everyone on their team the same way. Empirical data consistently refutes this premise. LMX

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theory argues that managers build different relationships with different employees, which naturally produces in-groups and out-groups within any team (Liden & Graen, 1980; Erdogan et al., 2006). These relationships grow over time. Trust builds up, expectations form, and the relationship expands well beyond what either party's formal role requires.

In a high-quality LMX relationship, trust, loyalty, respect, and open information sharing define how the two parties interact (Wu et al., 2010). Trust is particularly important here, as it is what makes people willing to share resources and support without demanding something back immediately, which keeps the exchange alive and growing (Sue-Chan et al., 2012). On the manager's side, this shows up as offering real development opportunities, greater autonomy, a voice in decisions, and genuine emotional support. From the employee's perspective, it manifests as enhanced dedication, increased proactivity, and improved overall performance (Volmer et al., 2011; Walumbwa et al., 2011). In low-quality LMX partnerships, interactions are limited to the formal agreement, with neither party exceeding their designated role (Joshi, 2006; Erdogan & Bauer, 2016). Employees without strong LMX connections receive diminished attention and fewer developmental opportunities, resulting in decreased motivation and inferior performance (Gerstner & Day, 1997).

A substantial body of research consistently points to the same conclusions. Improved LMX quality is associated with greater job satisfaction, higher commitment, enhanced performance, and elevated creativity. It also means less role confusion, less conflict, and lower intentions to leave (Dulebohn et al., 2012; Gerstner & Day, 1997; Ilies et al., 2007). Volmer et al. (2011) showed that the relationship runs both ways - LMX improves satisfaction, and satisfaction in turn strengthens LMX over time. There is also a social dimension worth noting. The extent to which an employee's LMX quality is perceived positively or negatively in relation to colleagues influences individual confidence and engagement, indicating dynamics that extend the basic dyad (Hu & Liden, 2013).

2.2 Key Antecedents of LMX Quality

LMX quality is not unilaterally determined; both the manager and the employee contribute to its development. From the manager's side, what matters most is the willingness to build real trust-based connections rather than limiting interactions to task management and performance monitoring (Masterson et al., 2000). This becomes complex when a manager commands a substantial team. Managerial time and attention are limited resources. When a manager cannot allocate equal attention to all employees, certain individuals inevitably feel excluded, while others may conjecture that some colleagues are receiving preferential treatment (Liden et al., 2006; Hooper & Martin, 2008). Even in circumstances devoid of intentional bias, such perceptions can erode team cohesion. Employees also make substantial contributions. Individuals that demonstrate initiative, create a favorable image, and exhibit their capabilities are more inclined to garner management attention that fosters a robust Leader-Member Exchange (LMX) connection (Lam et al., 2007; Wu et al., 2013). Newcomers encounter a distinct challenge, as the caliber of managerial support provided in the initial weeks of employment can profoundly influence their organizational integration rate and the enduring quality of the manager-employee relationship (Bauer et al., 2006; Thompson & Sluss, 2012).

2.3 LMX, Experience Sharing and Job Satisfaction.

One of the most tangible functions of a high-quality LMX relationship is transfer of knowledge from the manager to the employee. This form of knowledge transfer transcends formal training or documented protocols; it includes the implicit understanding gained through experience, such as navigating complex scenarios, exercising professional judgment, and interpreting the informal norms that regulate organizational dynamics. Managers who share this kind of knowledge freely are doing something that formal induction processes simply

cannot replicate (Cavell, 2007; Thompson & Sluss, 2012). The impact on the employee undergoing training extends beyond mere skill enhancement. Authentic investment fosters trust, enhances commitment, and engenders a sense of competence and security that directly elevates job satisfaction. The opposite pattern is similarly revealing. When managers suppress information and offer neither direction nor clarity, employees often feel alienated and unclear about their position within the firm. This indicates that a manager's readiness to share expertise signifies more than only a facet of leadership qualities. It is a tangible manifestation of LMX quality and a specific avenue via which the manager-employee interaction either enhances or diminishes employee welfare.

2.4 Cooperative Work Environment, LMX, and Job Satisfaction.

The academic impacts of LMX are more comprehensive than often perceived. While it affects the relationship between a manager and an individual employee, its influence permeates the broader business culture. Leaders that demonstrate trust, honesty, and integrity generally foster an environment conducive to the proliferation of similar qualities among colleagues (Jackson & Johnson, 2012). Such cultures are marked by common goals, reciprocal support, and a collective focus that mitigates information hoarding and counterproductive rivalry, hence fostering a more unified and efficient workplace (West et al., 2003).

In hospitality, where service delivery relies on coordinated efforts across several roles and levels, this relationship is especially significant. When employees regard their employment as equitable and fair, they experience reduced stress from everyday responsibilities and foster improved relationships with their colleagues. Perceived equity in supervisory conduct is essential for optimal team performance. Nishii and Mayer (2009) revealed that when employees perceive unequal treatment, team cohesiveness declines and collaborative performance is adversely affected. The personnel will not collaborate effectively if they perceive the supervisor as unjust against them. Collaboration with the staff is crucial for their advantage. Employees are sensitive to perceived injustices, and the resulting anger can severely disrupt the collaborative dynamics essential for hospitality operations (Hooper & Martin, 2008). In Georgia specifically, where holding onto staff is one of the industry's most pressing challenges, this connection between LMX quality and cooperative climate deserves careful attention.

2.5 Research Hypotheses

Drawing on the theoretical synthesis above, the following three hypotheses are proposed for empirical testing:

H1: LMX relationship quality has a significant positive effect on employee job satisfaction in the Georgian hospitality industry.

H2: LMX quality is positively associated with managers' motivation to share experience and knowledge, which in turn is positively associated with employee job satisfaction.

H3: LMX quality is positively associated with a cooperative work environment, which in turn is positively associated with employee job satisfaction.

3. Methodology

3.1 Research Design and Sample

The study employed a cross-sectional survey, deemed suitable due to the absence of prior research in the Georgian context. Respondents were obtained from various sectors of the hospitality industry, including hotels, restaurants, cafés, and wine tourism businesses. The data collection took place in the third quarter of 2022, aligning with Georgia's high tourism season, a deliberate choice. The peak season frequently complicates professional relationships in ways that quieter periods do not, prompting respondents to concentrate on circumstances that were

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immediate and tangible rather than distant or abstract. The sample was divided into three age categories: 102 respondents aged 18 to 30 (65.8%), 47 aged 31 to 45 (30.3%), and 6 aged 46 to 60 (3.9%). The oldest cohort was excluded from age comparison studies because the sample size of six respondents was insufficient for proper statistical assessment.

3.2 Measures

The survey instrument comprised 19 items distributed across five thematic areas: the LMX sub-dimensions of communication, trust, and support; experience-sharing motivation; cooperative work environment; job satisfaction; and demographic characteristics. Core construct items were measured on a 3-point Likert-type agreement scale (1 = strongly disagree; 2 = partially agree; 3 = strongly agree), adapted from LMX-7 constructs with established validity in prior hospitality research. The tool included scenario-based multiple-choice screening items intended to reveal the qualitative meanings respondents individually associated with each concept. This design decision tackled an acknowledged methodological issue: the direct conversion of Western measurement scales into culturally and linguistically diverse contexts poses a risk of response bias, as the conceptual meaning of items may not align seamlessly with how respondents in that context interpret the same terminology. The scenario items provided a check against this possibility and strengthened the overall construct validity of the instrument.

3.3 Data Analysis

Researchers used IBM SPSS Statistics to analyze the data. They examined relationships among variables using Pearson correlations, following Cohen's (1988) guidelines for effect sizes. Multiple regression was used to test how communication, support, and trust together predicted job satisfaction, after confirming that the data met key assumptions (Sykes, 1993). Independent samples t-tests compared LMX, experience sharing, and cooperation between two age groups, using Levene's test for equal variances and Welch's correction when appropriate. All tests used a significance level of .05.

3.4 Ethical Statement

Participation in the study was entirely voluntary, with no financial incentives provided or awarded. Ethical approval was secured from the relevant institutional authorities prior to commencing data collection. All individuals granted informed consent before participating. No personally identifiable information was gathered at any point, and all replies were managed with complete anonymity and secrecy. The authors declare no financial or personal conflicts of interest that might have influenced the design, execution, or reporting of this research.

4. Results

4.1 Descriptive and Perceptual Findings

Respondents rated the extent to which four specific managerial behaviours affected their job satisfaction. Table 1 shows the full breakdown of responses for each factor.

Table 1. Employee Perceptions of Factors Affecting Job Satisfaction (n = 155).

Factor	Strongly Agree	Partially Agree	Strongly Disagree
Manager's motivation to contribute to professional development	68.4%	22.6%	9.0%
Cooperative work environment	68.4%	21.9%	9.7%

Effective communication with the manager	66.5%	24.5%	9.0%
Manager's sharing of work experience	63.9%	27.1%	9.0%

Note. Rows may not sum 100% due to rounding.

The pattern that emerged from the data was notably consistent. Among the four management behaviors examined, 63.9% to 68.4% of respondents strongly concurred that each practice improved their work satisfaction, while an additional 21.9% to 27.1% indicated moderate agreement. Significant dissent was infrequent, with about 9 to 10% of respondents contesting any issue. Two characteristics ranked equally at the highest level: managerial support for professional growth and a collaborative work environment, both achieving a significant agreement rate of 68.4%. This convergence is noteworthy. Employees in Georgian hospitality perceive personal growth and team dynamics as interconnected and equally vital aspects of their work experience. The reliability and strength of these responses instilled assurance that the constructs accurately measured their intended variables and that the data were sufficiently valid to underpin the next inferential analyses.

4.2 Correlation Analysis

Table 2 presents pairwise Pearson correlation coefficients between the key study variables. All eight associations were statistically significant at the .01 level (two-tailed), providing robust preliminary support for the three research hypotheses. Correlations *are large by Cohen's (1988) benchmarks* ($r \geq .50$), *except for Trust-JS* ($r = .490$; *borderline large*).

The correlation between LMX and job satisfaction (.715) was the strongest in the data and is considered a large effect (Cohen, 1988), strongly supporting H1. Of the LMX sub-dimensions, communication had the strongest link to job satisfaction ($r = .678$), followed by support ($r = .532$) and trust ($r = .490$). The correlation between LMX and experience sharing ($r = .742$) was even higher, suggesting that motivation to share knowledge is a clear sign of high LMX in this group. The mediating correlations for H2 (LMX-sharing: $r = .742$; sharing-JS: $r = .634$) and H3 (LMX-cooperation: $r = .715$; cooperation-JS: $r = .610$) were both large and similar in size, showing that both pathways are important for organizational action.

4.3 Multiple Regression Analysis

A multiple linear regression model was constructed with communication, support, and trust entered as predictor variables and job satisfaction as the criterion. Prior to interpretation, the key statistical assumptions underlying ordinary least squares regression were systematically verified. Residual plots were examined to assess linearity and homoscedasticity, while the Kolmogorov-Smirnov test was applied to evaluate the normality of the residual distribution. All assumptions were satisfactorily met. The model summary, ANOVA table, and standardized regression coefficients are reported in Tables 3, 4, and 5 respectively.

Table 3. Regression Model Summary

Model	R	R ²	Adjusted R ²	SE
1	.721	.520	.510	1.408

Predictors: communication, support, trust. Dependent variable: job satisfaction.

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Table 4. ANOVA

Source	SS	df	MS	F	p
Regression	324.116	3	108.039	54.466	.000**
Residual	299.523	151	1.984		
Total	623.639	154			

** $p < .001$.

Table 5. Regression Coefficients

Predictor	B	SE	β	t	p
Constant	5.996	.741	—	8.090	.000
Communication	.537	.073	.513	7.353	.000
Support	.489	.144	.233	3.389	.001
Trust	.214	.156	.098	1.377	.170

Dependent variable: job satisfaction.

The regression model came back statistically significant ($F(3, 151) = 54.466, p < .001$) and explained 52% of the variance in job satisfaction ($R^2 = .520$; adjusted $R^2 = .510$). In the context of organizational research, this signifies a significant explanatory contribution, demonstrating that three relational aspects of the manager-employee relationship together account for more than fifty percent of the variance in employee satisfaction. Communication was identified as the foremost predictor ($\beta = .513, p < .001$), exhibiting an influence more than double that of support ($\beta = .233, p < .001$). Trust had a positive correlation but did not reach statistical significance ($\beta = .098, p = .170$). This should not be seen as proof that trust lacks significance. Trust functions indirectly, establishing the conditions for effective communication and support. In the absence of a trust foundation, same managerial practices would probably have much less impact. This establishes trust as a relationship necessity instead of a direct catalyst for satisfaction.

Table 6. Independent-Samples t-Test Results by Age Group

Variable	M ₁	M ₂	t	df	p	Decision
Support	4.980	5.106	-.771	147	.442	n.s.
Communication	7.294	7.426	-.525	147	.601	n.s.
Trust	5.029	5.170	-.893	147	.373	n.s.
Experience Sharing	7.500	7.936	-1.423	147	.157	n.s.
Cooperation*	2.490	2.723	-2.393	115.4	.018*	H ₀ rejected

*M1 = age 18–30 (n = 102); M2 = age 31–45 (n = 47). * Welch correction applied (Levene $F = 13.074, p .001$). n.s. = not significant.*

An analysis of the two primary age groups across the three LMX variables indicated no significant differences in support, communication, or trust (all $p > .05$). The mean scores were closely aligned, and the confidence intervals overlapped, suggesting that employees' assessments of their managerial relationships do not significantly vary with age or professional experience in this group. This is a noteworthy discovery. It indicates that Georgian hospitality employees, regardless of generation, possess largely uniform expectations for effective management, a consistency presumably rooted in collective cultural perceptions of leadership and authority rather than peculiar to any given age cohort.

The one place where age did make a difference was cooperative work environment. Older employees scored meaningfully higher than younger ones ($M = 2.723$ versus $M = 2.490$), and this gap was statistically significant ($t = -2.393$, $df = 115.422$, $p = .018$, with Welch's correction applied because the group variances were unequal). What did not differ by age was how much employees valued their manager sharing knowledge and experience both groups cared about this equally ($p = .157$). So younger and older employees want the same things from their managers, but older employees show a stronger orientation toward cooperative teamwork. A possible explanation for this pattern is taken up in Section 4.

4.4 Hypothesis Testing Summary

Table 7. Hypothesis Testing Outcomes

H	Statement	Direction	Outcome
H1	LMX quality has a significant positive effect on employee JS in Georgian hospitality	Positive	Supported
H2	LMX quality is positively associated with experience sharing, which positively affects JS	Positive	Supported
H3	LMX quality is positively associated with cooperative environment, which positively affects JS	Positive	Supported

5. Discussion

The findings confirmed all three hypotheses and contribute novel insights to the LMX literature, particularly evidence from a post-Soviet, emerging-market hospitality setting that has not been previously explored. The association between LMX quality and work satisfaction ($r = .715$) above exceeded the average range reported in most Western research, which often falls between .40 and .60 (Gerstner & Day, 1997; Dulebohn et al., 2012). This difference is noteworthy. In settings like Georgia, where power distances tend to be larger and employment protections are limited, employees lean more heavily on their direct manager for both practical and emotional support. A high-quality connection significantly impacts employee results. As it declines, employees possess relatively fewer alternate sources of assistance to rely on.

Communication emerged as the most significant predictor by a substantial margin ($\beta = .513$, $p < .001$). This discovery aligns with the extensive literature on management communication within service-oriented contexts. Clear and consistent communication from managers fulfills many functions: it diminishes uncertainty around expectations, indicates attentiveness, and provides workers with the necessary information to make informed decisions under pressure (Waldron, 1991). The observation that communication has more than double the impact of support is a practically beneficial insight; even modest improvements in managerial contact with teams might provide significant increases in satisfaction without necessitating extensive organizational alterations.

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Support was identified as the second most potent predictor ($\beta = .233$, $p < .001$). This corresponds with the extensive research, which repeatedly indicates that direct supervisor support is generally more significant to employees than organizational support in the abstract (Tan, 2008). In the hospitality sector, the manager frequently serves as the most prominent representative of the business to front-line personnel, making this dynamic particularly evident. For numerous employees, the direct supervisor serves as the principal source of assistance rather than one of several equally available options.

Trust did not achieve statistical significance in the regression analysis ($\beta = .098$, $p = .170$), however it exhibited a substantial correlation with work satisfaction independently ($r = .490$). This should not be construed as an indication that trust is insignificant. Rather, trust appears to operate in the background, creating the conditions under which communication and support feel credible. When employees trust their manager, they are more likely to receive communication as honest and experience support as genuine. In the absence of such foundation, some management activities would certainly yield markedly different outcomes. This explanation aligns with Sue-Chan et al. (2012), who discovered that trust typically facilitates other favorable outcomes rather than directly causing them, serving as a requirement rather than an independent process. Future research using structural equation modelling could test this more formally.

The two confirmed pathways, through experience sharing (LMX and sharing: $r = .742$; sharing and JS: $r = .634$) and cooperative work environment (LMX and cooperation: $r = .715$; cooperation and JS: $r = .610$), demonstrate that LMX improves satisfaction through more than one route. The effect is not limited to how an employee feels toward their manager personally. High-quality LMX also generates two forms of structural resources: knowledge flows when managers share experience, and team cohesion strengthens when managers model cooperative behavior. Both contribute to satisfaction in ways that persist even when individual manager relationships vary in quality. The practical implication is significant: organizations cannot address satisfaction simply by coaching individual managers. Equally important is building the structures, including mentoring cultures, team practices, and knowledge-sharing norms, that allow relational leadership to take effect at a collective level.

The age group findings introduced a nuance worth examining. It might reasonably be expected that older, more experienced employees would report to a stronger LMX quality, having had more time to accumulate social capital and refine their capacity for workplace negotiation. This was not the case. Both age demographics assessed their managerial interactions in fundamentally similar terms, indicating that leadership expectations in Georgian hospitality are influenced more by collective culture norms than by personal professional experiences. The distinction seen was in cooperative orientation, with older employees achieving significantly higher scores ($p = .018$), a trend presumably indicative of greater team experience, stronger colleague relationships, and a more established professional identity. Junior personnel are not intrinsically less competent in collaboration; they may only necessitate more intentional organizational assistance to cultivate it.

CONCLUSIONS

This study provides the first quantitative evidence linking LMX quality to employee job satisfaction in Georgia's hospitality sector. The findings indicate that LMX quality, measured through communication, support, and trust, explains 52% of the variance in satisfaction, with communication standing out as the single most powerful predictor. Two distinct mediating pathways were also confirmed: experience sharing and cooperative work environment. Collectively, these findings indicate that relational leadership enhances employee welfare not just via the direct manager-employee relationship but also via the knowledge-sharing cultures and team environments fostered by effective leadership.

For managers and organizations with workforce shortages and elevated turnover, the findings indicate three practical priorities. First, organized and consistent communication between management and front-line personnel warrants deliberate organizational investment. Secondly, formal mentorship and knowledge-transfer initiatives provide a tangible framework for cultivating the relational capital that maintains satisfaction over time. Third, team-building techniques need sincere attention, especially for younger employees, who have exhibited a comparatively lower cooperative orientation. Trust, the findings suggest, is best understood as the foundation that makes everything else function, not a separate intervention but the relational precondition for communication and support to achieve their full effect.

The study possesses several limitations that must be recognized. The cross-sectional design precludes causal inferences. Subsequent study ought to rectify these weaknesses by employing more rigorous methodological strategies, ordinal logistic regression, structural equation modeling, and mediation techniques as outlined by Baron and Kenny (1986) or bootstrapping methods. Extending this research to other Caucasian hospitality markets would elucidate the extent to which the findings are influenced by the unique Georgian cultural environment and their applicability outside it.

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THE USE OF LARGE LANGUAGE MODELS IN THE EDUCATIONAL PROCESS: AN EMPIRICAL ANALYSIS AMONG UNIVERSITY AND SECONDARY SCHOOL STUDENTS

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Abstract: *The increasing use of large language models (LLMs) in education has raised important questions regarding their impact on learning, trust, ethics, and data protection. This study examines the use of LLMs among secondary school and university students in Slovenia based on an online survey conducted in 2024 (N = 120). The main objectives were to analyze patterns of use, levels of trust and verification, perceptions of ethical issues, and the perceived impact of LLMs on learning efficiency. The study also investigates whether differences exist between educational levels and gender. The results indicate that LLMs are widely used for educational purposes, particularly for preparing assignments and presentations. Students report moderate trust in AI-generated information and frequently verify its accuracy, suggesting a cautious approach. Perceived time savings are significant, while privacy concerns remain high. No statistically significant differences were found between university and secondary school students or between genders. The findings highlight the growing integration of LLMs into education and emphasize the need for clear guidelines on their ethical and responsible use.*

Keywords: Artificial Intelligence, Large Language Models, Education, Ethics, Data Protection.

1 Introduction

In the past decade, Artificial Intelligence (AI) has entered numerous areas of human activity, particularly in educational systems. Among the most prominent technologies of modern AI are Large Language Models (LLMs), such as ChatGPT, Gemini, and Copilot, which are based on advanced deep learning methods. These models enable natural language generation, automatic question answering, text composition, and even the creation of new ideas. With the development of tools accessible to the public, LLMs are increasingly being established as learning support tools for university and secondary school students.

In the educational context, LLMs represent tools with great potential. Users report time savings in writing seminar papers, searching for information, and preparing presentations. At the same time, they facilitate better understanding of complex concepts, as the responses are often tailored to individual questions and needs. This type of interactivity and accessibility contributes to increased motivation for learning, which is especially important in the era of educational digitalization.

In this context, the present study was conducted in Slovenia, where the integration of digital technologies in education has been steadily increasing in recent years (European Commission, 2023). Recent studies confirm that AI tools are rapidly becoming part of the educational ecosystem, influencing both teaching and learning processes (UNESCO, 2023; OECD, 2024).

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Despite the obvious advantages, significant concerns have emerged. The most prominent include issues of information reliability, ethical conduct, questions of authorship authenticity, and especially the protection of personal data. LLMs often function as a "black box," where users are unaware of the mechanisms leading to specific responses. Furthermore, there is a risk that frequent use of these tools may reduce students' independence in critical thinking, problem-solving, and the formulation of their own ideas.

The aim of this study was to examine how individuals, particularly secondary school and university students, use large language models for educational purposes, to what extent they trust them, and what level of awareness they have regarding the ethical and security aspects of using these tools. In addition, the research analyzes whether there are statistical differences between genders and educational groups in terms of LLM usage, and how users perceive the impact of AI on learning effectiveness.

2 Theoretical Framework

The rapid development of AI, particularly large language models (LLMs), has significantly transformed educational environments in recent years. Advances in deep learning and natural language processing have enabled tools such as ChatGPT, Gemini, and similar systems to support a wide range of academic activities, including writing, problem-solving, and knowledge acquisition (UNESCO, 2023; OECD, 2024).

In higher education, LLMs are increasingly used to enhance learning efficiency, support independent study, and facilitate access to information. Studies show that students frequently use AI tools for writing assignments, preparing presentations, and understanding complex topics (Digital Education Council, 2024; Vieriu, 2024). At the same time, AI enables more personalized and adaptive learning experiences, which can improve student engagement and academic performance.

In contrast, the use of AI in secondary education remains less explored and is often influenced by institutional restrictions and varying levels of digital literacy. Research suggests that while secondary school students are increasingly exposed to AI tools, their use is often less structured and more dependent on individual initiative and school policies (Lumina Foundation, 2024). This highlights the importance of examining both educational levels to better understand differences and similarities in AI adoption.

A central issue in the literature concerns trust in AI-generated content and the extent to which users verify the information provided. Denny et al. (2023) argue that students often perceive AI-generated content as comparable in quality to human-generated materials. However, other studies emphasize that users maintain a degree of skepticism and frequently engage in verification, particularly in academic contexts (Đerić et al., 2024). This balance between trust and critical evaluation is essential for responsible AI use.

Ethical considerations and data protection represent another key dimension of AI adoption in education. The increasing use of AI tools raises concerns regarding privacy, data security, and academic integrity (Huang, 2023; Gujjula & Sanghera, 2023). Research indicates that users who demonstrate higher ethical awareness are more likely to emphasize the importance of personal data protection and responsible AI use.

In addition, several studies highlight the impact of AI on time efficiency and productivity. AI tools can automate routine tasks, provide instant feedback, and facilitate faster access to relevant information, thereby significantly reducing the time required for learning activities (Gupta et al., 2024; Tan, 2024). These benefits contribute to the growing acceptance of AI as a supportive educational tool.

Despite these advantages, concerns remain regarding overreliance on AI, potential biases in generated content, and the possible decline of critical thinking skills. As a result, the

integration of AI into education requires a balanced approach that combines technological innovation with ethical responsibility and critical engagement.

Recent contributions published in AIJES also emphasize the role of digitalization and AI in education, particularly in relation to student performance, ethical considerations, and the transformation of learning environments (Popescu & Ionescu, 2022; Marinescu, 2023; Stoica & Radu, 2021).

Large language models (LLMs) are based on advanced deep learning techniques and enable natural language generation and automated responses. The development of AI, particularly LLMs, has significantly reshaped education by enabling new forms of interaction, access to information, and support for learning.

The primary purpose of using LLMs in educational settings is to enhance learning efficiency, increase student motivation, and provide a personalized learning experience tailored to individual needs. LLMs can analyze large volumes of data and deliver relevant information aligned with specific learning objectives and student requirements. Moreover, they enable the simulation of various scenarios and discussions, helping students develop critical thinking and argumentation skills.

The development of LLMs has also prompted reflection on the ethical aspects of AI use, such as privacy protection, autonomy, and responsibility within educational processes. Ethics in the use of LLMs is becoming a key component of research and implementation, as educational institutions and researchers face the challenge of ensuring responsible usage and preventing potential misuse.

However, the rapid adoption of AI tools also raises concerns regarding overreliance and the potential decline of critical thinking skills.

Several studies have already been conducted on the use of LLMs for educational purposes. Ipek (2023), for example, examined the impact of AI, specifically ChatGPT, on educational systems, highlighting both the potential benefits and challenges this technology brings to academic environments. The study identified positive effects of integrating ChatGPT in education, as well as ethical concerns regarding academic integrity, due to risks of plagiarism and issues related to the bias and accuracy of the generated content. The study also proposed further steps for research and implementation of this technology in educational processes, emphasizing the importance of collaboration between researchers, developers, and policymakers in setting policies that address both the opportunities and risks associated with LLMs (İpek, 2023).

These findings are consistent with previous research, suggesting a broader trend of increasing reliance on AI tools across educational contexts.

In his study, Fitria (2021) focused on the use of AI and its impact on the educational process, particularly on how AI tools support and enhance education. AI technologies, such as virtual mentors, voice assistants, smart content, presentation translators, and more, enable more advanced methods of teaching and learning. According to research, AI allows for personalized learning, automatic assessment, and intelligent learning systems that adapt materials and evaluation to students' skills and needs. The study emphasizes that AI cannot replace human teachers, who are essential for developing social skills, empathy, and moral values. Nevertheless, AI enables teachers to focus on more creative and less routine aspects of teaching, as technological tools can take over repetitive tasks. A balanced approach is highlighted, where technology acts as a support, not a substitute, for human interaction (Fitria, 2021).

Gao (2022) highlights the role of AI in improving distance education through enhanced interaction and access to learning resources.

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The problem addressed in this article is the use of LLMs in the education of students in both secondary and higher education. Among other capabilities, LLMs enable fluent text generation, support in creative writing such as seminar papers and homework, responses to questions across various educational topics, though the accuracy of information remains questionable. Factchecking, translation capabilities, and educational uses that provide sources of information and learning tools are also part of the focus. The study also investigates respondents' views on ethics, data protection, bias, the impact on academic success, and, ultimately, time-saving potential. Based on the reviewed literature, this study focuses on key dimensions of AI use in education, including usage patterns, trust and verification behaviour, ethical considerations, data protection, and perceived efficiency. These dimensions form the basis for hypotheses H1–H7.

3 Methodology, Research Sample and Limitations

Data for the study were collected via an online survey conducted in Slovenia between May 31, 2024, and October 18, 2024. A total of 120 respondents participated, providing insights into the use of AI in educational environments. Participants were recruited through email, social media platforms, and various online forums. For data analysis, we used the statistical software IBM SPSS, which allows for detailed analysis and visualization of results.

Out of the 120 participants, 110 provided valid data on gender: 42 were male (38.2%) and 68 female (61.8%), while gender data were missing for 10 participants (8.3%), comprising the full sample. Secondary school students made up 42.5% (51 individuals), university students 51.7% (62 individuals), and the category "other" 5.8% (7 individuals). The largest group in the sample consisted of university students, followed by secondary school students, with a smaller proportion falling into the "other" category. Among them, 15 were full-time students (12.5%) and 47 part-time students (39.2%), while 58 respondents (48.3%) skipped the question, maintaining the total sample at 120.

Most respondents had completed secondary education (46 individuals, 38.3%), followed by 33 individuals (27.5%) with higher vocational education, 21 (17.5%) with a university degree, and 10 (8.3%) with postgraduate education. Cumulative percentages show that 90.9% of participants have attained a level of education up to higher vocational school, while 9.1% have completed postgraduate studies.

Most respondents (43 individuals, 35.8%) were in the 15–20 age group, followed by 20 individuals (16.7%) aged 31–40. The 21–25 age group included 17 participants (14.2%), and both the 26–30 and 41–50 age groups had 14 respondents each (11.7%). Only 2 individuals (1.7%) were over 50 years of age.

The inclusion of both secondary school and university students was intentional, as it enables comparison between different educational levels and provides insight into how AI tools are adopted across stages of education.

This study has several limitations. First, the sample was collected using a non-probability online survey, which may introduce self-selection bias. Second, the relatively small sample size limits the generalizability of the findings. Future research should include larger, more representative samples and combine survey data with experimental or longitudinal approaches.

4 Research Results

The results indicate that AI is widely used among respondents, with 81.7% reporting its use for educational purposes. Most participants are familiar with AI tools and demonstrate a moderate to good level of understanding.

AI is primarily used for preparing seminar papers, homework, and presentations, confirming its role as a supportive tool in everyday academic tasks. Respondents report moderate trust in AI-generated information ($M = 3.19$) and relatively frequent verification of its accuracy ($M = 3.26$), suggesting a cautious approach.

Perceived time savings are high ($M = 4.09$), indicating that AI contributes to greater efficiency in the learning process. At the same time, respondents assign high importance to data protection ($M = 4.06$), which exceeds their agreement with the ethical use of AI.

Overall attitudes toward AI are moderately positive, while opinions regarding potential restrictions or bans are divided, reflecting a balanced perception of its benefits and risks. These findings provide a general overview of AI usage patterns, which are further examined through hypothesis testing in the following sections.

4.1 Hypothesis H1 and Theoretical Background

The use of large language models (LLMs) as a tool for educational purposes has become one of the most frequently researched topics in the field of AI in education. According to data from the Digital Education Council (2024), as many as 86% of students regularly use AI in their studies, with over half using it at least once a week to assist with learning, preparing seminar papers, and reviewing material. The AIPRM (2024) study likewise confirms that 53% of students in higher education use AI for preparing study materials and assignments, reflecting its rapid integration into the academic environment. Similarly, a report by BestColleges (2024) states that 56% of students use AI for writing papers, studying, and exam preparation, confirming the trend that more than half of students already rely on tools such as ChatGPT and other LLMs as an essential part of the learning process.

The combined findings of these studies confirm that AI is becoming an indispensable educational tool, enabling students to search for information more efficiently, better understand complex content, and more effectively organize their academic tasks.

Authors Grájeda et al. (2024) further confirm the increasing use of AI among students. A study involving 4,127 students from a private university in Latin America showed that AI significantly contributes to students' academic experiences by enhancing their understanding, creativity, and productivity. The most frequently used tool was ChatGPT, valued by students for its ability to quickly provide answers and support learning. The study highlights the growing adoption of AI tools among students and emphasizes the importance of developing digital competencies for the effective and responsible use of AI in education (Grájeda, Burgos, Córdova & Sanjinés, 2024).

Based on these previous studies, we formulated and tested the first hypothesis using a frequency table.

H1: More than half of the respondents use large language models (LLMs) as a tool for educational purposes.

Table 1. Statistics on the use of AI in education

Do you use AI?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	89	74,2	81,7	81,7
	No	20	16,7	18,3	100,0
	Total	109	90,8	100,0	
Missing	System	11	9,2		
Total		120	100,0		

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The results presented in Table 1 confirm Hypothesis H1, as more than four-fifths of the respondents (81.7% of valid responses) use large language models (LLMs), or AI, as a tool for educational purposes, while 18.3% do not use such tools. This clearly indicates that AI tools are already strongly embedded in the educational process and represent an important component of the learning environment for many participants.

4.2 Hypothesis H2 and Theoretical Background

The issue of user trust in the results returned by large language models (LLMs), and whether users verify that information, is central to several recent studies. Denny et al. (2023), in their study *Can We Trust AI-Generated Educational Content? Comparative Analysis of Human and AI-Generated Learning Resources*, find that students often trust content generated by AI, rating it as comparable in quality and usefulness to learning materials produced by their peers. However, the study also warns that such trust is not always based on factchecking, which may lead to the spread of inaccurate information.

Similarly, Đerić et al. (2024), in the article *Trust in Generative AI Tools: A Comparative Study*, emphasize that trust in generative AI tools is multidimensional, grounded in perceived accuracy, safety, and the benevolence of the technology. Their findings suggest that while users mostly trust AI outputs, they frequently express critical caution and tend to verify results, particularly when dealing with complex tasks. Overall, they conclude that while trust in LLMs exists, it is not absolute. Users recognize the usefulness of these tools but maintain a level of skepticism and verification, indicating a growing responsible and reflective approach to AI use in education.

Chound et al. (2023) also addresses the issue of user trust in AI-generated data, finding that users often approach such content cautiously. Trust in AI-generated information is not guaranteed, as concerns remain regarding the reliability and accuracy of the outputs. The authors stress that trust is essential for the successful integration of AI into various domains, without a sufficient level of trust, users are unlikely to fully accept AI-generated results (Chound, David & Ross, 2023).

Based on these prior studies, we formulated the second hypothesis (H2), which was tested using a paired sample t-test.

H2: Respondents trust the information returned by large language models (LLMs) and do not verify it.

Table 2. Statistical data on the relationship between "How much do you trust the accuracy of AI data?" and "Have you ever checked the accuracy of the answers provided by AI?"

		Have you ever checked the accuracy of the answers provided by AI?					Total
		1 - I'm not checking.	2	3	4	5 - I always check.	
How much do you trust the accuracy of AI data?	1- I don't trust	5	0	0	0	3	8
	2	1	0	1	3	5	10
	3	4	5	14	18	11	52
	4	5	4	6	8	3	26
	5 - I trust a lot	1	6	2	0	1	10
Total		16	15	23	29	23	106

Table 2 presents the relationship between the level of trust in the accuracy of data provided by AI and the frequency with which respondents verify the correctness of that data. It can be observed that most respondents (52) report a moderate level of trust (score 3),

indicating a cautious and critical approach to AI-generated information. At the same time, most of these respondents also engage in verifying the accuracy of the responses provided by AI, demonstrating that trust in AI is not unconditional. Even among those with higher levels of trust (scores 4 and 5), data verification still occurs, which further reflects a careful and thoughtful use of AI. While respondents do express trust in AI, the fact that the majority still verify its outputs points to a deliberate and responsible approach to its use in the educational context.

Table 3. Descriptive statistics of the variables how much you trust AI data and whether you check its accuracy

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	How much do you trust the accuracy of AI data?	3,19	106	0,996	0,097
	Have you ever checked the accuracy of the answers provided by AI?	3,26	106	1,354	0,132

Table 3 presents the descriptive statistics for the variables “How much do you trust the accuracy of the data provided by AI?” and “Have you ever verified the correctness of the answers provided by AI?”. The average trust score is 3.19, while the average for verification behavior is slightly higher, at 3.26. This indicates that respondents have a moderate level of trust in AI but still frequently verify its answers. The standard deviation for verification (1.354) is greater than that for trust (0.996), suggesting that opinions regarding verification vary more widely, some users regularly verify AI outputs, while others do so less frequently. Overall, the participants exhibit measured trust in AI, but the fact that the mean verification score slightly exceeds the trust score suggests that users, despite trusting AI to a degree, still choose to validate the information it provides, indicating a cautious and reflective approach to its use.

Table 4. T-test of variables: how much do you trust the AI data and whether you check its accuracy?

Paired Samples Test									
		Paired Differences					t	df	Two-Sided p
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	How much do you trust the accuracy of AI data? Have you ever checked the accuracy of the answers provided by AI?	- 0,075	1,793	0,174	-0,421	0,270	-0,433	105	0,666

Table 4 presents the results of a paired samples t-test conducted to examine the difference between trust in AI-generated data and the frequency of verifying such data. The calculated difference between the means is -0.075 , indicating that verification is slightly more frequent than trust. However, this difference is not statistically significant ($p = 0.666$). The effect size (Cohen's d) is negligible ($d = 0.04$), indicating no meaningful practical difference. This means we cannot conclude that respondents either significantly trust AI more or verify it more; both behaviors occur at a similar frequency. There is no statistically significant difference between the level of trust and the frequency of verification, suggesting that individuals who trust AI more are not necessarily those who verify less and vice versa. Based on these analyses, Hypothesis H2, that respondents trust the information returned by LLMs and do not verify it, cannot be confirmed.

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Although users exhibit moderate trust in the accuracy of AI-generated information, the average values and t-test results indicate that they still verify information almost as often as they trust it. This suggests that the majority of users approach AI critically and responsibly, which is a positive indicator of awareness regarding the limitations of AI in educational settings.

4.3 Hypothesis H3 and Theoretical Background

In his article, De Fine Licht (2024) emphasizes that restricting the use of AI in higher education may have a negative impact on the educational process, primarily due to reduced access to tools that could enhance student productivity and foster the development of digital skills essential for future professional challenges. Tools such as ChatGPT and similar platforms allow students to engage in interactive learning, personalize content, and access information more efficiently, all of which can contribute to increased engagement and improved academic performance.

The author points out that limiting access to AI can hinder the development of critical skills such as critical thinking and digital literacy, which are increasingly important in today's technology-driven world. Students without access to AI may be less prepared for professional environments where the use of such technologies is becoming standard. The document also notes that AI restrictions could exacerbate inequalities among students, as those with access to private AI resources may gain advantages, while others are left behind.

In conclusion, the author argues that a complete ban on AI use is likely suboptimal, as it deprives students of key educational benefits that AI tools can offer and may cause them to fall behind in preparing for technologically advanced careers (De Fine Licht, 2024).

Based on these findings, we formulated Hypothesis H3, which was tested using a frequency table.

H3: At least 80% of respondents believe that banning the use of large language models (LLMs) would negatively affect their education.

Table 5. Display of statistical data on the opinion on whether banning the use of AI in education would negatively affect learning?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1- It will not have a negative impact	15	12,5	14,6	14,6
	2	11	9,2	10,7	25,2
	3	37	30,8	35,9	61,2
	4	17	14,2	16,5	77,7
	5 - Will negatively affect	23	19,2	22,3	100,0
	Total	103	85,8	100,0	
Missing	System	17	14,2		
Total		120	100,0		

Table 5 presents the results of responses to the question: “Do you believe that banning the use of AI in education would negatively affect your learning?” Among the 103 valid responses, 22.3% of respondents selected option 5 – it would negatively affect, indicating that they believe a ban on AI would significantly harm their learning. An additional 16.5% rated the impact as 4, also suggesting negative consequences. In total, 38.8% of respondents believe that banning AI would negatively impact education. Many other responses were neutral (score 3, 35.9%), indicating moderate or undecided views, while 25.3% of respondents believed that a ban would not have a negative impact (scores 1 and 2). Based on these results, Hypothesis

H3, which predicted that at least 80% of respondents would believe that banning the use of LLMs would negatively affect their education, cannot be confirmed.

Although a portion of respondents express concern over such a ban, the percentage of those who view it as negative (38.8%) falls significantly short of the hypothesized 80%. The results show that opinions on the potential impact of banning AI in education are divided, with roughly one-third seeing negative consequences, one-third remaining neutral, and one-third perceiving little or no impact.

4.4 Hypothesis H4 and Theoretical Background

The question of how ethical responsibility influences the protection of personal data in the use of AI within educational processes is addressed by numerous contemporary authors. Huang (2023), in the article Ethics of Artificial Intelligence in Education: Student Privacy and Data Protection, emphasizes that protecting personal data is a fundamental ethical challenge in the use of AI in schools, as it requires transparent data processing and responsible handling of students' personal information.

Gujjula and Sanghera (2023), in their study Ethical Considerations and Data Privacy in AI Education, find that ethical responsibility directly affects the level of data protection. Individuals and institutions that adhere to ethical principles are more likely to implement stricter security measures and mechanisms to safeguard privacy.

Similarly, Karpouzis (2024), in AI in Education: Ethical Considerations and Insights from Ancient Greek Philosophy, stresses the importance of balancing technological advancement with ethical values. He warns that a lack of ethical awareness may lead to the misuse of personal data and a decline in trust in AI. In summary, the existing body of research consistently confirms that ethical responsibility significantly influences the degree of personal data protection. It promotes transparency, accountability, and trust in the use of AI within educational environments.

Based on the reviewed studies, we formulated Hypothesis H4, which was tested using a paired samples t-test.

H4: Ethical responsibility influences the protection of personal data.

Table 6. Statistical data on the relationship between "How important is the protection of personal data when using AI to you?" and "Do you agree that it is ethical to use AI in education?"

		Do you agree that it is ethical to use AI in education?					Total
		1 – I strongly disagree	2	3	4	5 – I completely agree	
How important is the protection of personal data when using AI to you?	1- Very unimportant	3	1	0	0	0	4
	2	1	0	1	2	0	4
	3	0	2	15	3	3	23
	4	0	0	12	8	2	22
	5 - Very important	1	7	17	16	8	49
Total		5	10	45	29	13	102

Table 6 illustrates the relationship between the perceived importance of personal data protection in the use of AI and the level of agreement regarding the ethical use of AI in education. The results show that most respondents (49 out of 102) consider the protection of personal data to be very important (rating 5). Among these, a large proportion (17 + 16 + 8 = 41 individuals) agree or strongly agree that ethical use of AI in education is important. Only a

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small number of respondents rated the importance of data protection low (ratings 1 and 2), and these were predominantly among those who disagreed with the importance of ethical AI use.

Overall, the results suggest a positive relationship between the importance assigned to data protection and support for ethical AI use. However, there are some divergences, particularly among those who highly value data protection but hold mixed views on the ethical implications of AI.

Table 7. *Descriptive statistics of variables*

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	How important is the protection of personal data when using AI to you?	4,06	102	1,106	0,110
	Do you agree that it is ethical to use AI in education?	3,34	102	0,990	0,098

Table 7 presents descriptive statistics for two questions related to the use of AI in education. Respondents assign greater importance to the protection of personal data when using AI (mean = 4.06, Std. Dev = 1,106) than to the ethical use of AI in educational contexts (mean = 3.34, Std. Dev = 0,990). This indicates that privacy concerns outweigh ethical considerations for most respondents when evaluating the implications of AI in education.

Table 8. *Paired t-test of the variables how important it is to you to protect personal data when using AI and Do you agree that it is ethical to use AI in education*

Paired Samples Test									
		Paired Differences					t	df	Two-Sided p
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	How important is the protection of personal data when using AI to you? Do you agree that it is ethical to use AI in education?	0,716	1,230	0,122	0,474	0,957	5,877	101	0,000

Table 8 confirms that the observed difference is statistically significant ($t(101) = 5.877$; $p = 0.000$), indicating that respondents rate the importance of personal data protection significantly higher than the ethical use of AI in education. The effect size (Cohen's $d = 0.58$) indicates a moderate practical difference between the variables. This supports the conclusion that ethical responsibility indeed influences attitudes toward data protection.

The results of the analysis show a clear relationship between ethical responsibility and attitudes toward safeguarding personal data. Although respondents assign greater importance to privacy and data security than to the ethical dimension of AI use, the statistically significant difference ($p = 0.000$) confirms that these areas are perceived distinctly. Still, it is evident that higher ethical awareness promotes greater attention to data protection. Therefore, Hypothesis H4 can be confirmed.

4.5 Hypothesis H5 and Theoretical Background

The question of how the use of AI, particularly large language models (LLMs), impacts time savings in the learning process has been addressed by numerous researchers in recent years. Gupta, Kumar, and Rao (2024), in their quantitative study AI and Teacher Productivity: A Quantitative Analysis of Timesaving and Workload Reduction in Education, found that AI significantly reduces time spent by both teachers and students on administrative tasks and learning material preparation. This is largely due to automation of routine tasks and faster processing of information.

Vieriu (2024), in the article *The Impact of AI on Students' Efficiency in the Learning Process*, notes that 83.5% of students believe AI contributes to increased learning efficiency by providing faster access to knowledge, explanations, and resources, thus reducing the time needed to understand content.

Tan (2024), in *AI in Teaching and Teacher Professional Development*, also confirms that AI tools optimize the educational process and reduce teacher workload by automating repetitive tasks, allowing more time for creative and analytical work. Collectively, these studies confirm that the use of LLMs has a positive impact on time efficiency in education, contributing to greater productivity and effectiveness in the learning process. Based on these prior studies, we formulated Hypothesis H5, which was tested using a frequency table.

H5: The use of large language models (LLMs) affects time savings in the learning process.

Table 9. *Time savings when using AI in education*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1- No savings	5	4,2	4,8	4,8
	2	1	0,8	1,0	5,8
	3	25	20,8	24,0	29,8
	4	22	18,3	21,2	51,0
	5 - Big savings	51	42,5	49,0	100,0
	Total	104	86,7	100,0	
Missing	System	16	13,3		
Total		120	100,0		

Table 9 presents respondents' ratings on the extent to which AI contributes to time savings in education. Out of 104 valid responses, nearly half of the participants (49.0%) stated that the use of AI results in significant time savings, and an additional 21.2% believed AI allows for moderate time savings (rating 4). In total, more than two-thirds of respondents (70.2%) perceive AI as a time-saving tool in the learning process. Only a small portion (5.8%) felt that AI has little to no impact on time efficiency.

These results confirm Hypothesis H5, as most respondents believe that the use of large language models (LLMs) or AI positively impacts time savings during learning. Users recognize that AI tools enable faster information retrieval, easier comprehension of content, and more efficient completion of academic tasks, all of which contribute to greater productivity and better time management in the educational process.

4.6 Hypothesis H6 and Theoretical Background

Differences in the use of AI and large language models (LLMs) between university students and secondary school students have recently been the focus of various international studies. The Digital Education Council (2024), in a global survey, found that 86% of university students use AI in their studies, with more than half using such tools on a weekly basis, indicating a high degree of integration of AI into higher education environments.

In contrast, a study by the Lumina Foundation (2024), conducted among high school students, revealed that while nearly half of secondary school students already use AI for school tasks, 62% believe their teachers either disapprove of or prohibit its use. These findings suggest that while LLM use is present in secondary education, it is often limited by institutional policies and a lower level of understanding of such tools.

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Additionally, the systematic review AI in Higher Education: The State of the Field (2023) confirms that AI has already been recognized in higher education as a tool for improving efficiency, personalizing learning, and fostering digital competence. In contrast, similar studies in secondary education remain limited or underdeveloped.

The combined findings of these studies indicate that university students use LLMs for educational purposes more frequently and extensively than secondary school students, due to both greater autonomy in learning and the more open approach of higher education institutions toward AI adoption. Based on these insights, we formulated Hypothesis H6, which was tested using a chi-square test.

H6: University students use large language models (LLMs) for educational purposes to a greater extent than secondary school students.

Table 10. *Chi-square test output, contingency table for the variables what is your status, and do you use AI?*

			What is your educational status?		Total
			Secondary School Student	University Student	
Do you use AI?	Yes	Count	39	50	89
		Expected Count	40,0	49,0	89,0
		% within Do you use AI?	43,8%	56,2%	100,0%
	No	Count	10	10	20
		Expected Count	9,0	11,0	20,0
		% within Do you use AI?	50,0%	50,0%	100,0%
Total		Count	49	60	109
		Expected Count	49,0	60,0	109,0
		% within Do you use AI?	45,0%	55,0%	100,0%

Table 10 presents the relationship between respondents' status (secondary school student or university student) and their use of AI. The results show that 89 respondents use AI, of whom 43.8% are secondary school students and 56.2% are university students.

Among those who do not use AI, the proportion of secondary school students and university students is equal (50.0% each). Although there is a slightly higher percentage of university students among AI users, the differences between the two groups are minor and do not indicate a clear trend suggesting that university students use AI significantly more often than secondary school students.

Table 11. *Pearson chi-square test result for educational status*

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	0,252	1	0,616

Table 11 shows that the result of the Pearson chi-square test ($\chi^2 = 0.252$; $p = 0.616$) is not statistically significant, as the p-value is greater than 0.05. Cramér's V = 0.048, indicating a negligible association between educational status and AI use. This indicates that there is no significant difference in the use of AI between secondary school students and university students. Based on the analysis, Hypothesis H6 cannot be confirmed.

Although university students appear to use AI somewhat more frequently than secondary school students, the difference is not statistically significant. This suggests that the use of AI for educational purposes is similarly widespread across both groups, meaning that access to and use of AI tools is not dependent on educational status.

4.7 Hypothesis H7 and Theoretical Background

The question of whether gender-based differences exist in the use of AI and large language models (LLMs) in the educational process has been explored in several recent studies.

Carvajal-Zúñiga, Franco, and Isaksson (2024) from the Norwegian School of Economics found that women, especially high-achieving female students, are less likely to use generative AI tools compared to their male peers, indicating the presence of a so-called gender gap in AI usage.

Similarly, Iddrisu, Iddrisu, and Aminu (2023), in their study conducted among university students in Ghana, analyzed gender differences in the acceptance and use of AI tools for writing. Their findings revealed no statistically significant gender differences in perceived effectiveness or willingness to use AI, suggesting that such differences may be culturally or environmentally influenced, rather than universal.

A meta-analysis conducted by researchers from Harvard Business School (2024) concluded that women are approximately 20% less likely to use generative AI than men, confirming the existence of certain disparities in the adoption and use of such technologies.

In summary, international studies indicate notable gender differences in the degree of AI usage and trust in AI, with men generally using AI more frequently, while women tend to approach it more cautiously and critically.

Based on these prior findings, we formulated Hypothesis H7, which was tested using a chi-square test.

H7: There are statistically significant gender differences in the use of large language models (LLMs) in the educational process.

Table 12. Chi-square test output – contingency table for variables gender and do you use AI?

			Gender		Total
			Male	Female	
Do you use AI??	Yes	Count	37	47	84
		Expected Count	34,1	49,9	84,0
		% within Do you use AI?	44,0%	56,0%	100,0%
	No	Count	4	13	17
		Expected Count	6,9	10,1	17,0
		% within Do you use AI?	23,5%	76,5 %	100,0 %
Total		Count	41	60	101
		Expected Count	41	60,0	101,0
		% within Do you use AI?	40,6%	59,4%	100,0 %

Table 12 presents the relationship between respondents' gender and their use of AI in the educational process. Among 101 valid responses, 84 respondents (83.2%) reported using AI. Of these users, 44.0% were male and 56.0% were female, suggesting that female respondents use AI somewhat more frequently. Among those who do not use AI, 76.5% were female and 23.5% were male, which also shows that non-users are more often women.

Table 13. Results of the Pearson chi-square test, examining the relationship between the gender of respondents and their use of AI in the educational process

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2,468	1	0,116

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Table 13 presents the results of the Pearson chi-square test used to assess the relationship between gender and the use of AI. The calculated value is $\chi^2 = 2.468$ with 1 degree of freedom, and the p-value = 0.116. Cramér's $V = 0.156$, indicating a weak association between gender and AI use. Since the p-value is greater than 0.05, the difference is not statistically significant. This means that we cannot confirm that gender significantly influences the use of AI in the educational process. Therefore, based on the analysis, Hypothesis H7 cannot be confirmed.

Although female respondents appear to use AI slightly more frequently than male respondents, this difference is not statistically significant. We can thus conclude that AI usage is independent of gender, and that both groups are relatively equally active in utilizing AI in their learning.

5 Discussion

The findings are consistent with previous studies (e.g., Digital Education Council, 2024; Vieriu, 2024), which highlight the growing role of AI in improving learning efficiency. The high level of reported time savings confirms that AI tools are increasingly perceived as effective support in the educational process.

However, unlike some studies suggesting high levels of trust in AI-generated content (Denny et al., 2023), the results of this study indicate a more cautious approach. Respondents report only moderate trust and frequently verify AI-generated information, suggesting a balanced and responsible use of these tools.

These findings are also aligned with research published in AIJES, which highlights the increasing importance of digitalization, ethical considerations, and technology adoption in educational systems (Popescu & Ionescu, 2022; Marinescu, 2023). In particular, the emphasis on data protection observed in this study is consistent with previous AIJES research addressing privacy and ethical challenges in digital education (Stoica & Radu, 2021).

The absence of statistically significant differences between university and secondary school students contrasts with expectations from prior research, which often assumes higher adoption in higher education. This finding may indicate that the use of AI is becoming more widespread and uniform across different educational levels.

The results further show that respondents place greater importance on data protection than on the ethical acceptance of AI use. This highlights the growing awareness of privacy risks and suggests that ethical considerations in AI adoption are strongly linked to concerns about personal data security.

Overall, the findings suggest that AI is already an integral part of the learning process, primarily as a supportive tool that enhances efficiency while still requiring critical evaluation by users.

From a practical perspective, these results emphasize the need for educational institutions to develop clear guidelines for the responsible use of AI, including aspects of academic integrity, data protection, and critical thinking.

This study contributes to the ongoing discussion on digitalization and AI in education by providing empirical insights into user behavior, trust, and ethical perceptions across different student groups.

Despite its contributions, the study has several limitations. The use of a non-probability online sample and the relatively small sample size limit the generalizability of the findings. Additionally, the study relies on self-reported data, which may not fully reflect actual behavior.

Future research should include larger and more representative samples, as well as comparative and longitudinal approaches, to better understand the long-term impact of AI on learning outcomes.

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THE IESBA CODE AND THE EU AI ACT: NORMATIVE GAPS AND GOVERNANCE IMPLICATIONS FOR ROMANIAN ACCOUNTANTS

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Abstract: *The IESBA Code of Ethics (2023) does not mention artificial intelligence, automation bias, or large language models. The EU AI Act (Regulation EU 2024/1689) does so, imposing binding obligations on accounting organisations deploying AI in high-risk contexts, with full implementation required by August 2026. This study maps the normative gap between these two instruments and assesses its practical consequences for Romanian accounting practitioners. The analysis combines normative comparison of the IESBA Code against the AI Act, scenario-based risk assessment calibrated to the Romanian professional market, and deductive synthesis into a governance framework, drawing on secondary empirical evidence from the Special Eurobarometer 554 (European Commission, 2024) and the AICPA & CIMA Future-Ready Finance Survey (2025). Two critical gaps have been confirmed: the objectivity principle contains no provision for automation bias, and the confidentiality principle does not address the processing of client data by third-party AI systems. Both gaps are structurally worsened in Romania, where sole practitioners are the majority, enterprise AI with contractual data protection is financially out of reach for most practices, and the fiscal legislative framework changes frequently, making LLM outputs unreliable for tax interpretation. The only point of genuine normative convergence—the human oversight requirement shared by the IESBA competence principle and AI Act Article 14—remains aspirational rather than practical, given the absence of any AI guidance from CECCAR or CAFR since August 2024. The governance framework developed in response shows that these risks can be addressed through a coordinated reading of obligations already present across the IESBA Code, the AI Act, the GDPR, and the ISA standards, without requiring new legislation.*

Keywords: *professional ethics; artificial intelligence, accounting and auditing, EU AI Act, large language models, normative gap analysis, Romania*

1. Introduction

Accounting and auditing hold a unique position among professional services: practitioners are expected to serve the public interest while competing for clients in a commercial environment. This ongoing tension is being intensified by AI in ways that the profession's ethical codes were not designed to address.

The speed of adoption makes the issue urgent. The 2025 AICPA & CIMA Future-Ready Finance Survey shows that 88% of finance leaders expect AI to become the leading technology

within two years. Large language models, in particular, have lowered the barrier to entry so significantly that tools once only available to Big Four firms are now accessible to a sole practitioner in Bacău or Cluj with a standard internet connection. This is not a distant development. It is happening now, in practices with no IT governance structure, no formal AI policy, and no professional guidance tailored to their circumstances.

The gap at the centre of this study is specific and traceable. The IESBA Code of Ethics (2023) does not mention artificial intelligence, automation bias, or large language models. Regulation (EU) 2024/1689 (the EU AI Act) does so, imposing binding obligations on organisations deploying AI in high-risk contexts, including financial services, with full implementation required by August 2026. Romanian accounting practitioners are therefore subject to a regulatory framework that their professional code has not acknowledged. CECCAR and CAFR have not issued guidance on the use of AI since the Act entered into force in August 2024.

Romania makes a particularly clear case study for exactly this reason. It is one of only three EU member states where public distrust of AI-generated outputs exceeds expressed trust, according to Special Eurobarometer 554 (European Commission, 2024). Practitioners here face heightened stakeholder scrutiny of AI-assisted advice precisely when their governance capacity is weakest. The structural features of the Romanian market, a profession dominated by sole practitioners, frequent fiscal legislative changes, and limited IT infrastructure, amplify every risk that the normative gap creates.

This paper examines that gap. The analysis rests on three components: a systematic comparison of the IESBA Code against the EU AI Act across five ethical principles; a scenario-based risk assessment calibrated to the Romanian professional context; and a deductive governance framework derived from existing normative sources, without proposing new legislation. The contribution is as much practical as it is academic: the August 2026 deadline is fixed, and the window for professional bodies to act is narrowing.

2. Literature Review

Research at the intersection of accounting ethics, AI adoption, and regulatory governance has grown considerably over the past decade, though not always in directions useful to practitioners. Much of it examines large professional services markets and treats the governance question as a future concern. This study treats it as a present one. The three subsections below map what the literature has established, where it falls short, and why each gap motivates a research hypothesis.

2.1 Professional Ethics in Accounting: What the IESBA Code Was Built For

The ethical foundation of the accounting profession is based on a simple principle: because investors, creditors, and regulators depend on financial reports to make economic decisions, the professionals who prepare and verify these reports have a public interest duty that extends beyond their obligations to any single client (Duska, Duska, & Kury, 2011). This principle has influenced professional ethics across various national traditions since the late nineteenth century.

The IESBA International Code of Ethics for Professional Accountants (2023) outlines this responsibility through five principles: integrity, objectivity, professional competence and due care, confidentiality, and professional behaviour. What sets the Code's approach apart is its reliance on professional judgment instead of rigid rules. Rather than detailing what practitioners must do in every situation, the Code requires them to identify threats to the core principles and implement safeguards that are appropriate to those threats. Power (1997) describes the institutional logic behind this framework: without independence, both in fact and appearance, the credibility of the auditing assurance function is compromised.

The Code's technology-neutral design is both a strength and a vulnerability. Neutrality allows it to survive successive waves of technological change without constant revision. Accounting has absorbed computerised recordkeeping, enterprise resource planning, and cloud-based processing without the Code being formally amended for each development (Moll & Yigitbasioglu, 2019). But technology neutrality also means the Code can remain silent on genuinely new structural risks. Brynjolfsson, Rock, and Syverson (2019) document a consistent pattern in the relationship between technological change and institutional adaptation: standards evolve after technologies become entrenched, not before. The question for this study is whether that lag is acceptable when the technology can generate outputs that appear to confer professional authority.

Canning and O'Dwyer (2016) make a more pointed observation: professional bodies are not simply slow to adapt; they sometimes have structural incentives to resist adaptation, particularly when new technologies challenge established professional jurisdictions. Whether that dynamic explains the absence of any AI-specific provision in the 2023 IESBA Code is a matter of interpretation. What is not a matter of interpretation is the content of that absence. The Code says nothing about automation bias, AI literacy requirements, or the confidentiality implications of processing client data through third-party AI systems. These are not minor technical gaps; they correspond to documented failure modes in AI-assisted professional practice.

H1: There are significant normative gaps between the provisions of the IESBA Code and the ethical challenges associated with the use of artificial intelligence in accounting practice.

2.2 Large Language Models in Accounting: What They Can Do and Where They Break Down

AI technologies have been incorporated into accounting and auditing for some time. Early applications focused on transaction processing and anomaly detection. What has changed with large language models is qualitative: these systems can produce natural-language outputs that resemble professional analysis (Sutton, Holt, & Arnold, 2016; Kokina & Davenport, 2017). They can draft audit documentation, summarise regulatory texts, and generate preliminary financial risk assessments. Major professional services firms have deployed them in contract analysis, tax advisory, and compliance work. The capabilities are real.

The limitations are equally real and professionally more consequential. Bender et al. (2021) argue that the errors LLMs produce are not random: they arise from the probabilistic nature of language generation, which means a model can produce a confident, coherent, syntactically correct statement that is factually wrong. Bommasani et al. (2021) extend this to foundation models generally, noting that statistical correlation with training data is not the same as logical reasoning. For accounting and auditing - fields that involve interpreting specific regulatory provisions that change frequently - the temporal constraint on training data compounds this: a model trained before a fiscal amendment was enacted will apply the pre-amendment rule without signalling any discrepancy.

These limitations become professionally dangerous when they interact with automation bias. Parasuraman and Manzey (2010) define this as the tendency to over-reliance on automated system recommendations, particularly when those systems appear authoritative. The effect is not confined to inattentive users: Cummings (2004) found that experienced operators supervising automated systems accept machine-generated recommendations without independent verification at rates that would be considered unacceptable in purely human decision chains. In auditing, the stakes are specific. Professional scepticism - a questioning mindset toward the evidence being evaluated - is a core requirement under ISA 200. An auditor who treats AI-generated going concern analysis as a reliable baseline rather than a starting

point for independent assessment is not applying professional scepticism; they are outsourcing it.

What makes this a governance problem rather than simply a training problem is that practitioners currently receive no guidance on where the line falls. Eilifsen et al. (2020) show that adoption of audit data analytics is accelerating, but the methodological and ethical protocols for integrating these tools into audit judgment have not kept pace.

H2: The use of large language models in accounting and auditing generates identifiable ethical risks that existing professional standards do not adequately address.

2.3 The EU Regulatory Framework: What the AI Act and GDPR Actually Require

The EU AI Act (Regulation EU 2024/1689) classifies AI systems by risk level. Systems posing minimal risk face few obligations; those in the high-risk category must comply with requirements for risk management, data governance, transparency documentation, and human oversight. The categories in Annex III that bear on accounting include systems used in credit risk assessment and financial decision support. Whether a specific deployment falls within scope requires a fact-specific analysis, but accounting firms using AI to support audit risk assessment or going concern conclusions have reasonable grounds to treat themselves as within scope.

The compliance picture is complicated by the interaction between the AI Act and the GDPR (European Parliament and Council of the European Union, 2016). Veale and Zuiderveen Borgesius (2021) note that the two instruments use different analytical frameworks and do not always resolve into a single clear obligation. The GDPR's Article 5 principles of lawful processing, purpose limitation, and data minimisation apply to the personal data within AI inputs; the AI Act's Article 9 risk management obligations apply to the system itself. For a practitioner using a consumer-grade LLM to process client financial data, both frameworks apply simultaneously. The GDPR question is whether processing is lawful and whether data is adequately protected; the AI Act question is whether the system constitutes a high-risk deployment and whether the required governance structures are in place. In a sole practitioner context, neither question has an obvious answer.

Black (2008) describes the compliance difficulty that arises when multiple institutional frameworks with different logics apply to the same activity. That is precisely the situation Romanian accounting practitioners face: the IESBA Code, the GDPR, and the AI Act all apply, and none of them was designed with the others in view. Floridi et al. (2018) argue that the core principles of responsible AI governance - transparency, accountability, and human oversight - are not inventions but are dispersed across existing frameworks. What the profession lacks is a reading of those frameworks that coordinates them into practical guidance. This is what the third hypothesis tests.

H3: Existing professional and regulatory standards provide sufficient normative foundations to develop best-practice principles for the ethical governance of artificial intelligence in the accounting profession.

The three subsections above share a common analytical structure. Rapid AI adoption is colliding with an ethical framework built for human judgment exercised by human practitioners. The EU regulatory architecture has moved faster than professional standard-setting bodies. The result is a practitioner population subject to binding legal obligations that their professional code has not acknowledged.

3. Methodology

This study does not collect primary data. That is not an evasion of empirical responsibility; it is a choice that follows from the nature of the research question. Normative gaps between two regulatory instruments cannot be measured through surveys or field

experiments. They can only be identified by carefully reading the instruments and mapping what each requires against what the other provides. The methodology is therefore qualitative and sits within the tradition of doctrinal legal-ethical analysis, adapted here for the space where professional accounting standards and AI regulation overlap (Black, 2008; Veale & Zuiderveen Borgesius, 2021).

The analysis proceeds in three components, each applied in sequence and addressing one of the research hypotheses. The logic of the sequence matters: the first component identifies what is missing from existing standards; the second component asks what professional harm those gaps produce in practice; the third component tests whether those harms can be addressed within what already exists.

The first component compares the IESBA Code of Ethics (2023 edition) with the obligations set out in Regulation (EU) 2024/1689. The IESBA Code was chosen as the professional anchor because it forms the normative foundation that both CECCAR (2023) and CAFR (2023) have adopted for Romanian practitioners. The EU AI Act was chosen as the regulatory counterpart because, from August 2026, it imposes binding obligations on any organisation deploying high-risk AI systems within the EU, and several of its Annex III categories are directly relevant to accounting and audit work. The comparison uses the five fundamental principles of the IESBA Code (integrity, objectivity, professional competence and due care, confidentiality, and professional behaviour) as the primary analytical categories. For each principle, the corresponding provisions of the AI Act were identified and classified according to three possible outcomes: full normative convergence, partial coverage leaving residual gaps, or an absence of any corresponding provision. This classification draws on the methodology developed in comparative regulatory analysis (Black, 2008), modified to handle the asymmetry between a principles-based ethical code and a risk-based legislative instrument.

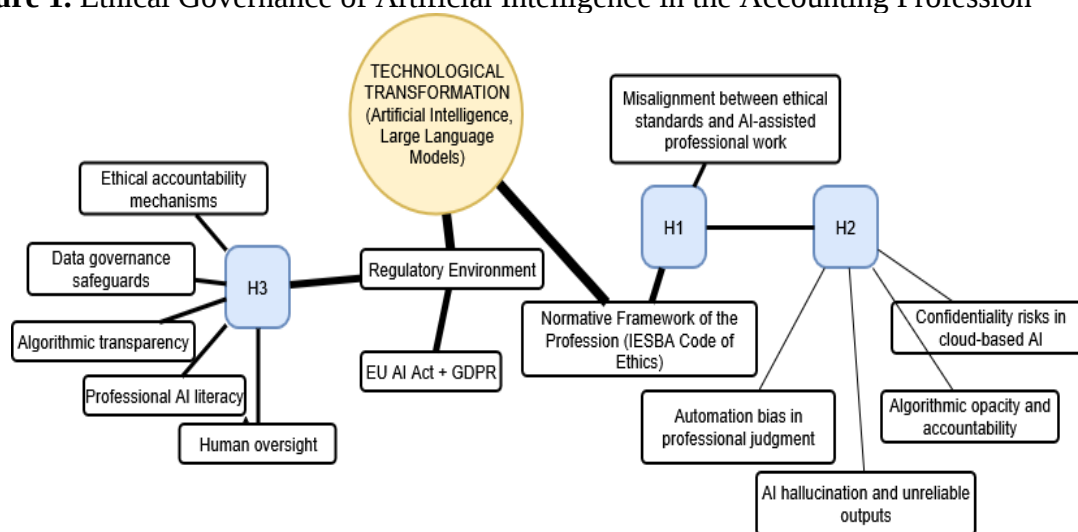
The second component translates the gaps identified in the first into practice-level ethical risks. Three scenarios were constructed, each tied to a specific normative gap and each calibrated to the structural conditions of the Romanian professional market. Selecting scenarios by these two criteria simultaneously, correspondence to a normative gap and fit with the Romanian context, was deliberate. The point was not to illustrate generic AI risks but to test whether the gaps identified in Component 1 produce concrete, foreseeable harm in the specific environment the study claims to address. The Romanian professional market is characterised by a high proportion of sole practitioners, limited IT governance capacity, and frequent legislative changes, as documented in the DESI 2024 Country Report (European Commission, 2024a) and the CAFR Annual Report (CAFR, 2023). Each scenario was evaluated on two dimensions: the probability of occurrence and the severity of the ethical impact. Probability estimates draw on secondary empirical data, specifically the Special Eurobarometer 554 (European Commission, 2024b) and the AICPA & CIMA Future-Ready Finance Survey (2025), rather than on field research. This is an acknowledged limitation, returned to at the end of this section.

The third component constructs a governance framework through deduction from existing normative sources. The working hypothesis throughout this component is that if effective governance can be built from what already exists, the argument for entirely new regulation is weakened and the path to implementation is shorter. The framework is organised across four levels (technical, individual, organisational, and normative), with each level grounded in a specific existing instrument. The technical level draws on GDPR data governance provisions; the individual level on ISA 200 and the IESBA competence principle; the organisational level on ISA 570, ISA 220, and EU AI Act Article 9; the normative level on the AI Act's AI literacy and transparency obligations. The framework does not invent new obligations; it clarifies and coordinates those to which Romanian practitioners are already subject.

Three limitations bound the study's scope. The analysis is specific to the Romanian professional context: its conclusions about structural risk amplification may not transfer directly to larger or more institutionally homogeneous EU markets. The absence of primary data means that probability estimates in the risk assessment reflect informed analytical judgement rather than statistically validated findings; they are presented as such and are not used to make causal claims. Finally, the normative analysis reflects regulatory texts as of early 2025. Subsequent guidance from the IESBA or the European AI Office could partially address the gaps identified here, thereby affecting the empirical relevance of the findings without invalidating the analytical framework.

Figure 1 maps the three analytical relationships developed in this section and the logic through which they connect to the findings presented in Section 4.

Figure 1. Ethical Governance of Artificial Intelligence in the Accounting Profession



Source: Own creation

4. Results and Discussion

Romanian accounting practitioners are already subject to binding AI governance obligations under the EU AI Act. Their professional code says nothing about those obligations. The gap is not theoretical: it corresponds to failure modes that are demonstrably probable in the structural conditions of the Romanian market, and it is addressable without new legislation. The sections below detail each of these claims.

The quantitative evidence that contextualises the analysis comes from two sources. The Special Eurobarometer 554 found that 84% of EU citizens expect careful management of AI in professional contexts. The AICPA & CIMA Future-Ready Finance Survey (2025) found that 8% of accounting organisations report being adequately prepared to provide it. That 80-percentage-point gap is the governance deficit this study addresses. In Romania, it is sharpened further by the national Eurobarometer subsample, which records net public distrust in AI outputs, a pattern found in only three EU member states. Practitioners here face closer stakeholder scrutiny of AI-assisted work than most of their EU counterparts, even as their governance infrastructure is among the thinnest in the bloc.

4.1 Normative Gap Analysis: IESBA Code versus EU AI Act

The comparison of the IESBA Code (2023) against Regulation (EU) 2024/1689 yields an unambiguous result: one principle aligns with AI Act obligations, two have partial coverage, and two have none. Table 1 maps the full picture.

Table 1. IESBA Code vs. EU AI Act: Normative Gap Analysis with Romanian Context

IESBA Principle	Relevant EU AI Act Provision	Alignment Status	Key Ethical Gap / Implication for Practitioners
Integrity (Section 111)	Art. 13 – Transparency for high-risk AI	Partial	The Code requires honest disclosure but provides no mechanism to identify or communicate errors originating in AI-generated outputs. For Romanian practitioners advising SMEs on AI-generated financial summaries, this creates an unaddressed accountability gap.
Objectivity (Section 112)	Art. 9 – Risk management; Recital 47 – Algorithmic bias	Gap	The Code does not address automation bias - the empirically documented tendency to over-rely on algorithmic outputs. This gap is structurally exacerbated in Romania by low AI literacy and frequent fiscal and legislative changes, which increase the likelihood that an LLM produces plausible yet outdated output.
Professional Competence and Due Care (Section 113)	Art. 4 – AI literacy; Art. 14 – Human oversight	Convergent	Both frameworks require human oversight and AI literacy. The convergence is normatively sound but operationally incomplete: no AI literacy programme has been adopted by CECCAR or CAFR, and over 60% of active members operate in sole-practitioner or micro-firm settings without structured CPD on technology.
Confidentiality (Section 114)	Art. 10 – Data governance; GDPR Art. 25 – Data protection by design	Gap	The Code prohibits disclosure of client information but predates third-party AI processing. In Romania, where enterprise AI solutions remain cost-prohibitive for most practices, the default workflow relies on consumer-grade LLM tools, a confidentiality exposure that neither the Code nor national professional standards explicitly address.
Professional Behaviour (Section 115)	Art. 22 – Prohibited AI practices; Art. 6 – High-risk AI classification	Partial	Deploying high-risk AI without adequate controls may create regulatory liability under the AI Act, effective from August 2026, thereby constituting a new dimension of professional misconduct. Romanian practitioners supervised by ANAF and ASF face compounded exposure from the parallel operation of the GDPR, national fiscal regulations, and the upcoming AI Act obligations.

Source: Authors' own elaboration based on IESBA Code (2023) and Regulation (EU) 2024/1689. Legend: Gap = no normative coverage; Partial = incomplete or indirect coverage; Convergent = substantively aligned. Romanian context annotations added by the authors.

The one genuine point of normative agreement is professional competence and due care, where both frameworks converge on the human-in-the-loop principle. That convergence is a useful foundation for future standards development, but it currently exists only on paper: CECCAR and CAFR have issued no guidance on AI since the Act entered into force in August 2024, and the 60%-plus share of practitioners in sole-practitioner settings without structured CPD access means the agreement has not been operationalised.

The objectivity and confidentiality gaps are the most consequential, and both are sharpened by conditions specific to Romania. The confidentiality problem is not primarily about carelessness. Enterprise AI with contractual zero-retention data clauses is financially out of reach for most Romanian sole practitioners, so the practical default is a consumer-grade LLM. Uploading client financial records to a publicly accessible platform breaches Section

114 of the IESBA Code, yet neither the Code nor any national guidance explicitly addresses this scenario. The objectivity problem has a different mechanism. Three major Fiscal Code amendment packages passed in Romania in 2023-2024 alone. A large language model trained on historical data cannot reliably interpret the current Romanian fiscal framework. An auditor who treats that model's output as authoritative is not exercising professional scepticism; they are substituting a systematically miscalibrated tool for their own judgement.

Taken together, the gap analysis confirms H1: two critical normative gaps are present, two principles offer partial coverage, and one genuinely aligns with existing AI Act obligations. Both confirmed gaps are structurally aggravated by Romanian market conditions.

4.2 Ethical Risk Assessment: LLM Deployment in the Romanian Context

The normative gaps identified above are not abstract. Each one corresponds to a foreseeable professional failure, and the structural conditions of the Romanian market make each failure more likely than the EU baseline would suggest. Three scenarios, assessed in Table 2, make this concrete.

Table 2. Ethical Risk Matrix: LLM Deployment Scenarios with Romanian Context

Scenario	IESBA Principle / ISA at Risk	Ethical Violation	Probability	Severity	Romanian Context - Aggravating Factors
A: Automation Bias in Going Concern Audit	Objectivity (S.112); ISA 570; ISA 200 §15	Negligent reliance on AI predictions; suppression of professional scepticism	High	Critical	Romanian SME clients often lack structured financial reporting histories; AI models trained on Western corporate datasets may produce systematically biased going concern outputs for this segment.
B: Client Data Uploaded to Public LLM	Confidentiality (S.114); GDPR Art. 25; EU AI Act Art. 10	Breach of confidentiality; client data potentially retained in third-party training infrastructure	High	High	Enterprise AI with data protection clauses is cost-prohibitive for most Romanian sole practitioners. The gap between professional obligation and financial capacity is not addressed by existing standards.
C: LLM-Based Tax Law Interpretation	Competence and Due Care (S.113); EU AI Act Art. 4	Substitution of professional competence; advice based on unverified AI output in a high-frequency legislative change environment	High	High	Romania averages multiple significant amendments to the fiscal code per year. LLMs trained on static datasets are structurally incapable of reflecting the current fiscal legal framework.

Source: authors' own elaboration. Probability and severity were assessed against the IESBA Code (2023), the ISA standards, the EU AI Act (2024), and the Romanian fiscal legislative framework. High probability = likely to occur in routine practice conditions without specific preventive governance.

Scenario A involves an audit engagement where an AI-based predictive model assigns a 98% confidence rating to a client's financial stability, leading the audit team to reduce substantive testing and omit risk disclosures. The client subsequently entered insolvency because early distress indicators were underweighted by the model and not independently

verified. The ethical violation is the suppression of professional scepticism under ISA 200 §15 and the failure to apply the going concern evaluation required by ISA 570. The Romanian dimension matters here because a substantial part of the SME client base of Romanian accounting practices has irregular financial reporting histories, high cash transaction volumes, delayed fiscal declarations, and structural reliance on ANAF payment deferrals. AI going-concern models trained on structured corporate data from Western European markets are poorly calibrated for this segment, meaning that high-confidence outputs carry a systematically higher error rate than the stated figure suggests. An auditor who accepts it without sector-specific judgement is misled by its apparent precision.

Scenario B involves a practitioner who, under deadline pressure, uploads a client's complete trial balance and revenue journals to a publicly accessible AI platform without prior anonymisation. The AI produces a high-quality cash flow analysis, but the client's financial data is potentially retained in the platform's training infrastructure. The cybersecurity risks associated with this type of data exposure are well-documented for AI systems (ENISA, 2023). Romania ranked 26th among 27 EU member states in the DESI 2024 digital connectivity dimension, which, in practice, pushes many practitioners toward consumer tools on personal devices while keeping enterprise platforms financially out of reach. CECCAR and CAFR have issued no guidance on permissible AI tools since August 2024. Practitioners are therefore exposed to disciplinary risk for conduct that their professional bodies have neither prohibited nor regulated, nor explained.

Scenario C concerns a practitioner who provides tax planning advice on the basis of an LLM's interpretation of a recently amended fiscal regulation, without cross-referencing the current Official Gazette text. The probability is assessed as high specifically for Romania, elevated from the medium EU baseline, because the Fiscal Code was substantively amended three times in 2023-2024 and the fiscal procedural code was modified multiple times by emergency ordinance in the same period. The static training data of current LLMs render them structurally unreliable for Romanian fiscal interpretation, not because of general tendencies toward hallucination (Ji et al., 2023), but because the legal framework itself has changed materially since the training datasets were compiled. Most consumer-grade AI tools do not disclose their knowledge cutoff, so practitioners cannot assess the currency of the interpretation they receive. That is a systemic risk, not an individual error.

Each scenario receives a high probability assessment. The Romanian specificity analysis shows that the EU risk baseline underestimates practitioners' exposure under these structural conditions: fiscal legislative frequency in Scenario C, cost barriers to enterprise AI in Scenario B, and SME data quality limitations in Scenario A, each of which functions as an independent risk amplifier. H2 is confirmed.

4.3 A Four-Level Governance Framework for Ethical AI in Accounting

The risk assessment and the gap analysis converge on a finding that is less obvious than it looks: the obligations needed to govern AI use in Romanian accounting practice already exist. They are dispersed across the IESBA Code, the EU AI Act, the GDPR, and the ISA standards, and they have not been read together. The framework in Table 3 does that reading. It requires no new primary legislation, only targeted professional guidance from CECCAR and CAFR.

Table 3. Proposed Four-Level Governance Framework for Ethical AI in Accounting Practice

Level	Actor	Recommended Action (DO)	Risk to Avoid (DON'T)	Normative Anchor	Romanian Priority
Technical	Firm Practice	Deploy enterprise AI with contractual zero-retention	Use free, consumer-grade LLM tools for	GDPR Art. 25; IESBA S.114; EU	Critical - the majority of Romanian practices

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Level	Actor	Recommended Action (DO)	Risk to Avoid (DON'T)	Normative Anchor	Romanian Priority
		clauses and audit trails for all AI-assisted outputs	processing client financial data	AI Act Art. 10	currently rely on consumer tools
Individual	Accountant	Treat AI output as secondary opinion; validate against Official Gazette and primary sources; maintain professional scepticism before signing	Delegate professional judgement to an algorithm or accept AI-generated tax interpretations without verification	IESBA S.113; ISA 200 §15; EU AI Act Art. 14	High — fiscal change frequency makes validation mandatory, not optional
Organisational	Management	Apply four-eyes principle for AI-assisted material judgements; log AI usage in audit documentation; maintain override capability	Allow AI to substitute human sign-off on financial statements, audit opinions, or significant tax advice	ISA 570; ISA 230; EU AI Act Art. 9; IESBA S.115	Medium — applicable to CAFR audit firms; low adoption likely in micro-practices
Normative	IESBA / CECCAR / CAFR	Update standards: (i) AI literacy as a competence component; (ii) verification obligations for AI-assisted judgements; (iii) explainability duty; (iv) proportionate guidance for small practices	Maintain a technology-neutral stance that leaves practitioners without specific guidance on AI-related confidentiality and competence obligations	EU AI Act Art. 4; IFAC Tech Agenda 2024; IESBA revision cycle	Urgent — CECCAR/CAFR have not issued any guidance on AI since the AI Act's entry into force

Source: authors' own elaboration based on IESBA Code (2023), EU AI Act (2024), ISA standards, and the empirical evidence reviewed in Sections 4.1 and 4.2. The Romanian priority column reflects the urgency of each measure, given the structural conditions of the Romanian market.

The technical level establishes a distinction that existing regulation supports but the profession has not enforced: enterprise AI deployments with contractual data protection and audit-trail requirements are compatible with professional confidentiality obligations; consumer-grade tools are not, regardless of output quality. Formalising this through a CECCAR or CAFR binding standard would require no new primary legislation, only a reinterpretation of Section 114 in light of the AI Act's data governance provisions.

The individual level translates professional scepticism toward AI into a specific procedural norm: AI-generated outputs are treated as secondary opinions that require validation before being incorporated into professional advice or audit documentation. This norm is already grounded in ISA 200 §15 and Article 14 of the EU AI Act. In Romania, a specific elaboration is required for fiscal queries: the validation protocol must include an explicit cross-reference to the current Official Gazette text, given the currency risk documented in Scenario C. The standards do not need amendment. They need an application.

The organisational level extends the four-eyes principle embedded in ISA 220 to all material AI-assisted professional judgements, including going concern assessments, significant accounting estimates, and tax advisory outputs with material client exposure. Logging AI usage

in audit documentation provides an evidentiary basis for professional liability assessment and aligns with Article 13 transparency obligations. For CAFR-supervised firms, this is operationally feasible and normatively overdue.

The normative level identifies four specific updates required in the IESBA Code. Explicit recognition of AI literacy as a component of professional competence would require CECCAR and CAFR to develop structured CPD programmes. Minimum verification requirements for AI-assisted judgements, calibrated to risk level, would close the operationalisation gap identified in Section 4.1. Clarifying confidentiality obligations by naming third-party AI processing directly would address Scenario B. An explainability duty - the obligation to understand and communicate the basis of any AI-assisted professional opinion - would address the authority problem at the root of automation bias. This agenda is consistent with the IFAC Technology Agenda (2024) and the EU AI Act's transparency provisions; it extends existing normative directions rather than replacing them. H3 is confirmed.

4.4 The accountability paradox and its implications for Romania

There is a structural tension in how AI affects professional accountability that the governance literature has not fully addressed. The features that make AI attractive to practitioners are speed, apparent consistency, and outputs that look authoritative. Those same features are what create the professional liability exposure. Speed reduces the time available for cross-validation. Apparent consistency builds trust in outputs that may be biased or outdated. Authority-looking outputs suppress the questioning mindset that ISA 200 requires. A practitioner who uses AI readily, without governance safeguards, is the practitioner most exposed to disciplinary action, not despite their efficiency but because of it.

Romania sits at the unfavourable end of this problem within the EU. The 80-percentage-point gap between the share of EU citizens who expect careful management of AI in professional contexts (84%, European Commission, 2024b) and the share of accounting organisations that report being adequately prepared to provide it (8%, AICPA & CIMA, 2025) is a European-level structural issue, but it is most pronounced in markets where trust in AI is lowest. Romanian clients and stakeholders scrutinise AI-assisted professional advice more closely than the EU average, precisely because net public distrust in AI outputs is documented in the national Eurobarometer data. Practitioners in high-trust markets can use AI to improve efficiency with lower accountability risk. Romanian practitioners face higher accountability expectations at the exact point when their governance infrastructure is thinnest. That is not an argument against using AI; it is an argument for getting the governance right before August 2026.

The structural conditions make this urgent. The Romanian profession operates amid frequent fiscal and legislative changes, with AI-related obligations split among ANAF, CAFR, and ASF in ways that are not yet harmonised. The August 2026 deadline for full AI Act compliance will arrive before most Romanian practitioners have received any profession-specific guidance on what it requires of them. The period between August 2024, when the Act entered into force, and August 2026 is the practical window for CECCAR and CAFR to act. A joint technical opinion on permissible AI tools in accounting and auditing, aligned with the four governance levels in Table 3, requires no new legislation and would directly address the three scenario risks confirmed in Section 4.2. Romanian accountants will enter August 2026 either with that guidance or without it. That is not a hypothetical risk; it is the current trajectory.

5. Conclusions

AI governance in accounting is not primarily a technology problem. It is an institutional one, and the institution that needs to act most urgently is the professional standard-setter.

The central finding of this study is specific: the IESBA Code of Ethics, in its 2023 edition, leaves Romanian accounting practitioners without professional guidance on two categories of risk that are already materialising in practice. The objectivity principle contains no provision for automation bias, despite decades of empirical literature showing that experienced professionals systematically over-rely on outputs from systems that appear authoritative. The confidentiality principle was written before client data could be processed through third-party AI infrastructure, and it has not been updated to address that reality. These are not edge cases or theoretical concerns. They correspond to concrete, high-probability failure scenarios in a professional market where sole practitioners are the majority, enterprise AI with contractual data protection is financially out of reach for most practices, and the fiscal legislative framework changes faster than most large language models can track.

The one point where the IESBA Code and the EU AI Act genuinely converge is professional competence and due care, both of which require human oversight of automated decision-making. That convergence is normatively meaningful but currently aspirational rather than operational: CECCAR and CAFR have issued no guidance on AI since the Act entered into force in August 2024, and the majority of active members in Romania operate in settings without structured continuing professional development on technology.

The governance framework proposed in this study does not require new regulatory instruments. It requires a coordinated reading of obligations that already exist across the IESBA Code, the EU AI Act, the GDPR, and the ISA standards, translated into practical guidance by the professional bodies authorised to issue it. The framework's central argument is that CECCAR and CAFR can close the most consequential gaps identified in this study, specifically the consumer-tool confidentiality exposure and the fiscal currency risk in AI-assisted tax interpretation, through a professional standard or joint technical opinion that reinterprets existing obligations in light of the AI Act. No new primary legislation is required. What is required is a decision to act before August 2026.

Theoretical contribution

The study contributes to the literature on AI governance in professional services in two respects. First, it demonstrates that jurisdiction-specific structural conditions, in this case, the composition of the Romanian professional market, the frequency of fiscal legislative change, and Romania's position as one of three EU member states with net public distrust in AI outputs, materially alter the risk profile of AI adoption beyond what EU-level governance assessments capture. EU-average risk assessments understate practitioners' exposure in markets with these structural characteristics. Second, the deductive framework developed here offers a replicable methodology for mapping AI governance obligations across multiple overlapping regulatory instruments without requiring primary empirical data, which makes it applicable to other EU professional markets facing similar regulatory fragmentation.

Limitations

Three boundaries constrain the study's conclusions. The analysis is calibrated to the Romanian professional context, and its findings about risk amplification may not transfer directly to larger or more institutionally homogeneous EU markets. The absence of primary data means that the probability assessments in the risk matrix reflect informed analytical judgement grounded in secondary empirical evidence rather than statistically validated field measurements. And the normative analysis reflects the regulatory texts as of early 2025; guidance subsequently issued by IESBA or the European AI Office could partially narrow the gaps identified here, thereby affecting the urgency of the recommendations without invalidating the analytical framework.

Future research directions

The framework developed here needs empirical grounding before any of its elements can be proposed as the basis for a binding national professional standard. A structured questionnaire administered to certified public accountants in Romania would enable direct measurement of current AI adoption patterns, self-assessed AI literacy, and any governance practices practitioners already apply to AI-assisted work. That quantitative baseline matters because the secondary data used in this study, the Eurobarometer subsample and the AICPA/CIMA survey, measure attitudes and organisational preparedness at a level of aggregation that cannot confirm whether the failure modes described in Scenarios A, B, and C are occurring in Romanian practice or merely plausible given structural conditions. Qualitative interviews with audit partners, compliance officers, and representatives of CECCAR, CAFR, and the Romanian Financial Supervisory Authority would add stakeholder grounding and expose implementation barriers that a normative analysis cannot anticipate. Longitudinal research tracking governance practice adoption as the AI Act's obligations become progressively enforceable would then allow an empirical test of the study's central institutional claim: that professional standard-setting bodies, not technology developers or regulators, are the decisive actors in closing the governance gap before it produces the professional and reputational consequences that the accountability deficit between societal expectation (84%, European Commission, 2024b) and organisational preparedness (8%, AICPA & CIMA, 2025) makes predictable..

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EMPLOYEE WELLBEING, CUSTOMER SATISFACTION AND ORGANIZATIONAL PERFORMANCE: AN INTEGRATED MIXED-METHODS ANALYSIS

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Abstract: *Employee wellbeing has emerged as a critical factor linking internal organizational dynamics with external market outcomes, particularly in shaping customer satisfaction and loyalty in contemporary management contexts. This article examines the extent to which employee wellbeing functions as a strategic driver of customer-related outcomes, addressing the research problem of whether it can be considered a key determinant of customer trust and long-term loyalty. The main objective of the study is to analyse how employee wellbeing—as a multidimensional construct encompassing engagement, motivation, and work experience—translates into measurable customer satisfaction and loyalty within an integrated empirical framework. The study adopts a mixed-methods approach, combining qualitative analysis of international secondary datasets (Gallup, Deloitte, Eurofound, PwC) with quantitative primary data collected through a survey of 162 employees across different sectors. The findings indicate a strong positive association between employee wellbeing and customer satisfaction, suggesting that higher levels of engagement, organizational support, and work–life balance are associated with improved customer trust and loyalty. The results highlight the strategic importance of investing in employee wellbeing as a driver of both internal performance and external competitiveness, offering valuable implications for managers seeking to enhance organizational effectiveness and sustainable business success.*

Keywords: *Employee wellbeing; Customer satisfaction; Employee engagement; Service-Profit Chain; Organizational performance*

Introduction

In an increasingly complex and competitive business environment, organizations are required to move beyond traditional performance-oriented models toward more integrated and human-centered approaches to management. Within this context, employee wellbeing has emerged as a critical factor influencing not only internal organizational dynamics but also external market outcomes. Contemporary research highlights that employees represent a key interface between the organization and its customers, and their level of wellbeing significantly shapes service quality, customer satisfaction, and long-term loyalty (Harter, Schmidt & Hayes, 2002). Accordingly, understanding the mechanisms through which employee wellbeing translates into customer-related outcomes has become an important area of inquiry. This study builds on this premise by examining the relationship between employee wellbeing and customer satisfaction within a comprehensive theoretical and empirical framework.

Contemporary Management, Marketing, and Employee Wellbeing

Contemporary management extends beyond operational coordination to a holistic and adaptive system integrating leadership, sustainability, and stakeholder orientation, evolving

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through systemic and contingency perspectives to address complex organizational and societal challenges (Kast & Rosenzweig, 1972; Carroll, 1999; Northouse, 2018; Bass & Riggio, 2006). Successful management has evolved from a purely performance-oriented concept toward a multidimensional approach that integrates long-term value creation, stakeholder orientation, and human capital development, where employee motivation and satisfaction are recognized as critical drivers of organizational effectiveness (Drucker, 1954; Freeman, 1984; Wright & Cropanzano, 2000). Building on this, contemporary research increasingly highlights that employee wellbeing is not only a determinant of internal productivity but also a key antecedent of customer satisfaction and loyalty, thereby revealing a crucial yet still insufficiently explored linkage between internal organizational practices and external market outcomes (Harter, Schmidt & Hayes, 2002). Contemporary management literature emphasizes that the integration of managerial functions and leadership capabilities—combining structural efficiency with inspiration and employee-centered approaches—is essential for fostering employee wellbeing and, consequently, enhancing organizational performance and customer satisfaction (Fayol, 1916; Kotter, 1990; Yukl, 2013; Bass, 1990).

Marketing, conceptualized as an integrated, value-creation and relationship-building process that connects organizational capabilities with customer needs, plays a strategic role in shaping customer perceptions and loyalty, while simultaneously acting as a mechanism through which internal factors such as employee wellbeing are translated into external market outcomes (American Marketing Association, 2017; Kotler & Keller, 2016; Simonović, Miletić & Miletić, 2012). Successful marketing, understood as a holistic and value-driven process that integrates customer experience, relationship-building, and internal organizational alignment, increasingly depends on employee-related factors—particularly wellbeing—as employees act as key carriers of brand value and directly influence customer satisfaction and loyalty (Kotler, 2016; McCarthy, 1960). Marketing professionals, as key actors in value co-creation and organizational–market interface, play a strategic role in translating internal organizational realities—particularly employee wellbeing—into authentic external communication and customer perceptions, thereby reinforcing trust and long-term relationships (Aleksić, 2021; Godin, 2005; Edelman, 2022).

Theoretical Foundations: Service-Profit Chain and Wellbeing as a Driver of Customer Outcomes

Human resources, as a strategic source of competitive advantage, play a dual role in fostering employee wellbeing and transmitting organizational values to customers, whereby investments in employee satisfaction and engagement directly enhance productivity, loyalty, and ultimately customer satisfaction (Barney, 1991; Harter, Schmidt & Keyes, 2003; Aleksić, 2021). The relationship between employee wellbeing and customer satisfaction is theoretically grounded in the Service-Profit Chain model, which demonstrates that investments in internal organizational climate and employee satisfaction drive service quality, customer loyalty, and ultimately superior business performance (Heskett et al., 1997; Anderson, Fornell & Rust, 1997). Employee wellbeing is a multidimensional construct encompassing physical, mental, emotional, and social aspects of work life, and prior studies show that psychologically well and engaged employees achieve higher job satisfaction, stronger performance, lower absenteeism, and more positive customer-related outcomes (Wright & Cropanzano, 2000; Harter, Schmidt & Hayes, 2002; PwC, 2021). Employee wellbeing functions as a critical driver of customer experience and loyalty, as engaged and satisfied employees demonstrate higher empathy, service quality, and relational commitment, thereby directly influencing customer satisfaction and long-term business success (Heskett et al., 1997; Harter, Schmidt & Hayes, 2002).

The effective implementation of employee wellbeing as a structured, multi-phase strategic process—encompassing needs analysis, planning, execution, and evaluation—not

only enhances employee productivity and satisfaction but also translates into improved customer satisfaction and organizational performance, confirming its role as a measurable driver of business outcomes (Robertson & Cooper, 2011; Harter, Schmidt & Keyes, 2003; PwC, 2021). The application of integrated wellbeing techniques—ranging from mental health support and flexible work arrangements to digital health tools and team-based interventions—demonstrates that systematic investment in employee wellbeing enhances engagement, reduces stress, and ultimately contributes to improved customer satisfaction and business performance (Harter, Schmidt & Keyes, 2003; PwC, 2021). Strategically aligned and systematically implemented wellbeing initiatives—supported by leadership, measurable outcomes, and continuous adaptation—are shown to enhance employee productivity and engagement while simultaneously increasing customer satisfaction and organizational profitability, positioning wellbeing as a core driver of competitive advantage (PwC, 2021; Gallup, 2020). Integrated methodological approaches that combine preventive, corrective, and motivational wellbeing practices are essential for achieving sustainable employee engagement and performance, which in turn translates into higher customer satisfaction and organizational success, confirming that no single method is sufficient without a holistic framework (Robertson & Cooper, 2011; Harter, Schmidt & Keyes, 2003; PwC, 2021).

Overall, employee wellbeing has both theoretical and practical significance as a multidimensional and strategic construct that links individual health, engagement, and organizational culture with productivity, customer loyalty, profitability, and sustainable business development (Harter, Schmidt & Keyes, 2003; Seligman, 2011; Gallup, 2020; PwC, 2021).

Scope and Research Framework of the Study

Building on prior research, employee wellbeing has been consistently established as a multidimensional and strategic organizational resource that directly influences employee engagement, performance, and, through mechanisms such as the Service-Profit Chain, customer satisfaction and organizational profitability (Heskett, Sasser & Schlesinger, 1997; Harter, Schmidt & Hayes, 2002; Wright & Cropanzano, 2000; Deloitte, 2019; Eurofound, 2021). However, despite these advances, recent research increasingly highlights the need for integrated, context-sensitive and interdisciplinary approaches that examine the bidirectional relationship between employee wellbeing and customer satisfaction—particularly within digitally transformed, sector-specific and culturally diverse environments—thereby revealing a clear research gap in linking internal employee experience metrics with external customer outcomes in a systematic and empirically grounded manner. While previous studies have predominantly examined employee wellbeing and customer satisfaction as separate constructs, fewer studies have attempted to integrate these dimensions within a single analytical framework combining international secondary datasets and regional employee perceptions. This study contributes to the literature by linking internal wellbeing indicators with customer-related outcomes through a mixed-methods approach and by providing evidence from the Southeast European context.

Accordingly, this study examines how employee wellbeing—as a multidimensional construct encompassing engagement, motivation and overall work experience—translates into measurable customer satisfaction and loyalty outcomes, thereby advancing existing models by integrating internal organizational indicators with external market perceptions within a unified empirical framework.

The central research problem addressed in this study is *whether employee wellbeing can be considered a significant determinant of customer satisfaction, loyalty, and trust, and to what extent internal employee experiences translate into external customer-related outcomes.*

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In this context, the study seeks to address the broader issue of the role of human resources and organizational culture in achieving long-term business success.

Accordingly, the research is structured around the following variables:

- the *independent variable is employee wellbeing*, encompassing physical, mental and emotional wellbeing, as well as employee motivation, engagement and job satisfaction;
- the *dependent variable is customer satisfaction and loyalty*, reflected in perceived service quality, satisfaction with the company relationship, and the propensity for long-term trust.

Based on this framework, the main hypothesis (H_0) is defined as: *Employee wellbeing has a positive effect on customer satisfaction and loyalty*, while additional hypotheses further explore the relationship between employee motivation and consumer loyalty:

- H1: Employees with a higher perceived level of workplace wellbeing report higher levels of work motivation and engagement.
- H2: Higher levels of employee satisfaction are positively associated with higher levels of customer loyalty and customer trust.

Methodology

This study adopts a mixed-methods research design, combining quantitative and qualitative approaches to examine the relationship between employee wellbeing and customer satisfaction. The empirical analysis is primarily based on secondary data sources, complemented by primary survey data and qualitative insights derived from previously conducted interview-based studies. The research covers the period 2019–2023 and integrates data from international reports published within this timeframe. Since the datasets originate from different years and sources, a harmonization procedure involving scale standardization and temporal alignment was applied to improve comparability across indicators.

Research Design, Data Sources and Data Harmonization

The methodological framework was adapted from the research design developed in the author's master thesis on employee wellbeing and customer satisfaction (Hadžihafizović, 2025). The study combines secondary quantitative indicators, secondary qualitative evidence, and primary survey data in order to triangulate findings and strengthen the validity of conclusions. The research design follows a convergent mixed-methods logic in which quantitative and qualitative findings are analysed separately and subsequently integrated during interpretation.

The study relies on secondary empirical data obtained from globally recognized research institutions, including Gallup, Deloitte, Eurofound, and PwC. These sources provide standardized indicators related to employee wellbeing, engagement, and customer satisfaction. The datasets include both quantitative indicators (e.g., engagement rates, Net Promoter Score, trust indices) and qualitative findings (e.g., interview insights), enabling a comprehensive analysis. The target population consists of employees and customers across various industries at global and European levels, enhancing the external validity of the findings.

A harmonization process was applied to ensure consistency across data sources, including standardization of measurement scales, temporal alignment through aggregated intervals, and classification of indicators into independent (employee wellbeing) and dependent (customer satisfaction and loyalty) variables. This integrated approach enables robust correlational and comparative analysis, supporting the testing of the main hypothesis that employee wellbeing positively influences customer satisfaction.

Overall, the methodological framework ensures analytical rigor and validity, while effectively linking theoretical models with empirical evidence from contemporary organizational contexts.

Qualitative Approach: Interview-Based Analysis

The qualitative component is based on secondary analysis of interview data from prior studies conducted by organizations such as Deloitte (2019) and Gallup (2020). These interviews, involving employees, managers, and Human resource (hereinafter: HR) professionals, provide in-depth insights into employee experiences, organizational culture, and perceived impacts of wellbeing initiatives. The qualitative analysis follows an interpretative approach, focusing on identifying recurring themes such as work–life balance, psychological safety, leadership support, and employee engagement. These findings are used to contextualize quantitative results and explain underlying mechanisms linking employee wellbeing to customer satisfaction.

Quantitative Approach

The quantitative component combines secondary data analysis with primary research conducted through an online questionnaire in March 2025. The survey included 162 respondents from various industries, with a particular focus on the retail and IT sectors due to their differing organizational cultures and HR practices. A convenience sampling approach was used due to accessibility considerations and the exploratory nature of the study.

The questionnaire consisted of 14 closed-ended items measuring employee perceptions of workplace wellbeing factors. Respondents evaluated each statement using a four-point scale ranging from 1 (not important) to 4 (very important). Participation was voluntary and anonymous. The survey was conducted among employees in the Republic of Srpska and included respondents of different ages, educational backgrounds, and employment sectors.

The aim was to assess employees' perceptions of working conditions, interpersonal relationships, professional development opportunities, and managerial support, and to examine how these dimensions influence motivation, job satisfaction, and organizational commitment.

To ensure comparability across heterogeneous data sources, all indicators were standardized to a 0–100 scale, including the transformation of Likert-scale data. Two composite indices were constructed:

- the WB-Index (employee wellbeing) and the
- CS-Index (customer satisfaction and loyalty).

The WB-Index was operationalized as a composite indicator incorporating employee engagement, work–life balance, perceived organizational support, and flexible working arrangements. The CS-Index integrated customer-related indicators including satisfaction, loyalty, trust, and recommendation measures. Prior to index construction, all variables were standardized to a common 0–100 scale to ensure comparability across heterogeneous datasets.

Descriptive statistics and comparative analysis were applied to identify patterns and relationships between variables.

Results

Qualitative Part: Empirical Evidence on the Relationship Between Employee Wellbeing and Customer Satisfaction

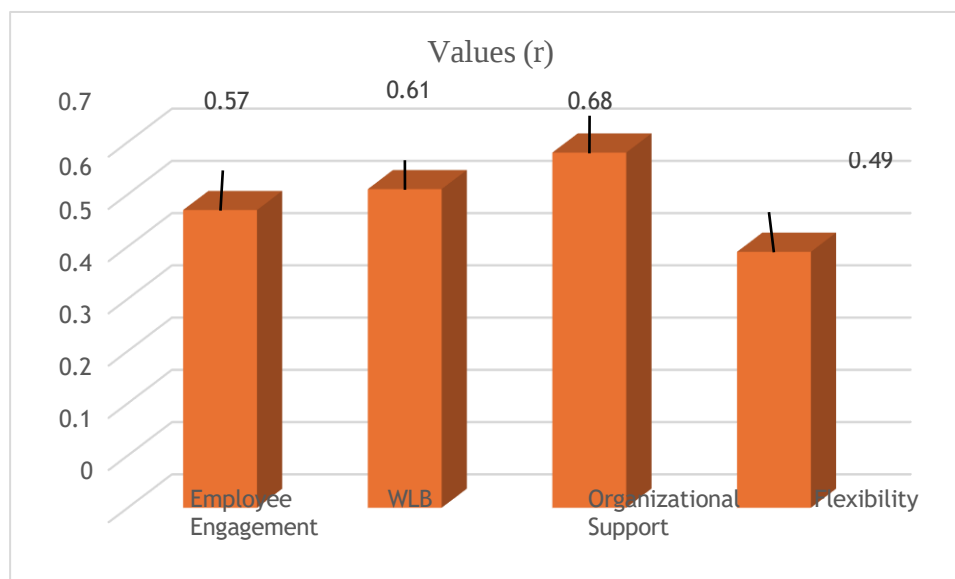
The empirical findings derived from international datasets confirm a consistent and empirically observable positive relationship between employee wellbeing and customer satisfaction, thereby supporting the theoretical assumptions of the Service-Profit Chain model (Heskett, Sasser & Schlesinger, 1997) and its contemporary extensions in global research (Gallup, 2022; Deloitte, 2019; Eurofound, 2021; PwC, 2021). Specifically, the results indicate that low levels of employee engagement—evidenced by only 23% of highly engaged employees and 44% experiencing daily stress (Gallup, 2023)—coexist with increasing organizational awareness of wellbeing, as reflected in the importance of work–life balance (61%) and perceived employer support (68%) (Deloitte, 2019; Eurofound, 2021), suggesting that wellbeing remains unevenly distributed but strategically recognized.

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At the same time, customer-related indicators demonstrate that organizations with higher levels of employee wellbeing achieve superior outcomes, including increased customer satisfaction (+10%) and loyalty (+12%) (Gallup, 2020), as well as high trust indices (up to 82/100) and recommendation rates (68%) (Deloitte, 2019; Eurofound, 2021), which aligns with the positive correlation identified in earlier models ($r = 0.45$) (Heskett et al., 1997). Furthermore, the findings reveal that specific dimensions of wellbeing—such as employee engagement, perceived organizational support, and work–life balance—differentially influence customer experience, with engagement primarily affecting perceived service quality, while psychological safety and organizational support contribute to long-term trust and loyalty.

Overall, the results provide robust empirical evidence that employee wellbeing functions as a critical mediating mechanism between internal organizational conditions and external market performance, confirming that investments in employee wellbeing simultaneously enhance workforce motivation and customer satisfaction, thereby reinforcing sustainable competitive advantage (PwC, 2021). The descriptive statistics and correlation analysis provide clear empirical support for the relationship between employee wellbeing and customer satisfaction. As shown in Table 1 and Figure 1, all observed wellbeing indicators demonstrate a positive correlation with the CS-Index, confirming that improvements in employee wellbeing are consistently associated with higher levels of customer satisfaction and loyalty. The strongest relationship is identified for the WB-Index ($r = 0.66$) and employee engagement ($r = 0.62$), indicating that overall wellbeing and active employee involvement are the most influential drivers of customer-related outcomes.

Figure 1. Correlation of Wellbeing Indicators with the CS-Index



Source: Author's calculation based on Gallup (2023), Deloitte (2019), Eurofound (2021), Regional Cooperation Council (2020).

Work–life balance ($r = 0.58$) and perceived organizational support ($r = 0.55$) also show substantial correlations, highlighting the importance of systemic organizational practices in shaping both employee experience and external service quality. Although flexible working arrangements ($r = 0.47$) exhibit a comparatively lower correlation, they remain a relevant complementary factor within a broader wellbeing strategy.

The findings provide consistent empirical support for the proposed hypotheses. However, due to the exploratory nature of the study and the use of aggregated secondary

indicators, the results should be interpreted as evidence of positive associations rather than proof of causal relationships. First, the results directly confirm the main hypothesis (H_0), as consistently positive correlations across all wellbeing indicators demonstrate that higher levels of employee wellbeing are consistently associated with higher levels of customer satisfaction and loyalty. Second, the strong relationship between wellbeing dimensions—particularly engagement, support, and work–life balance—and organizational outcomes is consistent with H_1 , indicating that employees with higher perceived wellbeing exhibit greater motivation and engagement. Finally, the observed increases in customer satisfaction, trust indices, and loyalty metrics in organizations with stronger wellbeing practices confirm H_2 , demonstrating that higher levels of employee satisfaction are positively associated with customer loyalty and trust. Overall, the qualitative and secondary-data findings collectively confirm that employee wellbeing not only enhances internal motivation and engagement but also translates into improved customer satisfaction, trust, and long-term loyalty.

Table 1. *Descriptive Statistics and Correlations (2019–2022)*

Indicator	Mean Value	SD	Min–Max	Correlation with CS-Index (r)
Employee Engagement (Gallup)	23	5.2	18–30	0.62
Work–Life Balance (Eurofound)	77.1	4.5	70–82	0.58
Perceived Organizational Support (Deloitte/EF)	68	6.3	60–75	0.55
Flexible Working Arrangements (SEE)	42	7.1	35–50	0.47
WB-Index (Composite)	52.5	6.0	45–62	0.66

Source: Author’s calculation based on Gallup (2023), Eurofound (2021), Deloitte (2019), Regional Cooperation Council (2020).

In Table 1, the correlation coefficients are based on aggregated secondary indicators obtained from international reports and should be interpreted as exploratory associations at the organizational level rather than individual-level relationships.

Quantitative Part: Employee Perceptions of Workplace Wellbeing Factors

The quantitative sample consisted of 162 respondents, predominantly female (74%), with males representing 26%. Most participants were employed in the private sector (79%), followed by the public sector (17%) and a smaller share of entrepreneurs (4%). A high proportion of respondents (85%) held permanent employment contracts, indicating relatively stable working conditions. In terms of age, the majority (approximately 75%) were between 25 and 45 years old, representing the most economically active population. Regarding education, the sample was balanced, with around 40% holding secondary education and 40% higher education degrees, while a smaller share held postgraduate qualifications.

The quantitative survey results provide a comprehensive insight into how employees perceive the importance of different wellbeing dimensions within the workplace. As presented in Table 2, all analysed items achieved relatively high average scores, ranging from 3.05 to 3.84 on a four-point scale, indicating that respondents generally consider all listed factors as important or very important for their job satisfaction and overall wellbeing.

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Table 2. *Quantitative Overview of Survey Respondents' Responses*

No.	Statement	Mean Score
1	Working fewer hours for the same pay	3.45
2	Having meals at work adapted to dietary preferences	3.10
3	Having access to high-quality healthcare	3.73
4	Having training and development opportunities that facilitate job performance	3.60
5	Receiving support and understanding from supervisors	3.80
6	Receiving support and understanding from colleagues	3.77
7	Having a pleasant working environment	3.84
8	Not being exposed to noise during working hours	3.40
9	Having access to recreational activities	3.20
10	Organizing team-building activities to strengthen relationships with colleagues	3.30
11	Having access to psychological support	3.05
12	Having a designated person responsible for workplace atmosphere	3.25
13	Having a person responsible for internal communication with employees	3.28
14	Having a person responsible for conflict prevention and management	3.35

The highest-rated factors are strongly related to interpersonal relationships and the overall work environment. In particular, a pleasant working atmosphere ($M = 3.84$), support and understanding from supervisors ($M = 3.80$), and support from colleagues ($M = 3.77$) stand out as the most significant contributors to employee wellbeing. These findings clearly emphasize the importance of social interaction, organizational culture, and emotional support in shaping positive employee experiences.

In addition to interpersonal factors, employees also place high importance on structural and developmental aspects, such as access to quality healthcare ($M = 3.73$) and opportunities for training and professional development ($M = 3.60$). These results suggest that wellbeing is perceived as a multidimensional construct that integrates both personal security and professional growth.

Moderately high scores are observed for working conditions, including shorter working hours for the same salary ($M = 3.45$) and reduced exposure to workplace noise ($M = 3.40$), indicating the relevance of work–life balance and physical working conditions. Meanwhile, somewhat lower scores are associated with additional organizational initiatives such as recreational activities ($M = 3.20$), team-building ($M = 3.30$), and formal roles related to communication and conflict management ($M \approx 3.25$ – 3.35). The lowest-rated factor is psychological support ($M = 3.05$), suggesting that although recognized, it is still less emphasized compared to other dimensions.

These findings are consistent with H1 and suggest that employees perceive workplace wellbeing factors as important antecedents of motivation, engagement, and job satisfaction. Employees who perceive supportive relationships and a positive work environment report higher satisfaction, which is a key antecedent of engagement. Furthermore, the results indirectly support H2, as dimensions such as communication quality, trust, and organizational support—identified as critical by respondents—represent foundational mechanisms through which employee satisfaction can translate into improved customer relationships. In this context, the results indicate that employees prioritize immediate interpersonal support and a positive work climate over more formalized or institutional wellbeing measures, highlighting the critical role of organizational culture in influencing employee wellbeing.

Discussion

The findings of this study confirm that employee wellbeing is not merely an internal human resource practice, but a strategic organizational resource that significantly shapes customer satisfaction and loyalty. The research problem—whether and to what extent employee wellbeing influences customer satisfaction and whether it can be considered a key factor in building customer trust and loyalty—was addressed through the integration of theoretical models, secondary international and regional data, and primary survey findings. The results support the main hypothesis that employee wellbeing has a positive effect on customer satisfaction and loyalty.

The findings are consistent with the Service-Profit Chain model, which argues that satisfied and engaged employees provide higher-quality service, leading to more satisfied and loyal customers and, ultimately, stronger business performance (Heskett, Sasser & Schlesinger, 1997). In this study, this theoretical assumption was supported by the positive correlation between the WB-Index and CS-Index, where the composite wellbeing indicator showed the strongest relationship with customer satisfaction and loyalty. This confirms that wellbeing should not be understood through isolated measures only, but as an integrated construct combining engagement, work–life balance, organizational support and flexibility.

The results also correspond with earlier findings by Harter, Schmidt and Hayes (2002), who demonstrated that employee engagement is closely linked to productivity, customer satisfaction and profitability. In the present study, employee engagement showed one of the strongest correlations with customer satisfaction, indicating that motivated and emotionally connected employees are more likely to create positive customer experiences. Similarly, Wright and Cropanzano (2000) emphasized the role of psychological wellbeing in employee performance, which is also reflected in the survey findings, where respondents rated a pleasant working environment, support from supervisors and support from colleagues as the most important wellbeing factors.

The first supporting hypothesis was broadly supported by both secondary evidence and employee perceptions collected through the survey. International findings from Gallup and Deloitte show that organizations with engaged employees achieve higher productivity and lower turnover, while the survey conducted among 162 respondents in the Republic of Srpska showed that interpersonal support, professional development and healthcare are perceived as highly important for job satisfaction. This indicates that wellbeing is strongly rooted in everyday organizational culture, communication and managerial support.

The second supporting hypothesis, that employee satisfaction contributes to customer loyalty and trust (H2), was also supported. The findings are aligned with Eurofound and PwC reports, which indicate that companies investing in wellbeing achieve stronger customer recommendation rates and higher levels of trust. This confirms that employee wellbeing has an external dimension: customers often experience the internal climate of an organization through employee behaviour, communication and service quality.

The added theoretical value of this study lies in connecting management, marketing and human resource perspectives within a single framework. While previous studies often examined employee wellbeing as an internal organizational issue or customer satisfaction as an external marketing outcome, this article demonstrates their interdependence. The use of the WB-Index and CS-Index also offers methodological value by transforming complex and multidimensional concepts into measurable indicators. Beyond human resource management, the findings suggest that employee wellbeing should be viewed as a strategic management issue. Investments in wellbeing influence organizational culture, service quality, customer relationships, and ultimately competitive positioning. Therefore, wellbeing management should be integrated into broader organizational strategy rather than treated solely as an HR function.

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From a practical perspective, the results suggest that managers should treat wellbeing as an investment, not as a cost. Companies that systematically support employees through positive work climate, health protection, training, psychological safety, flexible work arrangements and supportive leadership can expect stronger employee motivation and better customer relationships. This is especially important in service-intensive sectors such as retail, banking, tourism and IT, where employee–customer interaction directly affects perceived service quality.

The regional dimension of the study is also important. In Southeast Europe, wellbeing practices are still developing and are not equally implemented across sectors. The survey results show that employees in the regional context particularly value social and emotional dimensions of wellbeing, such as respectful communication, understanding from supervisors and a pleasant working atmosphere. This suggests that before introducing advanced wellbeing tools, organizations should first strengthen the basic foundations of trust, support and internal communication.

However, the study also has limitations. The secondary data were drawn from different international sources using different scales, timeframes and methodologies, which required standardization and harmonization. Although this enabled comparison, future research should use more unified instruments. In addition, further studies should include larger local samples, longitudinal data and direct customer responses in order to examine how changes in employee wellbeing affect customer loyalty over time. Future research should also explore digital wellbeing, hybrid work, generational differences and the relationship between wellbeing and innovation. Younger employees may value flexibility and development opportunities more strongly, while older employees may prioritize job security and healthcare. Understanding these differences could help organizations design more effective and inclusive wellbeing strategies.

Overall, the study confirms that employee wellbeing functions as a bridge between internal organizational culture and external market success. It strengthens employee motivation, improves service quality, builds customer trust and contributes to long-term competitiveness. Therefore, wellbeing should be understood as a central element of contemporary management and marketing strategy, rather than as a peripheral HR activity.

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CAN EDUCATION SPARK A REVOLUTION? EXPLORING HOW SUSTAINABLE ENTREPRENEURSHIP TRANSFORMS WOMEN'S ROLE IN AZERBAIJAN'S LABOR MARKET

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Abstract. *This study explores how sustainable entrepreneurship education can support Azerbaijani women in overcoming the systemic barriers they face in accessing and participating in the labour market. While official narratives often highlight progress in gender equality, the reality is more complex. Women in Azerbaijan continue to encounter deeply rooted obstacles ranging from limited access to financing and mentorship to prevailing gender norms that discourage risk-taking and entrepreneurial activity. To address these challenges, this study asks: How and to what extent does entrepreneurship education influence women's empowerment and labour market integration in Azerbaijan? A mixed-methods approach was adopted. Findings show that tailored entrepreneurship education can increase confidence, improve access to opportunities, and encourage sustained labour force participation, especially outside urban centers.*

Keywords: *women empowerment, entrepreneurship education, Azerbaijan, economic growth, women entrepreneurs*

1. Introduction

Promoting economic growth, gender equality, and sustainable development depends on the meaningful inclusion of women in the labour market. In Azerbaijan, women are underrepresented in entrepreneurial activity: they constituted about 23.6 % of individual entrepreneurs as of October 2025, and their participation continues to grow but remains modest relative to men (State Statistical Committee of the Republic of Azerbaijan, 2023; SMBDA, 2023). Support mechanisms such as training, consulting, and financial assistance are provided by the Small and Medium Business Development Agency (SMBDA, 2022), yet access and benefits vary across regions and sectors. Many women still face socio-cultural and structural constraints that limit full participation in business (Bayramov, 2020; CESD, 2012).

Entrepreneurship education is widely recognized as a means to build entrepreneurial capabilities and contribute to sustainable development. However, the role of sustainable

entrepreneurship education in empowering women and shaping sustainability-oriented practices remains underexplored in the literature (Hajiyeva, Burkadze, & Khalil, 2024; Rashid, 2019; Tsaknis, Sahinidis, & Kavoura, 2025). Systematic reviews on sustainable entrepreneurship education highlight its potential to nurture entrepreneurial attitudes, skills, and sustainable mindsets, yet they also point to a lack of consensus on how education should be designed to achieve these outcomes, particularly in emerging economies (Fayolle & Gailly, 2013; Tsaknis et al., 2025).

Feminist and gender-focused research emphasizes that women entrepreneurs face barriers related to education, access to networks, and socio-cultural norms, which intersect with sustainability goals in complex ways (Brush, Bruin, & Welter, 2009; Wilson, Kickul, & Marlino, 2007; Ahl & Nelson, 2015; Marlow & McAdam, 2013). This study therefore asks: How can sustainable entrepreneurship education empower women entrepreneurs in Azerbaijan to integrate sustainability principles into their ventures despite structural, cultural, and material constraints?

Using a mixed methods approach, data were collected from 300 women entrepreneurs across diverse regions and industries. This research aims to fill existing knowledge gaps and provide practical insights for policymakers, educators, and practitioners to develop gender-sensitive, contextually relevant, and sustainability-focused support programs (Hajiyeva et al., 2024; Koh, 1996). While global and regional research highlights the positive impact of entrepreneurship education on entrepreneurial intentions, mindset, and persistence, there is limited evidence on its effectiveness for empowering women in the Azerbaijani context. Existing studies rarely address gender-specific barriers or assess sustainable labor market outcomes for women.

This study demonstrates how sustainable entrepreneurship education can empower Azerbaijani women by strengthening their skills, confidence, and access to resources. At the same time, it highlights ongoing challenges, including regional disparities and socio-cultural barriers, which call for targeted, locally adapted policies and educational programs. The findings offer practical guidance for designing interventions and fostering cooperation between government, educational institutions, and the private sector to support women's participation in the labor market, promote sustainable business practices, and encourage inclusive economic growth across the country.

2.Literature review on the entrepreneurship education

Entrepreneurship education has become a vital component worldwide for preparing individuals to meet the demands of an evolving and often unpredictable business environment. It goes beyond the transmission of basic business knowledge; its true purpose is to develop a mindset capable of creativity, resilience, and opportunity recognition. In today's global economy, entrepreneurship education is seen as a key driver of innovation, economic development, and personal empowerment, providing learners with tools to create value both socially and economically (Fayolle & Gailly, 2003).

Peter Drucker in his "Innovation and Entrepreneurship" book, emphasizes the role of innovation which is the specific tool of entrepreneurs, how they exploit change as an opportunity for a different business or a different service. It is capable of being presented as a discipline, capable of being learned, capable of being practiced. He highlighted that entrepreneurship education helps people to detect and seize opportunities, which is a critical component of innovation. This education provides individuals with the knowledge and abilities required to transform ideas into valuable products or services. (Drucker, 2014)

The theoretical foundations of entrepreneurship education are well captured in the works of prominent scholars. Peter Drucker (2014) emphasizes that entrepreneurship is essentially the discipline of innovation teaching individuals how to identify and exploit change

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as a business opportunity. His work stresses that entrepreneurship can be learned and practiced, and that education plays a critical role in developing the ability to seize opportunities. Joseph Schumpeter views entrepreneurship as the creative reorganization of resources to drive economic growth, highlighting the importance of innovation, risk-taking, and the exploitation of opportunities despite constraints (Stevenson). Additionally, Gartner (1988) highlights the role of entrepreneurship education in cultivating critical thinking and decision-making skills necessary for turning ideas into actionable business ventures. These foundational perspectives affirm that entrepreneurship education is not only about skills acquisition but also about shaping an entrepreneurial mindset.

According to Schumpeter, entrepreneurship involves leveraging opportunities despite constraints. In the context of Azerbaijan, women face structural and social constraints in the labor market. Entrepreneurship education that fosters opportunity recognition and resource mobilization can therefore be a mechanism for overcoming these gendered barriers. Similarly, Drucker's view of entrepreneurship as a learnable discipline underlines the importance of targeted educational interventions to equip women with the skills and mindset to engage successfully in entrepreneurial activities, particularly in settings where societal support is limited.

Empirical studies from around the world reinforce the positive effects of entrepreneurship education. Exposure to such programs has been shown to increase entrepreneurial intentions, self-confidence, and persistence in pursuing entrepreneurial ventures (Souitaris et al., 2007; Krueger et al., 2000). It also contributes to social entrepreneurship, encouraging business initiatives that target social issues and community development (Mair & Marti, 2006). Regional research, including studies by Pergelova (2023), Harahap (2023), and Nafiati et al. (2023), emphasizes how family support and institutional collaboration can strengthen entrepreneurial outcomes, especially for women. Furthermore, scholarship by Mahmood et al. (2021) and Lv et al. (2021) links entrepreneurship education to technological entrepreneurship and broader national economic growth.

Entrepreneurship entails bringing new combinations of resources to generate creative products or services. Entrepreneurship education equips students with the information and mindset required to effect these changes in the business world, according to Joseph Schumpeter. It is about identifying and utilizing possibilities despite early constraints. Entrepreneurship education teaches students how to recognize and capitalize on opportunities via the use of their creativity, talents, and networks. (Stevenson) It has been identified as a driver of economic progress and innovation. It teaches people the skills and mindset required to detect market gaps, develop creative solutions, and establish new enterprises. Guerrero et al., 2014; Fayolle & Gailly, 2015) Exposure to entrepreneurship programs can foster a good attitude toward entrepreneurship, making people more likely to pursue their entrepreneurial dreams. (Souitaris et al., 2007; Krueger et al., 2000) It also boosts people's self-esteem and self-efficacy, allowing them to take initiative, create goals, and persevere in the face of adversity. (Robinson et al., 1991; Souitaris et al., 2007) It can go beyond commercial objectives to address social and community issues. Social entrepreneurship education prepares people to start businesses that have a beneficial social impact.

Mair and Mart (2006) Pergelova (2023) explores the influence of entrepreneurship education programs on participants' attitudes and intentions toward entrepreneurship. The study emphasizes the importance of considering participants' prior exposure to entrepreneurship and highlights the positive effects of entrepreneurship education for individuals with limited prior exposure. Harahap (2023) and Nafiati et al. (2023) discuss the role of entrepreneurship education in shaping entrepreneurial attitudes and skills. They emphasize the importance of family support and effective assistance in entrepreneurship

education. These studies highlight the need for collaboration between educational institutions, families, and individuals to enhance the impact of entrepreneurship education. (Hajiyeva, et.al., 2024) (Mahmood et al., 2021; Lv et al., 2021; and Pech & Řehoř (2021) provide insights into the role of entrepreneurship education in various circumstances, such as technological entrepreneurship and country economic growth. These studies underline the significance of entrepreneurship education in the development of entrepreneurial abilities, the preparation of individuals for business initiatives, and the adaptation to a changing business environment. When we turn our focus to Azerbaijan, the entrepreneurship landscape reflects a unique set of challenges and opportunities.

Since the 1990s, Azerbaijan has undergone a significant economic transformation, adopting market-oriented reforms and strengthening its SME sector (Bayramov, 2020). The government, together with specialized agencies such as the Small and Medium Business Development Agency, has launched numerous initiatives to support entrepreneurship, including financial assistance, training programs, and access to markets. These programs aim to improve the business environment, reduce bureaucratic barriers, and foster innovation. However, despite these efforts, women entrepreneurs still confront systemic barriers such as limited access to finance, mentorship, and entrepreneurship education programs tailored to their specific needs. Initiatives like the EE-KEY-AZ project demonstrate progress at the university level, but there remains a clear absence of structured, research-based frameworks to guide entrepreneurship education for women in Azerbaijan's labor market.

This points to a gap in the current scholarship: a lack of rigorous, locally grounded research that explores how entrepreneurship education can effectively empower Azerbaijani women and facilitate their meaningful participation in the labor force. Existing studies seldom focus on overcoming gender-specific challenges or measuring sustainable labor market outcomes for women. Therefore, this study aims to fill this gap by employing a mixed-methods approach to investigate the impact of entrepreneurship education on women's empowerment and labor market integration in Azerbaijan. Through this research, we seek to provide practical insights for policymakers, educators, and practitioners to design more effective, gender-sensitive programs that respond to the country's socio-economic context.

3. Overview of the formation of entrepreneurship landscape in Azerbaijan

In the early 1990s, Azerbaijan faced severe socio-economic and political disasters. As in other newly independent Soviet socialist republics, Azerbaijan faced the political, economic, legal, and social regularities of the new era. Entrepreneurship in Azerbaijan has a long history of development. The various natural resources owned by our country have created invaluable conditions for the arrival of foreign business companies in the country, as well as for the development of local entrepreneurship. At the end of the 19th century and the beginning of the 20th century, Baku had already become a major industrial center with a great reputation for the development of entrepreneurship. The entrepreneurship landscape in Azerbaijan after the 1990s was characterized by a shift towards a more market-oriented economy, legal and regulatory reforms, efforts to promote innovation and technology, and a growing emphasis on diversification. Despite challenges, the country witnessed the emergence of a dynamic and diverse entrepreneurial ecosystem that continues to evolve to this day.

Table 1. The development of entrepreneurship in Azerbaijan in the post-independence period

Period up to 1993	• The need to start systemic reforms aimed at a market economy • Implementation of privatization • Formation of the state defense system of entrepreneurship
1993-2002	• Accelerating the implementation of reforms on the established foundations

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	• Implementation of structural changes in the business sector from the sectoral, regional, and technological point of view to more fully realize the potential of the country
2002-2015	• Ensuring employment • Realization of regional potential: - industry - agrarian sector - tourism • Realization of export potential • Formation and development of innovative entrepreneurship
After 2015	• Electrification of services provided to entrepreneurs • Production of competitive and value-added products • Regularly evaluate the implementation of reforms in an appropriate manner • Improving legislation in the field of innovative entrepreneurship (startup), increasing access to finance and consulting services in this area • Improving legislation in the field of public-private partnership, development of cooperation. • Refining legislation and electronics in the field of customs (import-export operations) • Improving the relevant legislation in the judicial system • Making changes in the Tax Code of the Republic of Azerbaijan and related legislation

Source: The Ministry of Economy of the Republic of Azerbaijan.

Azerbaijan has adopted many legislative acts regulating the development of small and medium enterprises, which include the Law on Entrepreneurship, the Law on State Support to Small Entrepreneurship, the Law on State Registration of Legal Entities, and the Law on the State Register, etc. (National Fund for Entrepreneurship, 2020) The "Strategic Roadmap for the production of consumer goods at the level of small and medium enterprises in the Republic of Azerbaijan", approved by the President on December 6, 2016, plays a pivotal role in the effective development of entrepreneurship. The roadmap identifies the main directions of economic reforms and development in the SME in the short, medium, and long term. To achieve the strategic goals set out in the strategic roadmap for the development of SMEs in the country and to ensure the maximum use of relevant opportunities, the following have been identified as strategic goals below. (Strategic Roadmap, 2016)

- Further improvement of the business environment and regulatory framework in the country to increase the impact of SMEs on Azerbaijan's GDP in the long run;
- Ensuring efficient and effective access to financing resources to create a sustainable network of SMEs;
- Internationalization of SME activities and increasing access to foreign markets to increase the country's foreign exchange reserves and ensure compliance of goods produced in the country under international standards;
- Increasing the supply of quality products and services in regional markets, with special emphasis on the training of skilled labor and the development of skills of SME entities;
- Promotion of innovations to increase the competitiveness of SMEs, strengthening research, and development activities in this area. (Bayramov, 2020).

Currently, it is crucially important to improve the legislation in Azerbaijan to protect the rights of entrepreneurs, and the need for a "Competition Code" has long been recognized. For years, the draft "Competition Code" has been under discussion, but it was not until July 2024 that the Azerbaijan government finally enacted this law. (Competition Code, 2024) There is a need to reduce the number of licenses in Azerbaijan. The number of licenses in Azerbaijan

should be combined by sector. From this point of view, there is also a need to improve the legislation, adopt new one to stimulate entrepreneurship, reduce bureaucratic barriers, reduce interference in entrepreneurship, strengthen the fight against monopolies, and eliminate these gaps. This improvement must unequivocally provide for the protection of entrepreneurial activity. To bring about these changes, policymakers, regulators, and stakeholders need to work together to draft, review, and implement effective competition laws and regulations that address the specific needs of Azerbaijan's business environment. This can involve a combination of legislative changes, regulatory reforms, and the establishment of appropriate enforcement mechanisms.

Azerbaijan is thrilled to cooperate with international organizations, relevant state bodies (agencies) of foreign states, and investors to explore the possibilities of applying international experience in entrepreneurship. On the other hand, the government together with local universities tends to encourage young professionals and students to engage in entrepreneurship voluntarily to support entrepreneurs, make proposals for coordination in this field, and collaborate with local and foreign business companies effectively.

In the development of entrepreneurial ideas, Azerbaijani HEIs/universities are thrilled to work closely with European universities and think tanks in this direction, which plays an important role in making the ideas of young entrepreneurs a reality. For instance, in 2016, the University of Siegen, Germany, and the Azerbaijan State University of Economics (UNEC) jointly participated in the EE-KEYAZ Entrepreneurship Education: EE-KEY-AZ Entrepreneurship Education: a Key to Job Creation and Employability in Azerbaijan) the project won the competition held by the head office of the German Academic Exchange Service (DAAD) in Germany. Within the framework of the grant-winning project, meetings, and pieces of training with the participation of professors, young scientists, and students were regularly held in both Germany and Azerbaijan. At the same time, summer and winter schools and various seminars were organized in both countries. The training covered business planning, innovation management, logistics, ecommerce, risk management, and other areas. The project covered all levels of higher education. (UNEC, 2019)

Thus, the higher education institutions in Azerbaijan play a pivotal role in the teaching of entrepreneurial skills and the training of “entrepreneurial attachés”, because the education itself means a social environment. Within the social environment, the development of entrepreneurial skills, the introduction of new ideas, and their preservation are of great importance. (Sullivan, 2000) From this point of view, the involvement of the government together with universities and students in the development of entrepreneurship and the implementation of entrepreneurship education in Azerbaijan will play an essential role in the development of the national economy, increasing labor productivity, and creating new job places in the country. (Koh, 1996; Clark, 1998)

Currently, Azerbaijani government can help eliminate the difficulties and gaps, which may exist between universities, business sectors, and students that can hinder the development of social entrepreneurship. In general, the implementation of and positive economic impacts of entrepreneurship education are mainly essential for the future socio-economic development of Azerbaijan. The active engagement of government together with higher education institutions and business companies in the development of entrepreneurship. Furthermore, the implementation of entrepreneurship education courses in the academic curriculum by universities has to be launched through the constant support of the Azerbaijani government. Lecturers and professors could play an important role during the process: they are knowledge facilitators and multipliers of ideas and assistance for students to achieve results in entrepreneurship-related learning including knowledge, capacities, and attitudes.

4. The historical development of women's entrepreneurship in Azerbaijan

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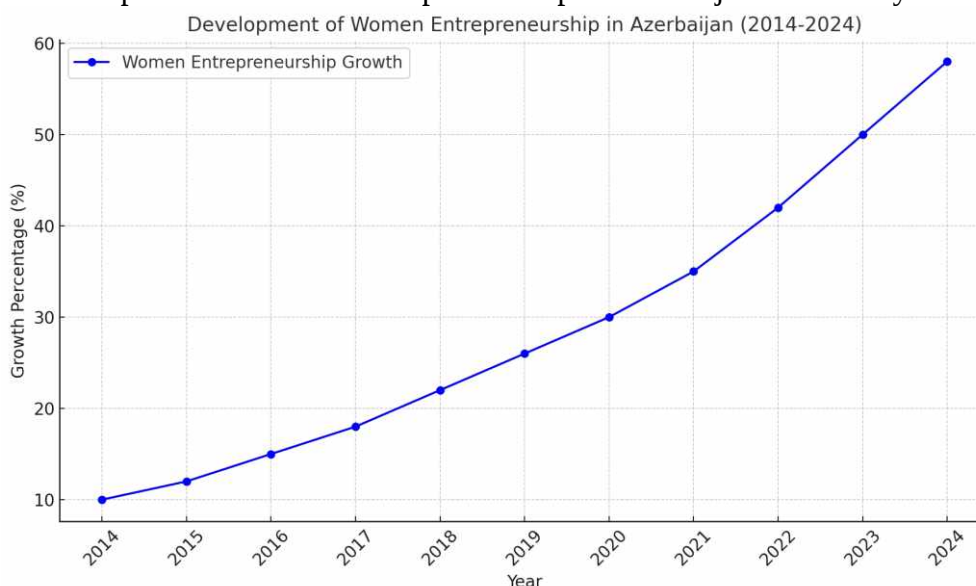
Women's entrepreneurship plays a significant role in Azerbaijan's economic development by fostering innovation, job creation, and inclusive growth. Over recent years, there has been a growing interest in micro and small-scale entrepreneurship and self-employment across the country, with women increasingly participating in various sectors such as agriculture and services. As of 2024, women constituted 23% of entrepreneurs registered to carry out entrepreneurial activities without forming legal corporations (AZSTAT, 2023). Geographically, female entrepreneurs are unevenly distributed: approximately 29.9% are based in Baku, followed by 10.2% in the Lankaran-Astara region, and 8.9% in the Gazakh-Tovuz zone, with the remainder spread across other economic regions. Supporting women entrepreneurs, the Small and Medium Business Development Agency (SMBDA) offers a variety of targeted mechanisms. These include business training and consultations, improved access to financial resources and marketplaces, grants, market research, and startup certification programs. In 2022 alone, nearly 3,000 women completed SMBDA-organized business training sessions, and over 100 participated in the "German-Azerbaijani Joint Program" coordinated by SMBDA (SMBDA, 2022). The agency also supported 40 projects in financing educational and scientific SME initiatives, nine of which were led by women entrepreneurs (AZSTAT, 2023). The impact of SMBDA's support is evident: over 40% of the 1,050 economic entities participating in exhibitions and fairs were women-owned, and 12 out of 25 businesses gaining access to retail chains were operated by women (SMBDA, 2023). Additionally, 11 female entrepreneurs received startup certificates, reflecting growing institutional encouragement. These initiatives demonstrate a strong commitment to empowering women entrepreneurs in Azerbaijan, enhancing their visibility and access to resources. However, challenges remain, particularly in expanding support beyond urban centers and into more diverse sectors, which this study further explores.

Table 2. Women's Entrepreneurship Support in Azerbaijan

Organization/Entity	Focus	Services Provided
Women's Entrepreneurship Development Association of Azerbaijan (WEDAA)	Promotes women's entrepreneurship in Azerbaijan	Training, mentorship, networking, and support services for female entrepreneurs
Azerbaijan Women's and Development Center (AWDC)	Women's empowerment and development, including entrepreneurship	Training, workshops, and advocacy in various fields, including business
United Nations Development Programme (UNDP)	Women's economic empowerment and entrepreneurship	Training, access to funding, and capacity-building programs with local partners
Azerbaijan Micro-finance Association (AMFA)	Supports microfinance institutions (not exclusively for women)	Financial services for women entrepreneurs and small business owners
International Finance Corporation (IFC) - Women Entrepreneurs Finance Initiative (We-Fi)	Global initiative to support women entrepreneurs	Financial resources, training, and access to markets, sometimes in collaboration with local institutions
Embassies and International Organizations	Various initiatives to support women entrepreneurs	Workshops, training, and networking events
Local Chambers of Commerce and Industry	Business support with potential focus on women entrepreneurs	Programs and initiatives to assist businesses, including women-owned enterprises
Academic Institutions and Universities	Entrepreneurship education and support	Resources and networking opportunities for women entrepreneurs
NGOs and Non-profit Organizations	Projects aimed at women's empowerment & entrepreneurship	Training, mentorship, and advocacy

The increased representation of women entrepreneurs in various sectors, including agriculture, services, and other industries, reflects the expanding opportunities for women to contribute to the country's economy. The geographic distribution of women entrepreneurs across different economic regions of Azerbaijan indicates a broad reach of these initiatives and the potential for economic development in various parts of the country. The efforts of the Small and Medium Business Development Agency (SMBDA) in promoting female entrepreneurship through training, consultations, access to financial resources, sales markets, and grants are crucial in providing the necessary support for women to succeed in their entrepreneurial endeavors. The fact that a significant number of women entrepreneurs have participated in business training and educational programs underscores their commitment to enhancing their skills and knowledge. The "German-Azerbaijani Joint Program" coordinated by the SMBDA further highlights the international collaboration and exchange of expertise that can greatly benefit women entrepreneurs and managers in Azerbaijan. The allocation of startup certificates, financial support for projects, participation in exhibitions and fairs, and assistance with access to retail chains all contribute to creating a conducive environment for women-led businesses to thrive. The participation of women entrepreneurs in these mechanisms demonstrates their potential to succeed and make a substantial impact on the economy. Overall, these initiatives are not only empowering women to become active participants in the economy but are also fostering a more inclusive and diverse entrepreneurial ecosystem in Azerbaijan. This can lead to sustainable economic growth, job creation, and innovation. It is important to continue monitoring these efforts and their outcomes to ensure that they continue to be effective in supporting women entrepreneurs and driving economic development.

Figure 1. Development of Women Entrepreneurship in Azerbaijan within 10 years.



Source: State Statistical Committee of the Republic of Azerbaijan (year of publication).

The development of women's entrepreneurship in Azerbaijan from 2014 to 2024 has shown a notable upward trend. In 2015, women constituted approximately 27% of entrepreneurs in small and medium-sized enterprises (SMEs). This figure increased to 30% by 2018, indicating a positive trajectory in female entrepreneurial participation. (UNECE, 2019) In 2020, women led 22.5% of micro, small, and medium-sized enterprises in Azerbaijan. However, it's important to note that the COVID-19 pandemic had a disproportionate impact on women-led businesses, with these enterprises being 20% more affected than those led by men. (UN Women - Azerbaijan, 2021)

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While specific data for the years 2021 to 2024 is limited, the available information suggests a continued focus on enhancing women's participation in entrepreneurship. The Azerbaijani government and various organizations have implemented policies and programs aimed at supporting women entrepreneurs, contributing to the overall growth and development of female-led enterprises in the country. In Azerbaijan, various groups seek to encourage and empower female entrepreneurs. These organizations provide a variety of programs, tools, and activities to assist women in overcoming obstacles and succeeding in their entrepreneurial endeavors.

5. Methodology

5.1. Research Design

To explore how entrepreneurial education impacts women's empowerment and integration into the Azerbaijani labor market, a mixed-methods research design was employed. This approach was chosen to capture both quantitative patterns and the nuanced experiences of women entrepreneurs. Quantitative methods allowed for the statistical examination of relationships between entrepreneurship education and empowerment, while qualitative interviews provided contextual depth, capturing participants' personal experiences, challenges, and perceptions of support mechanisms. This combination aligns with the study's goal to develop a comprehensive framework for assessing empowerment through entrepreneurship education.

5.2. Sampling and Participants

The study sample consisted of 300 female entrepreneurs from diverse regions and industries across Azerbaijan. A purposive-convenience sampling strategy was employed to ensure participants had prior entrepreneurial experience, including early-stage ventures and established businesses. To enhance qualitative insights, 20 participants were selected for follow-up semi-structured interviews, chosen to represent variation in geographic location, education level, and industry sector, ensuring rich and diverse narratives.

5.3. Data Collection Instruments

A self-administered questionnaire was developed based on a review of existing literature and consultations with local entrepreneurship educators. The survey included Likert-scale items (1 = Strongly Disagree to 5 = Strongly Agree) to measure perceptions of entrepreneurship education across five dimensions:

- Importance of Education (X1)
- Business Skills Development (X2)
- Access to Resources (X3)
- Networking Opportunities (X4)
- Perceived Empowerment (Y)

The survey also collected demographic and business-related information (e.g., age, education, industry, business size) to allow subgroup analyses. The questionnaire was reviewed for content validity by academic and field experts and pre-tested with a small pilot group (n = 15) to ensure clarity, comprehensibility, and reliability. Semi-structured interview questions were designed to complement the survey, focusing on personal narratives, perceived challenges, reflections on sustainability, mentorship experiences, and institutional support. Each interview lasted approximately 45–60 minutes, was audio-recorded with participant consent, and later transcribed verbatim for analysis.

5.4. Interview Recording and Transcription

All semi-structured interviews were audio-recorded with participants' consent to ensure accuracy and reliability of the data. Recordings were subsequently transcribed verbatim by the research team. On average, each 45–60 minute interview required

approximately 1.5–2 hours to transcribe, depending on the complexity of the responses. Transcriptions were then reviewed for accuracy against the recordings and anonymized to protect participants' identities. This process ensured methodological rigor and provided a reliable basis for thematic analysis.

5.5. Data Analysis

Survey data were analyzed using Pearson's correlation coefficient to assess relationships between education dimensions (X1–X4) and perceived empowerment (Y). A correlation matrix was constructed, and significance levels (p-values) were reported to evaluate the strength and reliability of associations. Descriptive statistics (means, standard deviations, frequencies) were also calculated to summarize participants' responses.

Interview transcripts were thematically coded using an inductive approach. Codes were organized into themes corresponding to empowerment, barriers, sustainability practices, and institutional support. Triangulation was performed by comparing qualitative themes with quantitative findings to reinforce, explain, or contextualize survey results. Quantitative and qualitative results were integrated during interpretation to provide a holistic understanding of how entrepreneurship education influences women's empowerment in Azerbaijan, highlighting both measurable outcomes and lived experiences.

6. Discussions and results

6.1. Explanation of Survey Results

The purpose of the survey was to thoroughly analyze how women business owners in Azerbaijan perceive and experience the contribution that entrepreneurship education makes to their empowerment and integration into the workforce. Between 2023 and 2024, the survey included 300 female entrepreneurs from a variety of Azerbaijani regions and industries. The study included women entrepreneurs from a range of age groups, educational backgrounds, and years of entrepreneurial experience, and the results offer insightful information about how entrepreneurship education affects women's empowerment in the context of the labor market. Demographics provide a complete picture of the women entrepreneurs in Azerbaijan in the survey analysis.

Table 3. Survey results based on the role of entrepreneurship education in empowering women to the labor market in Azerbaijan

Survey questions on different insights	Survey results
Importance of Sustainable Entrepreneurship Education	According to the study, a sizable majority of participants (82%) said that entrepreneurship education is essential for empowering women and boosting their success in the workforce. This demonstrates the perceived importance of education in empowering women economically. Notably, 91% of the respondents acknowledged that education was crucial in boosting their self-assured participation in the labor market and building their confidence in their entrepreneurial talents.
Impact on Business Skills	A substantial number (76%) said that their business management skills have improved as a result of their entrepreneurship education. This highlights the usefulness of education in improving one's capacity for managing businesses. The fact that almost 65% of respondents said they learned good marketing methods through training and education further demonstrates the importance of education in providing women entrepreneurs with useful skills.
Access to Resources	According to the study results, 61% of respondents said that learning about entrepreneurship increased their access to funding sources. This shows that education can help women entrepreneurs overcome a significant barrier that prevents them from obtaining financing. A significant 72% of respondents said that schooling improved their ability to manage resources by introducing them to a variety of financial management strategies.

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Networking Opportunities	A significant majority (82%) acknowledged that entrepreneurship education offered valuable networking platforms. This underscores the pivotal role of education in creating avenues for women to connect with mentors, fellow entrepreneurs, and industry professionals. 63% of respondents reported that they formed valuable partnerships through networking opportunities facilitated by entrepreneurship education, indicating its potential to foster collaborative endeavors.
Barriers Addressed	A substantial portion (66%) of respondents reported that entrepreneurship education helped them overcome gender-specific barriers prevalent in the business environment. This suggests that education contributes to breaking down gender-related obstacles that hinder women's progress. Over half of the respondents (53%) felt that education raised awareness about their legal rights and protections as women entrepreneurs, contributing to a more informed and empowered business approach.
Business Growth and Expansion	An overwhelming 78% of respondents noted that entrepreneurship education played a role in fostering business growth and expansion, reaffirming its influence in driving economic progress. Approximately 41% reported an increase in their customer base after applying the knowledge gained from education, indicating a tangible impact on business outcomes.
Challenges of Entrepreneurship Education	A notable insight emerged with 45% of respondents mentioning that the availability of quality education programs was limited in their region. This highlights the need for more widespread access to relevant and effective education. Time constraints were identified as a barrier by 33% of respondents, indicating the need for flexible educational formats that accommodate women's busy schedules.
Government Initiatives	A considerable proportion (57%) of respondents were aware of government initiatives promoting entrepreneurship education for women. This reflects an existing level of awareness about such initiatives. Interestingly, 75% believed that stronger government support is needed to enhance the impact of these initiatives, indicating a desire for increased governmental involvement in advancing entrepreneurship education for women.

The survey results provide strong evidence that entrepreneurship education significantly empowers women in Azerbaijan's labor market. 82% of participants emphasized the importance of such education, and 91% confirmed it boosted their confidence and labor market participation. Additionally, 76% reported improved business management skills, while 65% learned effective marketing strategies highlighting the role of education in building core entrepreneurial competencies. Access to resources also improved: 61% gained better funding access and 72% improved financial management. Networking was a key benefit, with 82% acknowledging new connections and 63% forming partnerships supporting theories that emphasize collaboration in entrepreneurship. Importantly, 66% said education helped them overcome gender-related barriers, and 53% became more aware of their legal rights. However, challenges remain: 45% noted limited access to quality programs, and 33% cited time constraints. Though 57% were aware of government initiatives, 75% called for stronger state support. The survey's findings show how entrepreneurship education is essential to empowering women business owners in Azerbaijan. Their networks grow, their abilities improve, and it helps them succeed in the job market. However, problems like poor accessibility and time restraints continue. The favorable effects of entrepreneurial education on women's empowerment and labor market inclusion could be further amplified by strengthening government initiatives and expanding the accessibility of high-quality educational programs.

6.2. Correlation Analysis

To investigate these relationships, a correlation analysis was conducted using **Pearson's correlation coefficient**. This method was chosen due to its effectiveness in quantifying the strength and direction of linear relationships between continuous variables. Pearson's r provides a clear statistical measure to test how individual aspects of entrepreneurship

education—treated as interval-scale survey responses—correlate with the outcome variable, *Perceived Empowerment*.

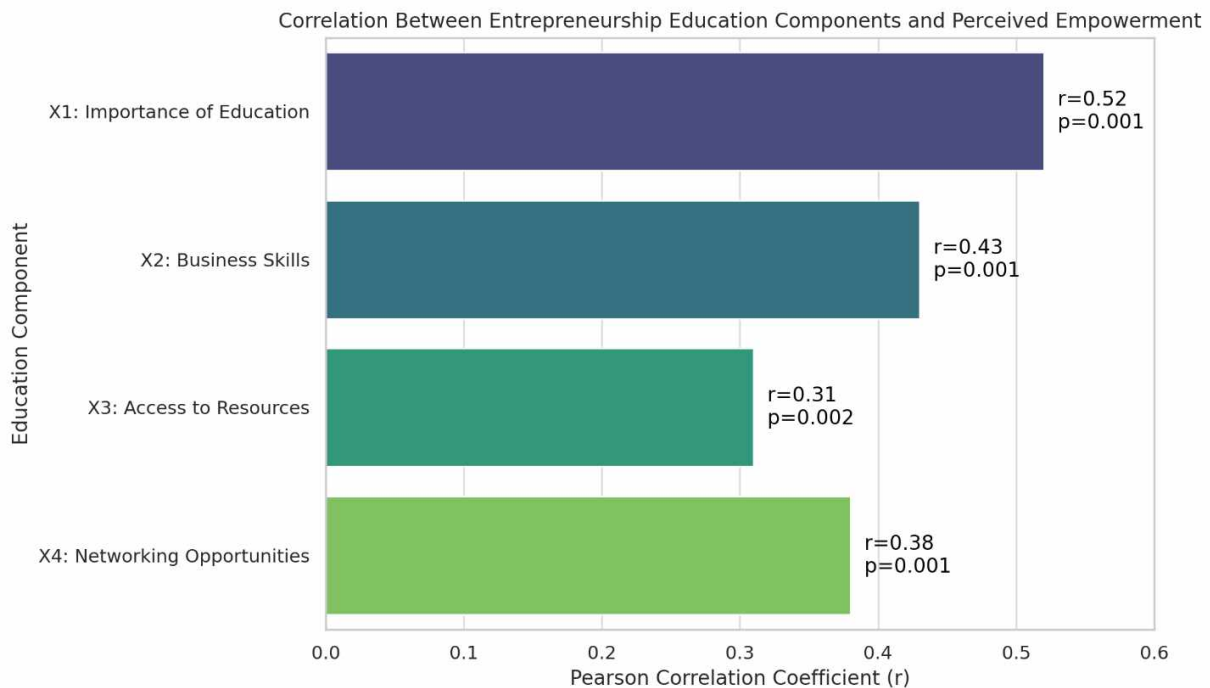
The analysis involved a sample of 300 women entrepreneurs from diverse regions and industries across Azerbaijan. The following variables were examined:

1. **X1 – Importance of Entrepreneurship Education:** Perceived relevance of entrepreneurship education to women's empowerment.
2. **X2 – Impact on Business Skills:** Effect of education on managing business operations.
3. **X3 – Access to Resources:** Extent to which education improved access to funding, markets, and support.
4. **X4 – Networking Opportunities:** Role of education in building professional connections.
5. **Y – Perceived Empowerment (Dependent Variable):** Participants' overall sense of empowerment in the labor market attributable to their entrepreneurial education.

The variables were selected based on theoretical literature emphasizing knowledge, skills, access, and social capital as foundational elements in empowerment frameworks. The correlation analysis revealed statistically significant positive relationships across all variables:

- **X1 and Y:** $r = 0.52, p < 0.001$
- **X2 and Y:** $r = 0.43, p < 0.001$
- **X3 and Y:** $r = 0.31, p = 0.002$
- **X4 and Y:** $r = 0.38, p < 0.001$

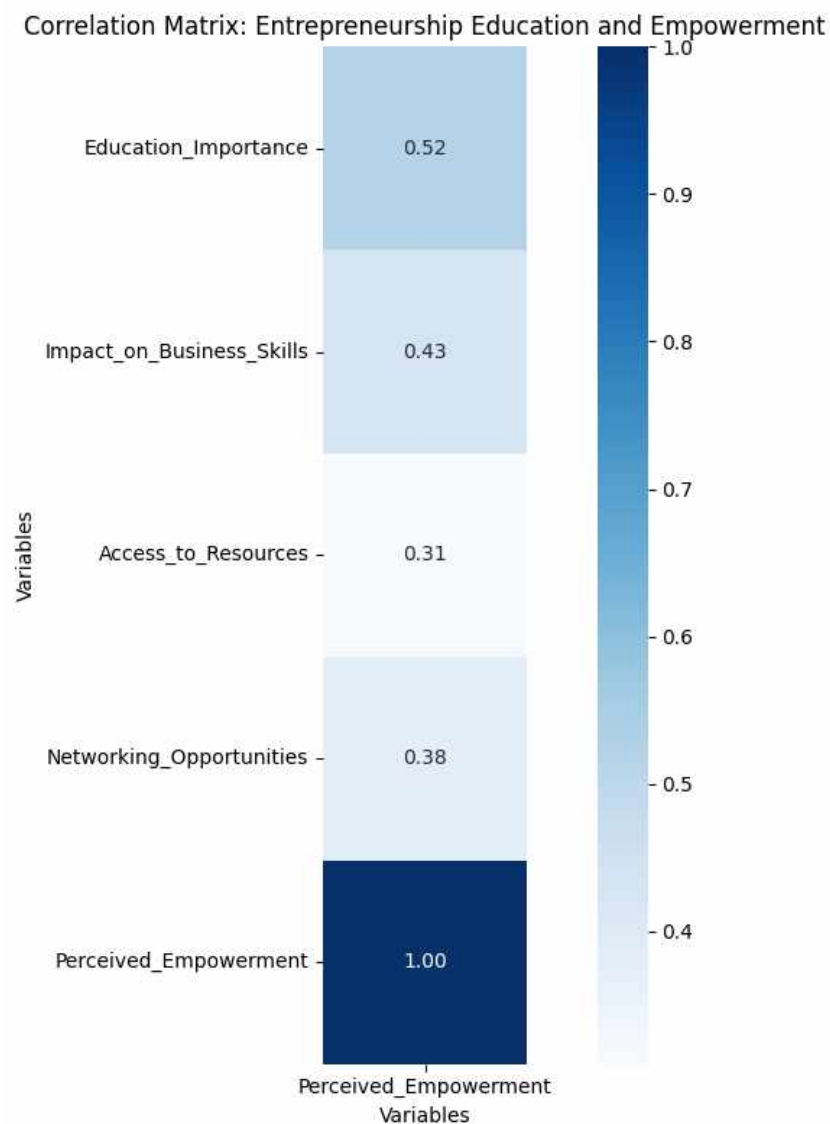
Figure 2. Correlation between Entrepreneurship Education Components and Perceived Empowerment



These findings suggest that women who place greater importance on entrepreneurship education, report improved business skills, gain better access to resources, and benefit from networking are more likely to feel empowered in the labor market. The strength of these associations underscores the multidimensional impact of education, not only as a skills provider but also as a platform for access and agency.

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Figure 3. Correlation Matric: Entrepreneurship Education and Empowerment



The correlation analysis results given describe the connections between various study variables.

Source: Composed by authors based on the collected data from the survey. (2025)

1. Correlation between Education Importance and Perceived Empowerment:

- Pearson's $r = 0.52$, $p < 0.001$
- Interpretation: There is a significant positive correlation between the importance that participants place on entrepreneurship education and their perceived empowerment in the labor market. As participants value entrepreneurship education more highly, they tend to report higher levels of perceived empowerment in their professional pursuits.

2. Correlation between Impact on Business Skills and Perceived Empowerment:

- Pearson's $r = 0.43$, $p < 0.001$
- Interpretation: There is a significant positive correlation between participants' perceptions of how entrepreneurship education impacts their business skills and their perceived empowerment in the labor market. Participants who believe that entrepreneurship education enhances their business skills also tend to feel more empowered in their work.

3. Correlation between Access to Resources and Perceived Empowerment:

- Pearson's $r = 0.31$, $p = 0.002$
- Interpretation: There is a significant positive correlation between participants' perceptions of their access to resources through entrepreneurship education and their perceived empowerment in the labor market. Participants who feel that entrepreneurship education improves their access to resources are more likely to experience a sense of empowerment.

4. Correlation between Networking Opportunities and Perceived Empowerment:

- Pearson's $r = 0.38$, $p < 0.001$
- Interpretation: There is a significant positive correlation between participants' perceptions of networking opportunities provided by entrepreneurship education and their perceived empowerment in the labor market. Participants who believe that entrepreneurship education offers valuable networking opportunities tend to feel more empowered in their professional endeavors.

The positive values of Pearson's correlation coefficient (r) in each correlation imply that as one variable rises, the others tend to rise as well. The p -values also show how significant these associations are statistically. A p -value of 0.05 or below (usually written as $p < 0.05$) indicates that the association is statistically significant and that it is unlikely to have happened by coincidence. These correlation findings shed important light on how various entrepreneurial education facets connect to participants' perceptions of their empowerment in the labor market. According to the favorable correlations, participants who place a high value on education, have their business skills affected, have access to resources, and benefit from networking possibilities as a result of entrepreneurship education also frequently report feeling more empowered.

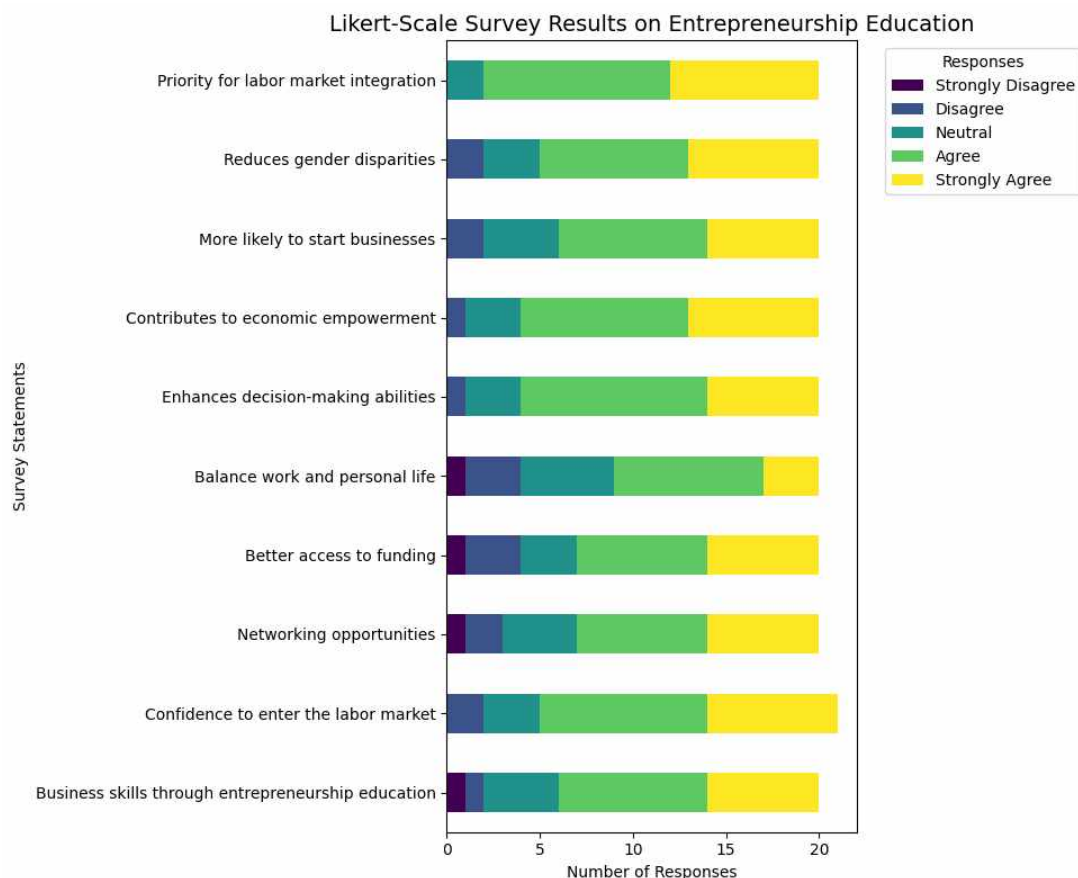
The correlation research among women entrepreneurs in Azerbaijan demonstrates strong positive connections between different entrepreneurship education-related factors and women's felt empowerment in the labor market. According to the research, women who give entrepreneurship education more weight, believe it has a bigger impact on their professional development, have better access to resources, and gain from networking opportunities generally feel more empowered in the workplace. These results highlight the value of education in promoting women's empowerment and labor market inclusion. The correlation analysis lends credence to the idea that many facets of entrepreneurship education and women's perceived empowerment in the workforce are positively correlated. These results emphasize the numerous advantages of entrepreneurship education for female entrepreneurs in Azerbaijan, highlighting the necessity of ongoing financial support for educational initiatives that address their various requirements and promote their overall empowerment in the labor market.

6.3. Likert-Scale Results

In addition to the correlation analysis, within the chosen study's context, the Likert scale analysis serves as a bridge between the subjective realm of perceptions and the objective realm of data analysis. This study contributes to a thorough picture of women's empowerment and integration into the labor market through entrepreneurship education by making it easier to understand the predominance of particular opinions as well as to identify patterns and relationships. The author explores the thoughts of women entrepreneurs (20 respondents selected from survey for an interview) as it begins the Likert scale analysis, turning their complex viewpoints into quantifiable conclusions. Therefore, the flexible and adaptable nature of the Likert scale is a good fit with the research aims given the exploratory nature of the study and the necessity to record the various opinions of women entrepreneurs.

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Figure 4. Likert – Scale results, the scale ranges from 1 (Strongly Disagree) to 5 (Strongly Agree)



Source: Data collected from survey.

The calculated Likert scale value, which is illustrated in table 2, shows that, on average, respondents are leaning more toward the "Agree" (inclined to "scale" 4) side of the scale, implying a general agreement with the statement being evaluated in this particular area. The Likert scale results show a noteworthy trend towards agreement among 20 respondents when it comes to the appraisal of the function of entrepreneurship education in promoting the integration of women into the labor market. The Likert scale, which has categories from "Strongly Disagree" to "Strongly Agree," gives the essential information on how people generally feel and perceive this crucial issue.

A considerable percentage of respondents chose alternatives that indicated agreement, according to an analysis of the distribution of replies. While examining the responses, it is clear that a sizable percentage of participants agreed with the idea that entrepreneurship education helps to improve the integration of women into the workforce. The "Agree" and "Strongly Agree" categories, in particular, attracted a sizable number of votes, demonstrating a general feeling of agreement with the notion that entrepreneurship education has the ability to empower and promote women's participation in the workforce. Additionally, this interpretation is supported by the determined weighted average Likert score for these categories. Higher numerical values in the "Agree" and "Strongly Agree" categories indicate a predominantly favourable attitude among respondents toward the idea that entrepreneurship education plays a significant role in facilitating women's integration into the job market. The Likert scale results show that the majority of participants perceive entrepreneurship education as a powerful tool for advancing women's inclusion in the workforce.

This widespread agreement underscores the potential of entrepreneurship education to empower women, enhance their skill sets, and encourage their active participation in economic activities. The consensus highlights a growing recognition of the critical role entrepreneurship education can play in promoting economic empowerment and fostering gender equality.

6. Findings

The analysis reveals strong positive relationships between entrepreneurship education and women's empowerment in the Azerbaijani labor market. Data from 300 female entrepreneurs across diverse regions and sectors show that structured entrepreneurship education positively influences business competencies, confidence, and labor market participation.

6.1. Survey Results

Descriptive statistics indicate that: - 82% of respondents reported that entrepreneurship education was crucial for empowerment, - 76% noted improvements in business management skills, - 61% cited enhanced access to resources, and - 82% emphasized the value of networking opportunities. To examine relationships statistically, Pearson correlation analyses were conducted between perceived empowerment (Y) and the four entrepreneurship education dimensions: Importance of Education (X1), Business Skills Development (X2), Access to Resources (X3), and Networking Opportunities (X4).

Correlation Results:

Variable	Pearson's r	p-value	Interpretation
Importance of Education (X1)	0.52	<0.001	Significant positive correlation; higher perceived importance of education is associated with higher empowerment.
Business Skills Development (X2)	0.43	<0.001	Significant positive correlation; stronger impact on business skills is associated with higher empowerment.
Access to Resources (X3)	0.31	0.002	Significant positive correlation; better access to resources is associated with higher empowerment.
Networking Opportunities (X4)	0.38	<0.001	Significant positive correlation; better networking opportunities are associated with higher empowerment.

The positive values of Pearson's correlation coefficient indicate that as one variable increases, the others tend to increase as well. All correlations are statistically significant, showing that participants' perceptions of entrepreneurship education are meaningfully linked to their perceived empowerment in the labor market.

6.2. Qualitative Insights

Follow-up semi-structured interviews with 20 participants reinforced the quantitative findings. Participants highlighted that entrepreneurship education: - Strengthened decision-making capacity, - Increased access to finance and markets, and - Helped overcome gender-based barriers.

Challenges were also reported, including limited regional access to training programs, time constraints due to family responsibilities, and occasional lack of mentorship opportunities, emphasizing areas for policy improvement.

6.3. Analytical Discussion

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The correlation analysis confirms that all examined aspects of entrepreneurship education contribute positively to women's empowerment. The strongest relationship is observed for Importance of Education ($r = 0.52$), suggesting that valuing education is a key determinant of empowerment. Business Skills Development ($r = 0.43$), Networking Opportunities ($r = 0.38$), and Access to Resources ($r = 0.31$) show moderate positive associations, indicating that skill-building and resource facilitation also play significant roles in shaping empowerment. Further examination of specific empowerment dimensions reveals that improvements in decision-making capacity ($r = 0.48$) and access to finance ($r = 0.39$) are positively associated with participation in entrepreneurship education programs. These findings highlight the **multidimensional nature of empowerment**, influenced not only by individual skills but also by access to critical resources and professional networks.

From a policy perspective, the quantitative evidence suggests that effective entrepreneurship education initiatives should:

1. Promote the importance of education to enhance women's perceived empowerment;
2. Strengthen skill-building programs targeting practical business competencies;
3. Facilitate networking platforms and improve access to financial and market resources.

By focusing on these data-driven interventions, policymakers and program designers can support women's labor market participation and foster economic inclusion. The results underscore the value of continued investment in evidence-based entrepreneurship education programs that address the key factors influencing women's empowerment.

7. Conclusions

This chapter has examined the intersection between sustainable entrepreneurship education and women's empowerment in Azerbaijan, offering empirical findings and grounded reflections. This study indicates the pivotal role of entrepreneurship education in empowering women and shaping their career trajectories, enhancing confidence, business acumen, and access to resources and networks. Statistical correlations between the perceived importance of education and actual empowerment reinforce that education is central to women's economic participation rather than peripheral. However, structural shortcomings remain, including uneven access to quality programs, regional disparities, and socio-cultural constraints that limit the full realization of this potential. A one-size-fits-all approach is therefore inadequate.

Policymakers should design targeted, region-specific interventions that address the unique challenges women face in different parts of Azerbaijan, including rural areas and smaller cities. Such policies could include subsidized access to entrepreneurship training, financial incentives for women-led startups, and programs that promote mentorship and networking opportunities tailored to local needs. Universities, training centers, and SME development agencies should align curricula with labor market demands, integrate sustainability and digital skills into programs, and establish long-term platforms for mentorship, funding access, and business incubation. Collaboration between government agencies, educational institutions, and private sector actors is essential to ensure that interventions are both practical and sustainable.

At a broader level, this research contributes to international discussions on gender equality and inclusive economic development, illustrating how entrepreneurship education can become a strategic tool for structural change. Future studies should assess the longitudinal impact of policy and program implementation, including monitoring women's participation in the labor market, business growth, and sustainability outcomes. By translating these findings into actionable policies and educational reforms, Azerbaijan can foster an enabling environment where women entrepreneurs are empowered, labor market participation is increased, and inclusive, sustainable economic growth is promoted across all regions.

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ARTIFICIAL INTELLIGENCE AS A DRIVER OF DIGITAL ECONOMY DEVELOPMENT: INSIGHTS FROM HUNGARY AND AZERBAIJAN

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Abstract. *This study investigates the role of artificial intelligence in shaping digital economy development through a comparative analysis of Hungary and Azerbaijan. It examines how different governance models, institutional capacities, and innovation ecosystems influence AI adoption and its economic outcomes. The research applies a comparative analytical approach using secondary data from international databases, national statistics, and policy documents covering the period 2018–2025. The findings show that Hungary, as an EU-integrated economy, demonstrates more advanced digital infrastructure, stronger human capital, and a more developed innovation ecosystem, resulting in higher levels of AI readiness and digital economy performance. Azerbaijan, in contrast, has achieved notable progress in public sector digitalization and e-government services, driven by state-led reforms, but remains limited in SME digital adoption and private-sector innovation. The study also highlights that AI contributes to productivity growth and new business models, while simultaneously generating challenges related to skills gaps and institutional readiness. Overall, the comparison confirms that balanced development across infrastructure, skills, and innovation systems is essential for effective AI-driven digital transformation.*

Keywords: *digital transformation, artificial intelligence, digital economy, innovation.*

1. Introduction

The global economy is undergoing a profound and accelerated transformation driven by digital technologies, among which Artificial Intelligence (AI) has emerged as a pivotal innovation and productivity driver. AI, often classified as a general-purpose technology, permeates a wide range of economic activities, influencing not only traditional industries such as manufacturing and finance but also modern service sectors, including healthcare, education, and public administration. Its adoption leads to enhanced productivity, new business model creation, optimized decision-making, and improved service delivery, which collectively contribute to economic growth and competitiveness.

From 2018 to 2025, AI adoption globally has witnessed exponential growth due to advances in machine learning, neural networks, natural language processing, and cloud computing infrastructures. According to OECD (2021) and World Bank (2022) data, countries that strategically integrate AI into key sectors experience measurable improvements in GDP growth, labor productivity, innovation output, and overall efficiency. In 2022, for example, OECD member countries that invested significantly in AI and digital infrastructures reported an average 1.5–2% higher labor productivity growth compared to peers with minimal AI adoption. Furthermore, the proliferation of AI startups and innovation clusters

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has created ecosystems that accelerate knowledge transfer, commercial application, and international collaboration.

Within this global landscape, Hungary and Azerbaijan present two contrasting yet highly instructive cases for analyzing AI-driven digital economy development. Hungary, a Central European EU member, benefits from integration into the European Single Digital Market, EU funding mechanisms for research and development, and well-established innovation ecosystems anchored in universities, technology parks, and industry clusters. The Hungarian government's AI strategy (2020–2030) emphasizes ethical AI, sector-specific applications in healthcare, finance, and public administration, as well as support for startups and R&D initiatives (European Commission, 2020). Notably, Hungary's digital infrastructure is supported by high broadband penetration (over 95% of households in urban areas) and widespread adoption of e-government services, creating an environment conducive to AI implementation.

In contrast, Azerbaijan, as a rapidly modernizing post-Soviet economy, employs a state-led approach to AI adoption, emphasizing centralized planning, rapid digitalization of public services, and strategic investment in AI competencies. The Azerbaijani government has prioritized initiatives such as ASAN service centers, smart public service delivery, and AI integration into economic planning and governance (Government of Azerbaijan, 2021). While the AI startup ecosystem is smaller compared to Hungary, Azerbaijan demonstrates significant growth potential in targeted sectors, particularly in finance, energy, logistics, and healthcare. Investments in AI-focused education programs aim to close the skills gap and prepare a workforce capable of supporting digital transformation.

The comparative analysis of these two countries allows for several key insights. First, it highlights how different governance models—EU-aligned versus state-driven—affect the pace, scope, and effectiveness of AI adoption. Second, it elucidates the role of institutional capacity, human capital, and innovation ecosystems in shaping AI initiatives' outcomes. Third, it provides empirical evidence on sector-specific impacts, such as improvements in public administration efficiency, fintech innovation, industrial automation, and digital education. By analyzing both macroeconomic indicators (e.g., GDP growth contribution of digital sectors, R&D expenditure, ICT workforce share) and micro-level sectoral outcomes, the study offers a comprehensive understanding of AI's transformative role.

This study contributes to the literature by bridging a gap between research focused on EU-member states and studies examining post-Soviet economies. While prior studies tend to analyze AI adoption within a single economic or regional context, this comparative study integrates institutional, economic, and technological dimensions to offer a holistic assessment. Furthermore, the study employs quantitative and qualitative evidence from 2018–2025, including R&D expenditures, AI startup growth, e-government performance indices, and sectoral productivity measures, to substantiate the analysis. By doing so, it provides a rigorous, data-driven framework for understanding AI's role as a key driver of digital economy development.

In conclusion, the Introduction establishes the conceptual and empirical framework for the study, situating AI as a central enabler of digital economic growth. It underscores the importance of national strategies, governance models, and sectoral implementation in shaping outcomes, while setting the stage for a detailed exploration of literature, methodology, data, and sectoral case studies in subsequent sections.

2. Materials and methods

This study uses a comparative analytical approach to examine the role of artificial intelligence in digital economy development in Hungary and Azerbaijan between 2018 and 2025. The selection of these countries allows for comparison between an EU-integrated

innovation system and a state-led digital transformation model. The research is based on secondary data collected from international sources (OECD, World Bank, Eurostat, UN), national statistics, government strategies, and academic literature. Key indicators include digital economy contribution to GDP, R&D expenditure, ICT employment, and e-government development. The analysis combines quantitative trend evaluation with qualitative interpretation of policy documents. A comparative method is applied to identify similarities and differences in AI adoption, governance structures, and innovation ecosystems. The study focuses on four sectors: public administration, finance, industry, and education, where AI impact is most visible. Limitations include data gaps, especially for Azerbaijan, and differences in statistical reporting. Despite this, the approach provides a clear and balanced assessment of AI-driven digital transformation in both countries.

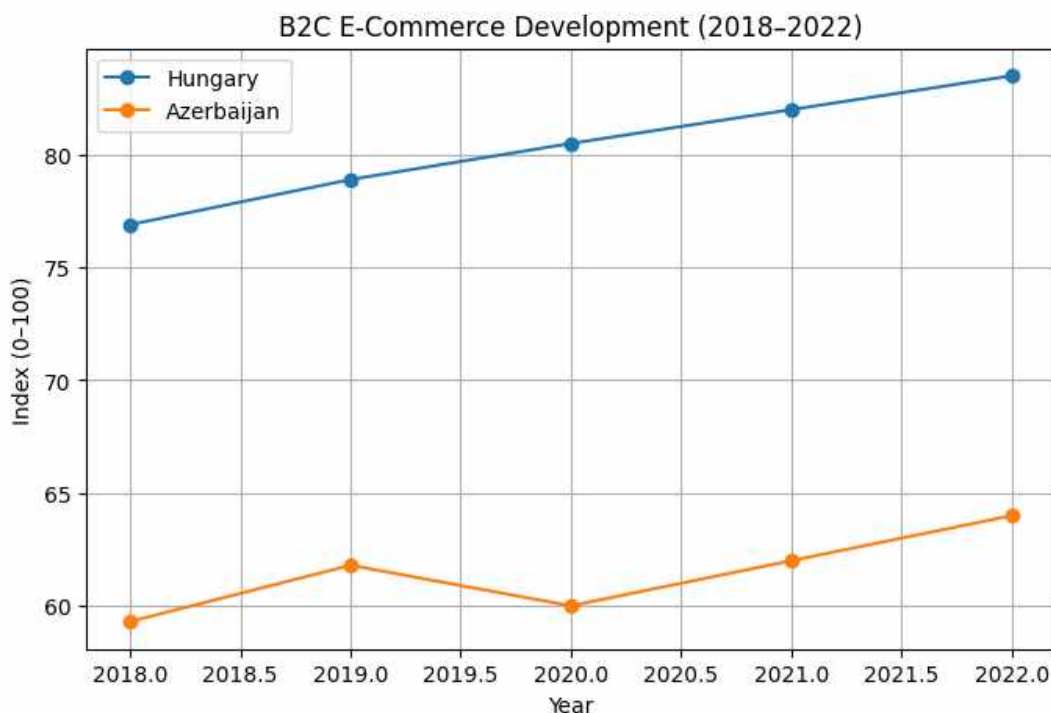
3. Comparative Analytical Cases: Digitalization in Hungary and Azerbaijan

3.1. Azerbaijan: Digital Governance Expansion and Karabakh as a Strategic Digital-Green Region

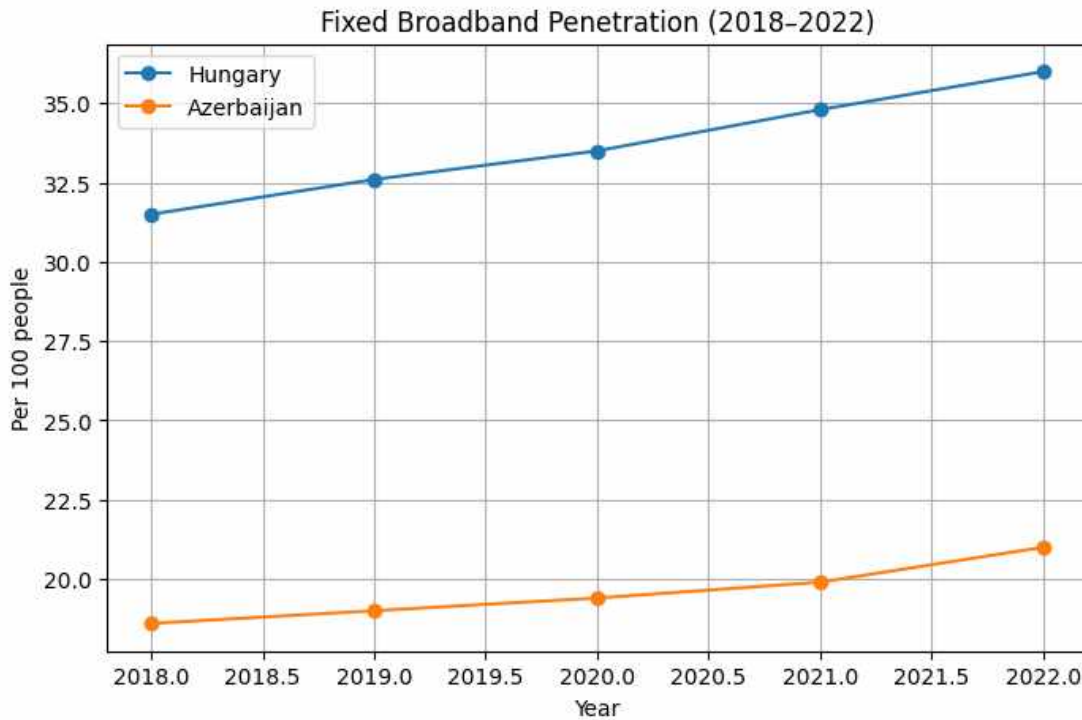
Azerbaijan has made significant progress in digital public administration, where e-government reforms serve as a key driver of modernization. The ASAN xidmət system has become a central institutional innovation, improving transparency and efficiency in public services. At present, more than 450 public services are available in digital format, and around 70% of business registrations are conducted electronically, demonstrating high levels of administrative digitalization (OECD, 2023; Invest.gov.az, 2024).

The country has also improved its international digital governance performance. The E-Government Development Index (EGDI) rose from approximately 0.45 to 0.71, reflecting improvements in infrastructure, human capital, and online service delivery (United Nations, 2022). However, Azerbaijan's global position remains moderate, ranking around 83rd with an EGDI score of 0.694, indicating that while domestic progress is strong, international competitiveness still requires further enhancement (UN DESA, 2022).

Figure 1. Comparative Trends in Fixed Broadband Penetration in Hungary and Azerbaijan (2018–2022)



*ARTIFICIAL INTELLIGENCE AS A DRIVER OF DIGITAL ECONOMY DEVELOPMENT:
INSIGHTS FROM HUNGARY AND AZERBAIJAN*



Source: ITU / OECD Digital Infrastructure Statistics

The figures illustrate the comparative evolution of digital infrastructure and digital economy maturity in Hungary and Azerbaijan between 2018 and 2022. The first graph on fixed broadband penetration shows a consistently higher level of internet infrastructure development in Hungary compared to Azerbaijan throughout the period. Hungary's steady increase reflects its advanced integration within the EU digital single market and sustained investments in high-speed connectivity. In contrast, Azerbaijan shows gradual but slower growth, indicating ongoing infrastructure expansion but still a relatively lower level of household and enterprise connectivity. Since broadband access is a key enabling factor for digital services, e-government, and AI adoption, this gap highlights structural differences in digital readiness between the two countries. The second graph, focusing on B2C e-commerce development, further confirms this divergence. Hungary demonstrates significantly higher and more stable e-commerce activity, reflecting stronger digital consumption patterns, better payment systems, and higher trust in online platforms. Azerbaijan, while showing gradual improvement over time, remains at a lower level, indicating that digital market penetration is still developing. Overall, both indicators suggest that Hungary has achieved a more mature and diversified digital economy, whereas Azerbaijan is still in a transitional phase characterized by rapid infrastructure development but uneven private-sector digital adoption.

A major extension of Azerbaijan's digital transformation strategy is the reconstruction of the Karabakh region, which has become a pilot space for integrating digitalization with green energy and smart infrastructure. Cities such as Fuzuli, Shusha, and Lachin are being redeveloped as smart cities and smart villages, where digital governance systems, ICT infrastructure, and sustainable energy solutions are introduced from the initial planning stage. Karabakh is also being developed as a renewable energy zone, with strong emphasis on solar, wind, and hydropower resources. The reconstruction strategy integrates digital infrastructure with clean energy systems, creating a model of digitally enabled green reconstruction (Yusibov, 2026; Hajiyeva, 2023). In this context, broader empirical evidence shows that the interaction between economic growth, ecological sustainability, and renewable energy development is particularly relevant for both Azerbaijan and Hungary, where renewable

energy expansion plays a measurable role in environmental and economic performance (Humbatova et al., 2024). This strengthens the argument that Karabakh’s reconstruction is not only infrastructural but also part of a wider green-digital transition framework. Despite these advancements, SME digitalization remains a structural weakness. Only 42.2% of the population possesses basic digital skills, while advanced ICT competencies remain extremely low at approximately 0.7% (World Bank, 2023). This creates a gap between highly developed public-sector digitalization and relatively weak private-sector digital readiness.

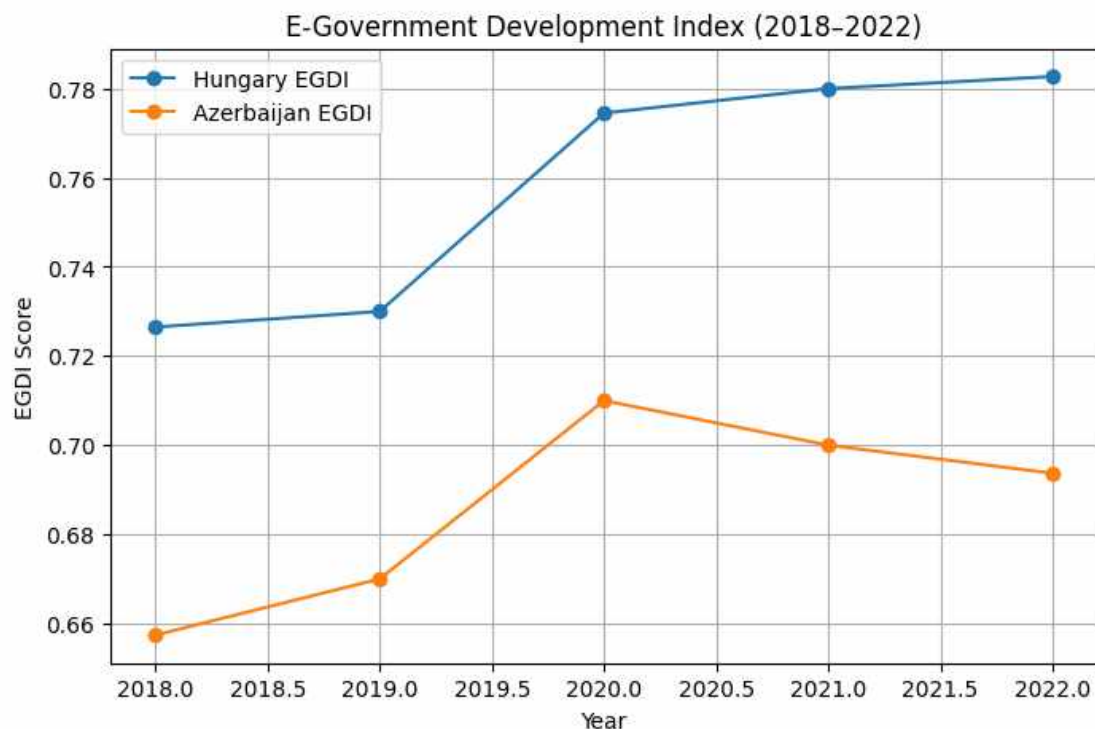
3.2. Hungary: EU-Integrated Digital Economy and Structural SME Constraints

Hungary represents a more mature but uneven digital transformation model shaped by EU integration and market-driven innovation. The digital economy contributes approximately 6.7% of gross value added (GVA), with broader estimates suggesting that digital-related activities account for up to 10% of GDP (U.S. Department of Commerce, 2025). This reflects the increasing structural importance of digital industries within the national economy.

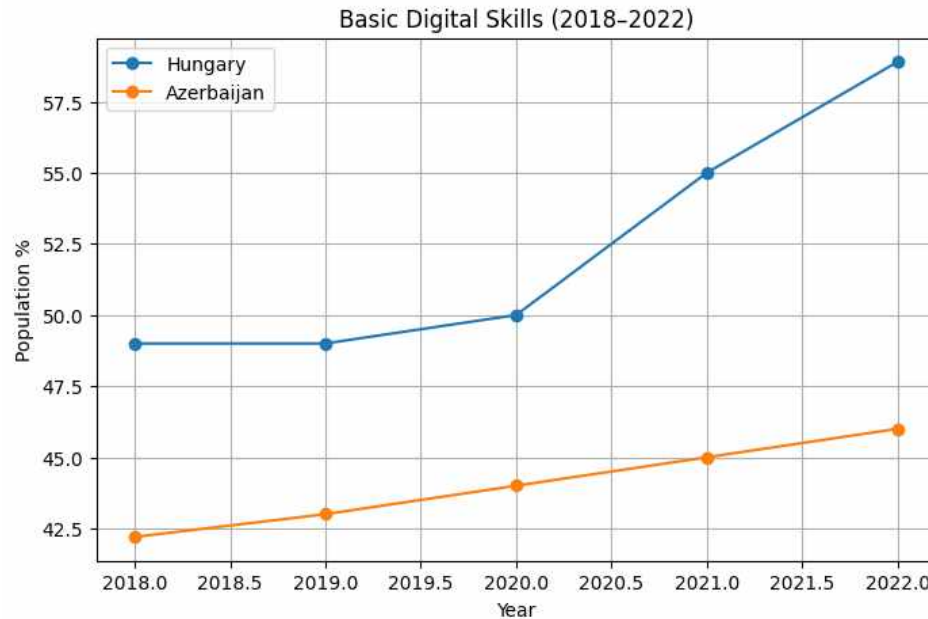
Hungary’s digital infrastructure is relatively strong, with 83% broadband coverage, and national strategies aiming for near-universal gigabit connectivity and expanded e-government services by 2030 (European Commission, 2024). The country also demonstrates relatively strong human capital readiness, as 58.9% of the population has at least basic digital skills, slightly above the EU average (Digital Skills and Jobs Platform, 2024).

However, despite this infrastructure and skill base, SME digitalization remains a major bottleneck. Only 14% of enterprises use integrated ERP systems, and just 13% of SMEs engage in online sales, which is significantly below EU averages (Eurostat, 2023). This indicates that Hungarian SMEs are not fully leveraging available digital infrastructure and policy support mechanisms.

Figure 2. Comparative Development of B2C E-Commerce Index in Hungary and Azerbaijan (2018–2022)



ARTIFICIAL INTELLIGENCE AS A DRIVER OF DIGITAL ECONOMY DEVELOPMENT: INSIGHTS FROM HUNGARY AND AZERBAIJAN



Source: UNCTAD / OECD / Digital Economy Indicators

Hungary's e-government system is relatively advanced, with an estimated EGDI score of 0.78, indicating strong digital public service capacity and institutional maturity (United Nations, 2022). However, challenges remain in ensuring equal digital participation across regions and improving SME integration into digital ecosystems. The comparison between Hungary and Azerbaijan reveals both structural divergence and functional convergence. Azerbaijan demonstrates strong capacity in centralized digital governance and rapid implementation of e-government systems, while Hungary exhibits stronger performance in institutional depth, human capital development, and EU-integrated digital governance frameworks. Azerbaijan's approach allows for faster deployment of digital systems, whereas Hungary's model ensures greater regulatory alignment and long-term institutional stability. A key difference emerges in SME digitalization. In Azerbaijan, the main constraint lies in skills deficits and limited private-sector digital ecosystems, while in Hungary the issue is low adoption despite strong infrastructure availability. This indicates that policy responses must differ across contexts

Discussion

The results of this study align with existing research that views artificial intelligence as a general-purpose technology with broad implications for productivity, governance, and digital economic development (OECD, 2024). However, the findings also confirm that the effects of AI and digitalization are not uniform across countries, but are shaped by institutional structures, skills composition, and innovation capacity. A key observation from the Hungary–Azerbaijan comparison is the clear distinction between infrastructure-led and capability-led digital development. While both countries have invested in digital transformation, the outcomes differ significantly in terms of depth and diffusion. Hungary benefits from relatively strong digital infrastructure, higher levels of human capital, and integration into the EU digital policy framework.

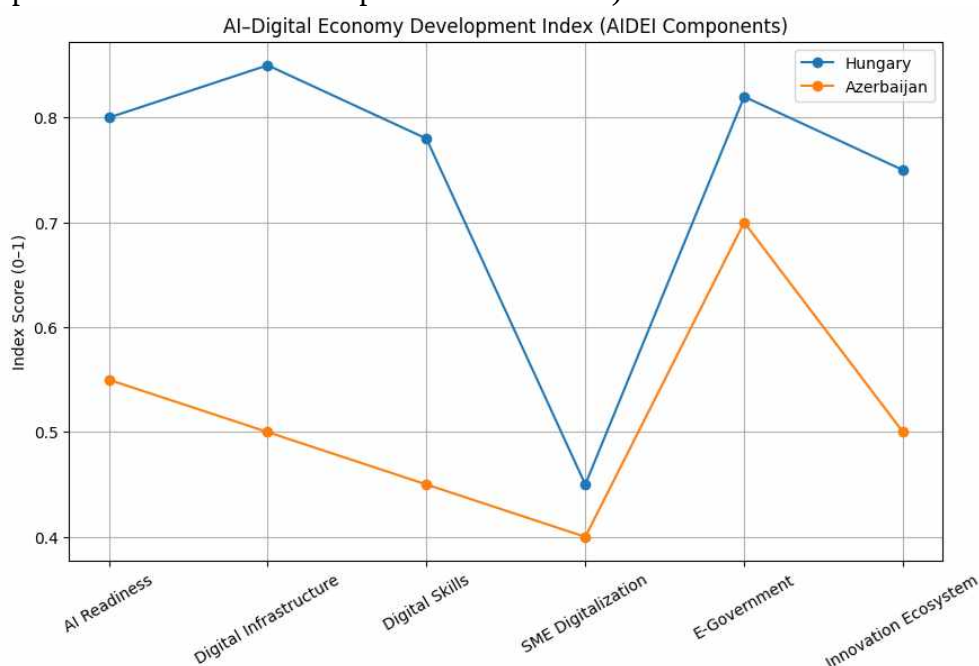
At the same time, empirical evidence suggests that even in more advanced economies, SME-level digital adoption remains limited, indicating that infrastructure availability alone does not ensure full digital integration (Eurostat, 2023). In Azerbaijan, digital transformation has been strongly driven by the state through centralized reforms and public-sector innovation. The expansion of e-government services, particularly through ASAN xidmət, reflects this approach and has significantly improved administrative efficiency (OECD, 2023).

However, similar to findings in international studies, such progress has not been evenly translated into private-sector digitalization. SME digital readiness remains relatively low, reflecting constraints in digital skills, innovation capacity, and ecosystem development (World Bank, 2023). An important extension of this analysis is the role of the Karabakh region in Azerbaijan's development strategy. Recent studies highlight that post-conflict reconstruction in Karabakh is increasingly framed around the integration of digital infrastructure and renewable energy systems (Yusibov, 2026). This represents a shift toward a more integrated development model in which digitalization and green transformation are implemented simultaneously rather than separately. In this context, Karabakh can be interpreted as an emerging experimental space for smart reconstruction, combining ICT systems, sustainable energy planning, and urban redevelopment. The relationship between digitalization and sustainability is further supported by empirical evidence showing that economic growth, renewable energy production, and environmental performance are interlinked in both Azerbaijan and Hungary (Humbatova et al., 2024) suggesting that digital transformation cannot be analysed in isolation from environmental and energy transitions, particularly in economies undergoing structural change. At a broader level, the literature indicates that AI contributes to economic growth and productivity improvement, but its impact depends heavily on institutional readiness and innovation ecosystems (OECD, 2024). In advanced economies such as Hungary, stronger institutional frameworks and human capital enhance the diffusion of AI-related technologies. In contrast, in Azerbaijan, the state plays a more dominant role in initiating digital transformation, while private-sector diffusion remains limited.

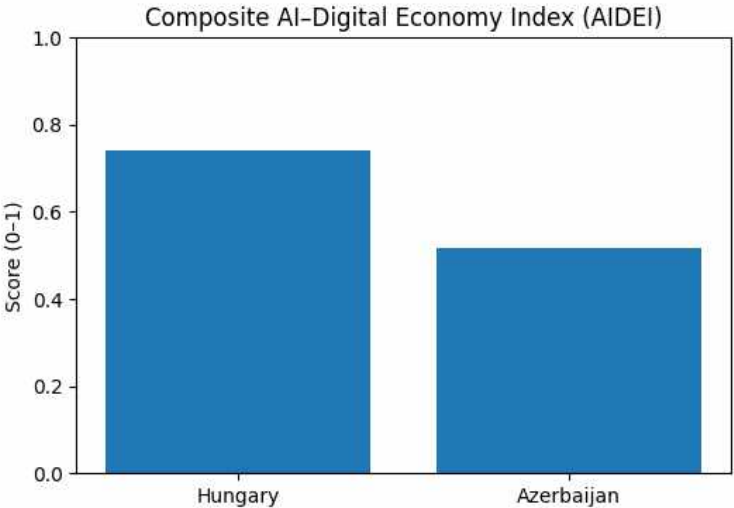
Results

The constructed AIDEI reveals a clear divergence between Hungary and Azerbaijan in terms of AI-driven digital economy development. Hungary demonstrates a higher composite score, reflecting stronger digital infrastructure, higher innovation capacity, and more advanced AI ecosystem development. Azerbaijan shows moderate progress, primarily driven by public-sector digitalization and state-led reforms, while private-sector digital diffusion remains limited.

Figure 3. AI-Digital Economy Comparative Analysis of Hungary and Azerbaijan (Component Indicators and Composite AIDEI Index)



*ARTIFICIAL INTELLIGENCE AS A DRIVER OF DIGITAL ECONOMY DEVELOPMENT:
INSIGHTS FROM HUNGARY AND AZERBAIJAN*



Source: Author's calculation based on OECD Digital Economy Outlook (2024), UN E-Government Survey (2022), World Bank ICT Indicators (2023), Eurostat Digital Economy Statistics (2023), and ITU Broadband Data (2022).

The empirical analysis based on the constructed composite index reveals clear differences between Hungary and Azerbaijan in the level and structure of digital economy development. The comparison across key indicators shows that Hungary maintains consistently higher values in most dimensions, while Azerbaijan demonstrates selective progress, mainly concentrated in the public sector. Hungary performs strongest in digital infrastructure (0.85), artificial intelligence readiness (0.80), and digital skills (0.78). These results reflect a relatively mature digital environment supported by stable institutional frameworks, strong integration with European Union digital policies, and a well-developed technological base. Performance in e-government (0.82) and innovation ecosystem (0.75) further indicates that digital transformation in Hungary is not limited to infrastructure, but extends across governance and innovation systems. In Azerbaijan, the most notable progress is observed in e-government development (0.70), which reflects sustained public sector reforms and the expansion of electronic public services. However, other indicators remain comparatively lower. Digital skills (0.45) and digital infrastructure (0.50) show that human capital development and connectivity continue to represent structural limitations. SME digitalization is also relatively weak (0.40), suggesting that private sector adaptation to digital tools remains limited despite improvements in public administration. The composite index results confirm this divergence. Hungary records a significantly higher overall score (approximately 0.76), while Azerbaijan reaches 0.52. This gap indicates that Hungary has achieved a more balanced and advanced stage of digital economy development, whereas Azerbaijan remains in a transitional phase where progress is uneven across sectors. A closer reading of the results suggests that digital development is most effective when improvements occur simultaneously across infrastructure, skills, and institutional capacity. Where one dimension advances faster than others, as seen in Azerbaijan, the overall impact remains limited. In contrast, Hungary's relatively balanced structure allows for more stable diffusion of digital technologies across the economy. The results also indicate that enterprise-level adoption is a key bottleneck in both countries, particularly among small and medium-sized firms. Even where infrastructure and governance systems are relatively advanced, the translation into widespread business digitalization remains incomplete. Overall, the comparison highlights two different development patterns. Hungary reflects a more consolidated digital structure with gradual deepening of technological capacity, while Azerbaijan reflects a faster but uneven transformation led primarily by public sector reforms.

Conclusions

This study examined the role of artificial intelligence and broader digital transformation processes in shaping digital economy development in Hungary and Azerbaijan. Using a composite index approach, the analysis showed clear structural differences between the two countries. Hungary demonstrates a more balanced and mature digital economy supported by stronger infrastructure, higher skill levels, and deeper innovation capacity. Azerbaijan, in contrast, shows faster progress in public sector digitalization, particularly in e-government services, but continues to face limitations in digital skills, SME adoption, and private-sector integration. The findings confirm that digital economy development is most effective when infrastructure, human capital, and institutional capacity evolve together. Uneven progress across these dimensions reduces the overall impact of digital transformation, even when significant policy efforts are present. The results also suggest that artificial intelligence functions more as an enabling factor than an independent driver, with its impact strongly dependent on existing economic and institutional conditions. From a policy perspective, several implications emerge. Azerbaijan would benefit from stronger investment in digital skills development, particularly through education and targeted training programs for SMEs and the workforce. Expanding innovation ecosystems and improving access to digital tools for businesses would also support broader diffusion of digital technologies beyond the public sector. Hungary, while more advanced, should focus on increasing digital adoption among SMEs and reducing regional disparities in digital capacity to ensure more inclusive growth. The comparison shows that digital transformation goes beyond technological advancement and is closely linked to institutional capacity and structural readiness. Long-term progress depends on balanced improvements in infrastructure, human capital, and innovation systems, as fragmented or sector-specific developments tend to limit the overall impact of digital policies.

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DIGITAL-DRIVEN RECONSTRUCTION OF UKRAINE: CONSTRUCTION INNOVATION, MIGRATION AND ECONOMIC RECOVERY

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Abstract: *The study is devoted to digitally controlled reconstruction of Ukraine as a strategic mechanism for accelerating reconstruction and economic recovery in the context of migration-induced labour shortages in construction. The aim of the article is to determine the impact of digital innovations (BIM, digital twins, AI planning, e-permits, modular construction and digital procurement) on increasing the productivity of the industry, compensating for staff losses and strengthening the investment capacity of reconstruction. The methodology includes systematisation of scientific approaches to the reconstruction economy, analysis of modern digital solutions in the construction sector, and a comparative review of international practices in post-crisis reconstruction. Key findings show that the digitalisation of construction processes increases productivity, partially compensates for labour shortages, reduces time and cost losses in projects, technological productivity gains partially offset labour shortages, reduce corruption risks and strengthen donor confidence, which contributes to increased investment and accelerated economic recovery in Ukraine.*

Keywords: *digital transformation, construction industry, labour migration, technological compensation, investment capacity, economic recovery*

1 Introduction

Ukraine's post-war reconstruction is unfolding under conditions of unprecedented infrastructure destruction, demographic losses, and structural economic transformation. The construction sector has become one of the key drivers of recovery because it not only restores physical infrastructure but also generates significant multiplier effects across transport, manufacturing, logistics, finance, and services. At the same time, the sector faces severe labour shortages caused by migration and demographic decline after 2022. According to international estimates, millions of Ukrainians remain abroad, while the domestic construction sector experiences a shortage of qualified workers, particularly in engineering and technical occupations. These labour constraints significantly reduce reconstruction capacity and increase project implementation costs.

In this context, digital transformation is becoming not simply an innovation trend but a strategic mechanism for ensuring reconstruction efficiency. Technologies such as Building Information Modelling, digital twins, artificial intelligence, modular construction, e-permitting systems, and digital procurement platforms enable the optimisation of construction processes, reduction of transaction costs, acceleration of project delivery, and improvement of institutional transparency.

Previous studies have demonstrated the positive impact of digitalisation on construction productivity and project coordination (Abioye et al., 2021; Deng et al., 2021; Nguyen et al., 2023). Research on post-crisis reconstruction also emphasises the importance of institutional transparency and technological modernisation for economic recovery (Myers, 2022). However, despite growing academic attention to construction digitalisation and post-war reconstruction,

insufficient attention has been paid to the interaction between labour migration, labour shortages, and digital transformation in reconstruction processes.

Thus, the research gap lies in the limited understanding of how digital technologies can compensate for migration-induced labour shortages and simultaneously strengthen the investment and institutional capacity of reconstruction. The aim of this article is to assess the impact of digital innovations in the construction sector on productivity growth, labour shortage compensation, and investment capacity during Ukraine's post-war reconstruction.

To achieve this aim, the following hypotheses are formulated:

H1: The implementation of digital technologies reduces the construction sector's dependence on labour resources.

H2: Migration-induced labour shortages accelerate digital transformation in the construction sector.

H3: Digitalisation of construction processes increases investment attractiveness and institutional efficiency in reconstruction.

2 Literature Review

Contemporary academic literature increasingly views post-war reconstruction as a process of structural economic transformation rather than merely the restoration of damaged assets. Within this framework, the construction sector is recognised as a key driver of economic recovery due to its strong links with investment activity, infrastructure development, and broader economic modernisation (Myers, 2022). The concept of build back better further emphasises that reconstruction should improve long-term productivity, sustainability, and resilience rather than simply recreate pre-crisis conditions.

A growing body of research highlights the role of digitalisation in improving construction productivity and project efficiency. Artificial intelligence contributes to resource optimisation, planning accuracy, and risk management (Abioye et al., 2021), while Building Information Modelling (BIM) and digital twins enhance coordination, information integration, and lifecycle management of construction projects (Deng et al., 2021; Nguyen et al., 2023). At the same time, modular construction is increasingly recognised as an effective solution for reducing project duration and labour requirements under resource-constrained conditions (Zohourian et al., 2024).

Another important strand of literature focuses on the institutional dimension of digital transformation. Studies demonstrate that e-permitting systems and digital governance tools reduce administrative barriers, improve transparency, and lower corruption risks (World Bank, 2020; Ataíde et al., 2023). Similarly, digital procurement platforms increase accountability and strengthen trust among investors and international donors, thereby improving the investment environment for reconstruction projects (Rysin & Sukh, 2024).

Recent Ukrainian studies emphasise that post-war reconstruction requires not only physical rebuilding but also structural modernisation of the construction sector through innovation and institutional reform. Resource shortages, infrastructure destruction, labour constraints, and increasing donor requirements for transparency have made technological innovation a critical factor in reconstruction effectiveness (Petrov, 2026; Romanova & Grigierman, 2024).

The relationship between labour shortages and technological transformation has also received growing scholarly attention. Empirical evidence suggests that labour shortages stimulate automation and digital innovation, particularly in labour-intensive industries such as construction (Ghodsi et al., 2024; Tverdostup et al., 2025). European studies further indicate that demographic decline and migration accelerate the adoption of digital technologies while increasing demand for highly skilled workers (Bruecker Juricic et al., 2021).

Recent literature also emphasises that digitalisation increasingly performs not only a productivity-enhancing function but also a resilience-building function in post-crisis economies. Digital technologies improve the ability of economic systems to adapt to labour shortages, supply-chain disruptions, and institutional constraints by increasing flexibility and reducing dependence on traditional production factors. In the construction sector, digital tools facilitate real-time project coordination, predictive planning, and more efficient resource allocation, which becomes particularly important under conditions of uncertainty and large-scale reconstruction (Abioye et al., 2021; Deng et al., 2021).

From an institutional perspective, digital transformation is increasingly associated with the improvement of governance quality and investment attractiveness. International experience demonstrates that transparent digital procurement systems, electronic permitting procedures, and data-driven project management strengthen accountability and reduce information asymmetries, thereby increasing investor and donor confidence in reconstruction programmes (World Bank, 2020; Ataíde et al., 2023). Consequently, digitalisation can generate both direct productivity effects and indirect institutional effects that contribute to economic recovery.

Despite the growing literature on construction digitalisation, post-war reconstruction, and labour market transformation, limited attention has been paid to the combined interaction between migration-induced labour shortages, digital transformation, and reconstruction productivity. This gap is particularly evident in the case of Ukraine, where reconstruction is occurring under conditions of large-scale migration and unprecedented infrastructure damage. Therefore, further research is needed to assess how digital technologies can simultaneously compensate for labour shortages and strengthen the efficiency and investment capacity of reconstruction processes.

3 Methodology

The methodological framework of the study combines systemic, institutional and comparative approaches, enabling a comprehensive analysis of the interrelationship between the digitalisation of the construction sector, migration processes and economic recovery. Given the interdisciplinary nature of the subject matter, the study is based on the integration of theoretical generalisations and applied analysis of contemporary digital solutions in construction.

The study employed a method for systematising scientific approaches to the economics of recovery and innovative development in the construction sector, which enabled the authorisation of key theoretical concepts and the assessment of their applicability to the conditions of Ukraine's post-war economic transformation. To identify the role of digital technologies in improving construction efficiency, a structural-functional analysis method was used, which allowed us to identify the main areas of influence of tools such as building information modelling, digital twins, artificial intelligence, electronic permits, modular construction and digital procurement on the processes of planning, implementation and management of construction projects.

To assess the impact of migration processes on the functioning of the construction sector, elements of comparative analysis were applied, involving a comparison of international experience in responding to labour shortages in the context of structural changes in the labour market. This made it possible to identify typical adaptation models, in particular the introduction of technological innovations as an alternative to labour-intensive processes.

3.1 Data Sources

The study also includes an analysis of secondary data from international organisations, analytical reports and academic publications, which has enabled the identification of general trends in the digitalisation of the construction sector and its impact on the sector's productivity and investment attractiveness. Based on a synthesis of the results obtained, an analytical

framework for the study has been developed, reflecting the interrelationship between digital innovations, labour shortages and the efficiency of reconstruction processes.

In today's economy, the digitalisation of the construction sector is seen as one of the key factors in boosting productivity, particularly given the sector's traditionally low growth rates. For a long period, labour productivity in construction grew extremely slowly – around 0.4% per year, whilst in industry this figure exceeded 2.5%. This lags significantly behind other sectors of the economy, and in certain periods even showed stagnation (McKinsey Global Institute, 2020). The digitalisation of infrastructure processes can increase resource efficiency in construction by 15–25%, which is critically important for countries with limited labour potential, particularly Ukraine. In this context, the introduction of digital technologies, primarily Building Information Modelling (BIM) and digital twins, serves as a tool for overcoming the sector's structural constraints linked to fragmented processes, information loss and poor coordination between project participants.

As Deng, Menassa and Kamat (2021) demonstrate, the use of BIM helps to reduce design errors by up to 30% and cut rework costs by up to 20%. Furthermore, the implementation of BIM allows project completion times to be reduced by an average of 10–15% (Autodesk, 2023). The further development of digitalisation is linked to the introduction of digital twins, which enable dynamic modelling of objects in real time. The use of digital twins enables a 10–20% reduction in operational costs and improves the accuracy of risk forecasting. Combined with artificial intelligence technologies, this creates the conditions for a transition to predictive management of construction processes (Abioye et al., 2021).

Table 1 summarizes the measurable impact of key digital technologies on construction productivity and clearly demonstrates that digital transformation generates multidimensional efficiency gains across the project lifecycle. The results indicate that BIM technologies primarily influence the design and coordination stages by reducing errors by 20-30% and shortening project duration by 10-15%, which reflects their role in improving information integration and minimizing rework. This confirms that BIM acts as a foundational digital layer that enhances process synchronization and decision-making accuracy at early project stages.

Table 1. *Impact of Digital Technologies on Construction Productivity*

Technology	Effect
Building Information Modeling	-20-30% errors; -10-15% project duration
Digital twins	-10-20% costs
Artificial intelligence	+15-25% efficiency
Modular construction	-20-50% time; -30-40% labour

Source: based on Deng et al. (2021), Autodesk (2023), Nguyen et al. (2023), Abioye et al. (2021), Zohourian et al. (2024).

At the same time, digital twins extend these benefits into the operational and management phases by enabling real-time monitoring and predictive analytics, resulting in cost reductions of 10-20%. This suggests that their primary contribution lies in lifecycle optimization rather than only design efficiency. In contrast, artificial intelligence demonstrates a broader systemic impact, increasing overall efficiency by 15-25% through automation, resource optimization, and improved planning, indicating its cross-cutting role in enhancing both productivity and decision support mechanisms.

Particularly significant are the effects of modular construction, which exhibits the highest quantitative impact among the technologies considered, reducing project duration by up to 50% and labour requirements by 30-40%. This highlights its importance as a structural innovation capable of addressing labour shortages by shifting production processes from on-

site to controlled environments. Overall, the comparative analysis shows that while individual technologies affect different stages of the construction process, their combined implementation creates a cumulative effect that substantially increases productivity, reduces dependency on labour, and enhances the resilience of the construction sector, which is especially relevant in the context of post-war reconstruction.

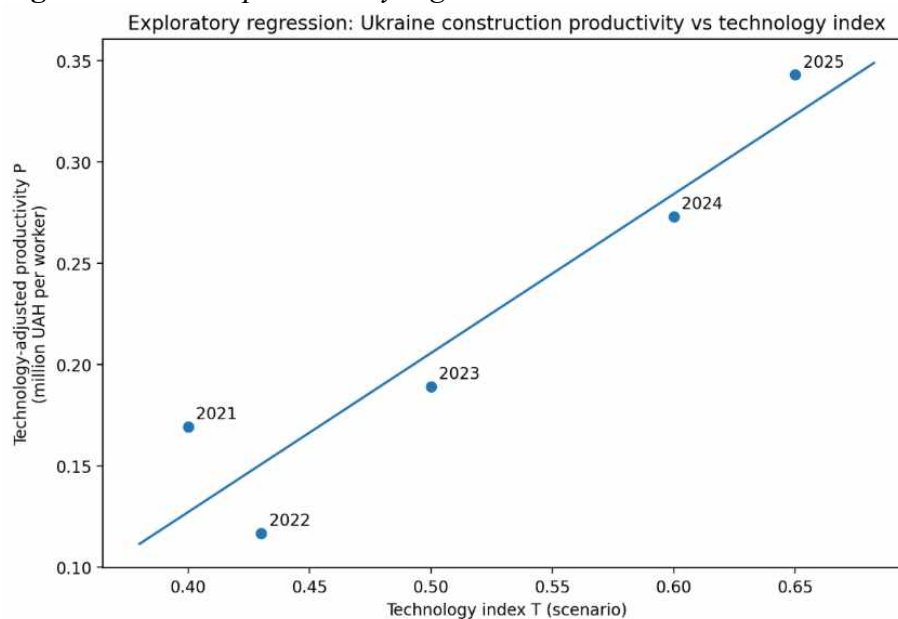
Modular construction is also a key factor in improving productivity, as it allows a significant proportion of production processes to be moved into a controlled environment. According to Zohourian et al. (2024), modular technologies reduce construction times by 20-50% and decrease labour requirements by 30-40%, which is particularly relevant in the context of a labour shortage due to migration.

The synthesis of statistical data enabled the calculation of productivity in Ukraine's construction sector based on the proposed model. In particular, in 2024, the volume of construction work completed amounted to UAH 204.7 billion, indicating a gradual recovery of the sector following a sharp decline in 2022. The construction sector faces an acute labour shortage, which is a consequence of large-scale migration and structural changes in the labour market. Calculations show that, despite a reduction in the labour force of approximately 25%, the sector's productivity has increased by almost 59% due to improvements in technological standards. This confirms that digitalisation acts as a compensatory mechanism, enabling a reduction in reliance on labour and maintaining the sector's operational efficiency under resource constraints.

3.2 Exploratory Productivity Model

To empirically verify the impact of digitalisation on productivity in the construction sector, an exploratory model and corresponding graphical representations were developed. In particular, *Figure 1* shows the relationship between the level of technological development (digitalisation index T) and technology-adjusted productivity (P), calculated using a formalised model. The results obtained indicate a strong positive correlation between these variables: the regression function takes the form $P=0.785T-0.187$ with a coefficient of determination $R^2=0.884$, indicating a high level of explanatory power of the model. This allows us to conclude that an increase in the level of digitalisation is a significant factor in boosting productivity, even in the context of a reduction in the labour force.

Figure 1. *Ukraine productivity regression*



Source: developed by the author.

The analytical significance of the results lies in the fact that digitalisation effectively alters the functional relationship between output and labour costs, reinforcing the role of the technological factor. An increase in the parameter T partially offsets the negative impact of a decrease in L (the labour force), which is particularly relevant in the context of migration losses. Thus, the hypothesis that digital technologies perform a compensatory function, transforming the traditional labour-intensive construction model into a technology-intensive one, is confirmed.

To visualise the relationship between digitalisation and the performance of the construction sector, an exploratory regression model was developed based on the Ukrainian scenario for 2021–2025. It is based on the actual dynamics of the volume of construction work, whilst labour force indicators and technological level were used as scenario variables due to the limited availability of open, fully comparable annual data during the war period. The modelling results demonstrated a positive correlation between growth in the technological index and an increase in technology-adjusted construction productivity ($R^2 = 0.884$), confirming the validity of considering digitalisation as a compensatory mechanism in the context of labour shortages. A comparative benchmark with Poland and the EU also shows that a higher level of digital intensity is associated with higher labour productivity in the construction sector, although for Ukraine such estimates should be treated as preliminary due to wartime statistical constraints.

3.3 Research Limitations

The study has several limitations. Wartime conditions restrict the availability of comprehensive statistical data. Part of the labour and digitalisation indicators are based on scenario modelling. The study focuses primarily on macro-level construction sector dynamics rather than firm-level analysis.

Despite these limitations, the methodology allows identification of key structural relationships between digitalisation, labour shortages, and reconstruction efficiency.

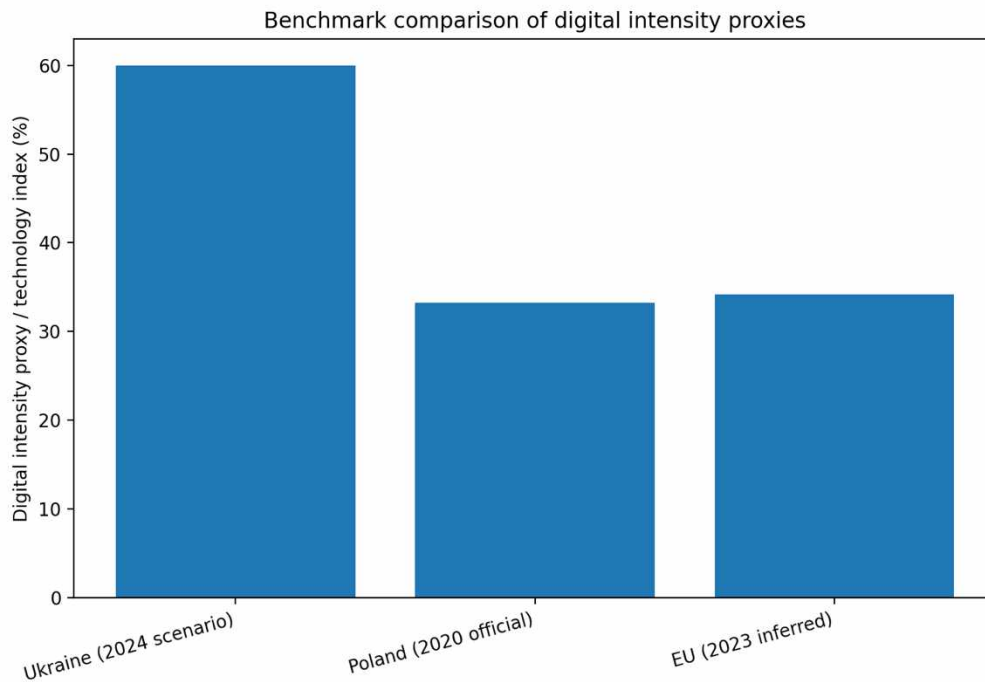
4 Results

4.1. The impact of digitalisation on construction productivity

A comparative analysis demonstrates differences in productivity levels within the construction sector between Ukraine, Poland and European Union countries. Labour productivity in construction in EU countries significantly exceeds the corresponding figure for Ukraine, which is explained by both a higher level of technological equipment and more developed institutional mechanisms for managing the sector. Poland, which serves as a relevant comparative case for Ukraine, occupies an intermediate position, reflecting the transitional nature of its economic structure and the gradual digital transformation of the construction sector.

Figure 2 illustrates the level of digital intensity in the construction sector across the economies under review. The analysis shows that a higher level of digitalisation correlates with higher labour productivity, which is consistent with the results of the regression analysis. Ukraine is characterised by a lower level of digital intensity compared to the EU; however, the positive trend in the adoption of digital tools, particularly in the areas of public procurement and licensing procedures, creates the conditions for improving the sector's efficiency. Some of the indicators used in the model, notably data on employment and the level of digitalisation in Ukraine, are based on scenarios, due to the limited availability of official statistics during the war. However, even under such conditions, the results obtained allow us to identify general patterns and confirm the key role of digitalisation as a driver of increased productivity in the construction sector.

Figure 2. *Digital intensity benchmark*



Source: developed by the author.

The integration of regression analysis and comparative graphical tools leads to the conclusion that the digitalisation of the construction sector not only improves resource efficiency but also shapes a new model for the industry's operation, in which technological development becomes a key driver of economic recovery.

One of the key challenges facing Ukraine's construction sector during post-war reconstruction is an acute labour shortage, caused by large-scale migration, demographic decline and structural changes in the labour market. Over 6 million Ukrainians remain outside the country, which significantly affects labour-intensive sectors, particularly construction. The shortage of skilled workers in construction after 2022 will reach 20–30%, significantly limiting the pace of infrastructure project implementation (GMK Center, 2025). At the same time, even assuming a partial recovery in construction volumes by 2024 (Interfax-Ukraine, 2025), the sector's labour potential remains below pre-war levels, necessitating the search for alternative mechanisms to ensure productivity.

In this context, digital technologies serve not only as a tool for improving efficiency but also as a mechanism for partially replacing human labour. In particular, the automation of construction processes based on artificial intelligence and digital platforms makes it possible to reduce dependence on manual labour and improve the efficiency of resource management. As noted by Abioye et al. (2021), the application of AI in construction facilitates the automation of planning, work supervision and risk analysis, thereby reducing the need for labour resources without compromising the quality of project delivery.

Formally, this can be expressed as a transformation of the productivity function:

$$P=Q/(L-\theta TP)$$

where θ is the technological labour substitution coefficient, reflecting the ability of digital technologies to compensate for labour shortages. This interpretation implies that an increase in the level of digitalisation (T) effectively reduces the demand for labour (L), a finding confirmed by the results of empirical analysis (see Figure 1), which show an increase in productivity even amidst a decline in employment.

4.3 Institutional and Investment Effects of Digitalisation

The key tools for technological compensation are process automation, modular construction and remote project management. In particular, the use of artificial intelligence enables the automation of planning, work progress monitoring and risk management, which significantly reduces the need for manual labour and improves resource efficiency (Abioye et al., 2021). In turn, modular construction brings about a structural transformation of the production process. Unlike traditional approaches, modular technologies involve the manufacture of a significant proportion of structural elements in factories, followed by their assembly on-site, which substantially reduces the need for labour directly at the construction site. According to general estimates, the use of such technologies reduces labour requirements by 30–40% and shortens project completion times by up to 50% (Zohourian et al., 2024), which is critically important in the context of labour shortages caused by migration.

Empirical case studies confirm the effectiveness of this model. In particular, in the UK, rapid housing construction projects based on off-site manufacturing (for example, Homes England initiatives and the use of technologies from companies such as Legal & General Modular Homes) have demonstrated the potential to reduce construction times by 30–50% whilst simultaneously reducing reliance on unskilled labour. In Sweden, where modular construction accounts for a significant share of the housing market, the use of industrialised solutions has helped stabilise costs and mitigate the impact of labour shortages on construction rates, which is particularly relevant in the context of an ageing population.

Similar trends are also observed in Central and Eastern European countries. In Poland, the active introduction of prefabricated technologies in residential and commercial construction helps to compensate for labour shortages by increasing the automation of production processes and requiring fewer staff on construction sites. In Germany, the use of modular solutions in social housing construction, particularly in response to migration challenges, has made it possible to rapidly scale up infrastructure projects despite limited labour resources.

In the context of Ukraine, the potential of modular construction takes on particular significance in the context of post-war reconstruction. Even in the early stages of reconstruction, solutions involving rapidly assembled housing and temporary modular structures are being used, enabling a swift response to the population's needs. In the long term, scaling up such approaches could become one of the key tools for reconstruction, as it allows for combining the speed of project implementation with limited use of labour resources.

Full-scale war has caused significant destruction to Ukraine's housing stock: by the end of 2024, over 236,000 buildings had been damaged or destroyed, with direct losses estimated at approximately \$60 billion. In such circumstances, ensuring the rapid and cost-effective restoration of housing has become a key priority, driving the growing role of modular construction as a strategic direction for the sector's development. The efficiency of modular construction is largely determined by the integration of digital technologies, in particular BIM, artificial intelligence, remote monitoring systems and cloud platforms, which ensure the coordination of project participants, optimisation of resource use and cost reduction. A practical example of this innovative approach is the project by WZMH Architects (Canada), which involves the use of concrete modules with built-in engineering systems to restore damaged buildings, thereby reducing reconstruction times to a matter of weeks. (Pro-Consulting, 2025).

In the medium term, modular construction could become a viable alternative to traditional methods, particularly in the areas of social housing and infrastructure regeneration, due to high demand, limited resources and the need to implement energy-efficient solutions.

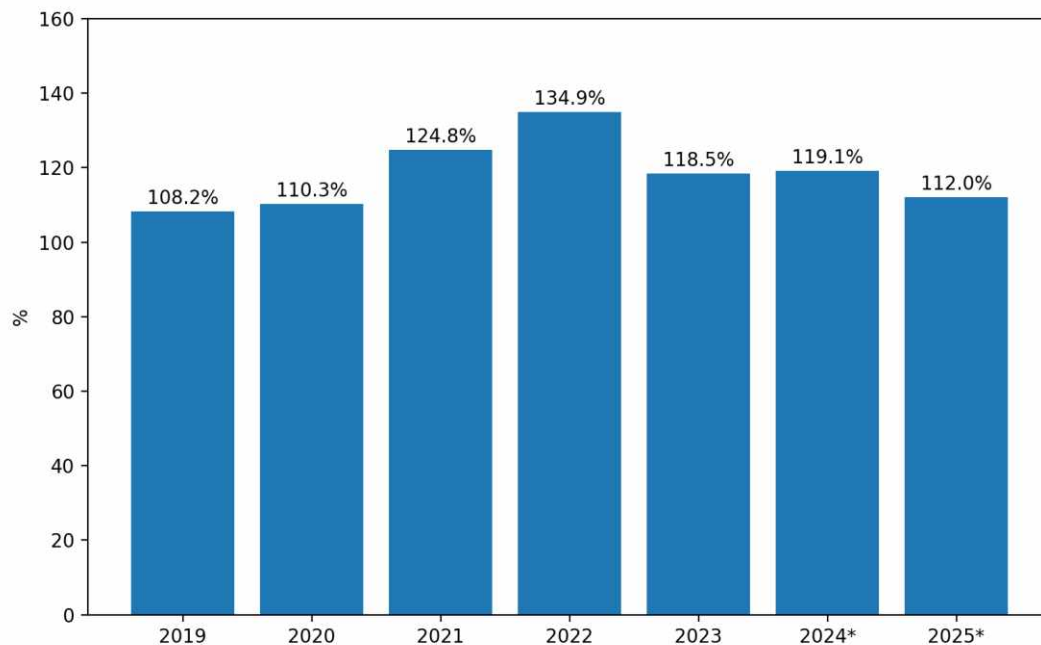
The process of addressing the labour shortage is taking place against a backdrop of profound structural changes in Ukraine's construction and renovation market. Until 2022, the sector demonstrated steady growth, but the full-scale war caused a sharp decline: the volume of construction work fell by more than half in nominal terms, whilst the real decline exceeded

65%. Despite this, a gradual recovery has been observed since 2023; in the first quarter of 2024, the market volume grew by 57% compared to the same period of the previous year, indicating the emergence of positive growth dynamics in the sector.

Structurally, the construction sector remains dominated by the civil engineering segment, which exceeds the share of residential and non-residential construction. This structure is characteristic of a recovery period, when the main focus shifts to infrastructure reconstruction, particularly transport, energy and utilities. The geographical structure of construction activity has undergone significant changes, with new projects concentrated mainly in the western regions of the country, whilst in the central and eastern regions, work on the restoration of damaged facilities dominates.

The investment side of the market has also undergone a transformation. Private investment has fallen significantly, whilst public funds and international aid – in the form of grants, loans and targeted programmes – have come to play a key role in financing construction. This means that the efficient use of resources is becoming a critical factor, further reinforcing the importance of digitalisation and industrialisation of construction processes as tools for cost optimisation.

Figure 3. *GDP deflator, % (2019–2025)*



Source: author's elaboration based on World Bank data.

It is advisable to analyse the performance of the construction sector within a broader macroeconomic context, particularly taking into account inflationary trends, which directly affect the cost of implementing infrastructure projects and the sector's investment attractiveness. As shown in *Figure 3*, the trend in the GDP deflator for 2019–2025 reflects significant fluctuations in price levels in the Ukrainian economy. During 2019–2021, a moderate increase in the indicator is observed, from 108.2% to 124.8%, indicating a gradual intensification of inflationary pressure against the backdrop of economic growth. The deflator reaches its highest value in 2022 – 134.9% – reflecting a sharp acceleration in inflationary processes due to full-scale war, disruptions to production and logistics chains, as well as devaluation and resource shocks. In subsequent years, a partial stabilisation of the indicator is observed: in 2023, it falls to 118.5%, and in 2024, it shows a slight increase to 119.1%, which may indicate the economy's gradual adaptation to new operating conditions. The figure for 2025 (112%) indicates a trend towards a further reduction in inflationary pressure, which is an important signal of macroeconomic stabilisation. At the same time, the deflator remains higher

than pre-crisis levels, reflecting the incomplete nature of economic recovery processes. The dynamics of the GDP deflator suggest that the economy is undergoing a transition from a shock inflationary surge to gradual stabilisation, creating more favourable conditions for investment activity and the implementation of large-scale reconstruction projects, particularly in the construction sector.

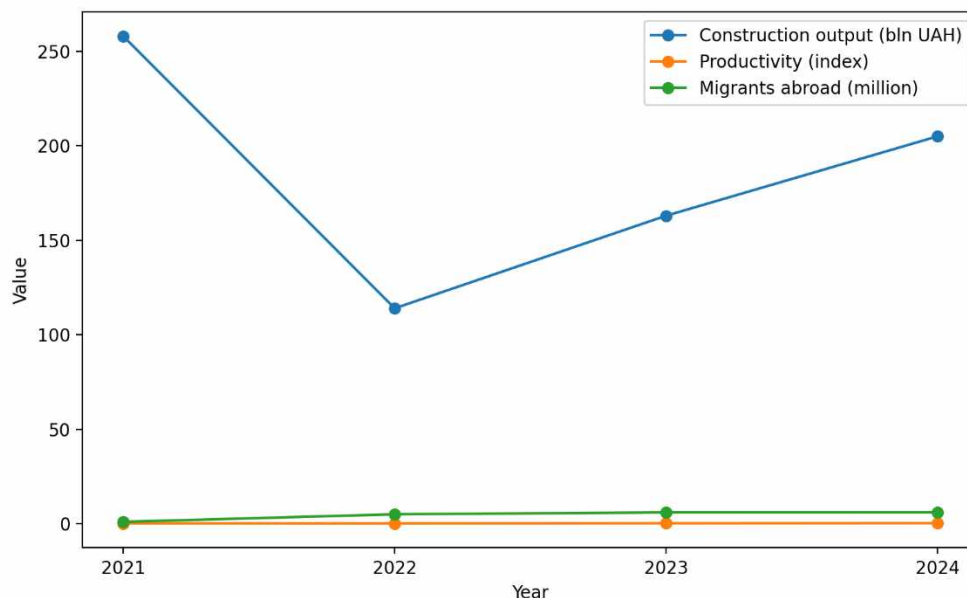
In the context of this study, this is of fundamental importance, as high inflation reinforces the need to adopt digital technologies and industrialised solutions, particularly modular construction, which enable cost optimisation and improved resource efficiency. Macroeconomic instability, reflected in the dynamics of the GDP deflator, acts as an additional factor stimulating the transition to a technology-compensated model of development in the construction sector, where productivity is achieved not through increased labour input but through the intensive use of digital tools.

To deepen the analysis of the relationship between labour shortages, productivity and the dynamics of the construction sector, an integrated graphical model (Figure 4) was constructed, reflecting the simultaneous changes in construction volumes, productivity levels and migration processes in 2021–2024.

After 2022, there is a sharp increase in the scale of labour migration, accompanied by a significant reduction in construction volumes. However, despite the reduction in the labour force, the sector's productivity shows positive dynamics in 2023–2024. This indicates that the construction sector is adapting to new operating conditions by intensifying the use of technology and optimising production processes.

The rise in productivity against a backdrop of a shrinking labour force supports the hypothesis that there is a technologically compensated labour economy model, within which digitalisation partially replaces human labour. Even in the face of a significant outflow of labour, the sector retains its capacity for recovery, which is attributable to improvements in the technological level of production and the implementation of innovative solutions.

Figure 4. *Construction output, productivity and migration trends (2021–2024)*



Source: compiled by the author based on World Bank data and industry estimates.

In the context of Ukraine's post-war recovery, the digitalisation of the construction sector has not only operational implications but also significant institutional and investment implications that determine the overall efficiency of the sector's functioning. Of particular importance is the introduction of electronic permitting systems and digital public procurement

platforms, which transform the mechanisms of interaction between the state, business and international partners.

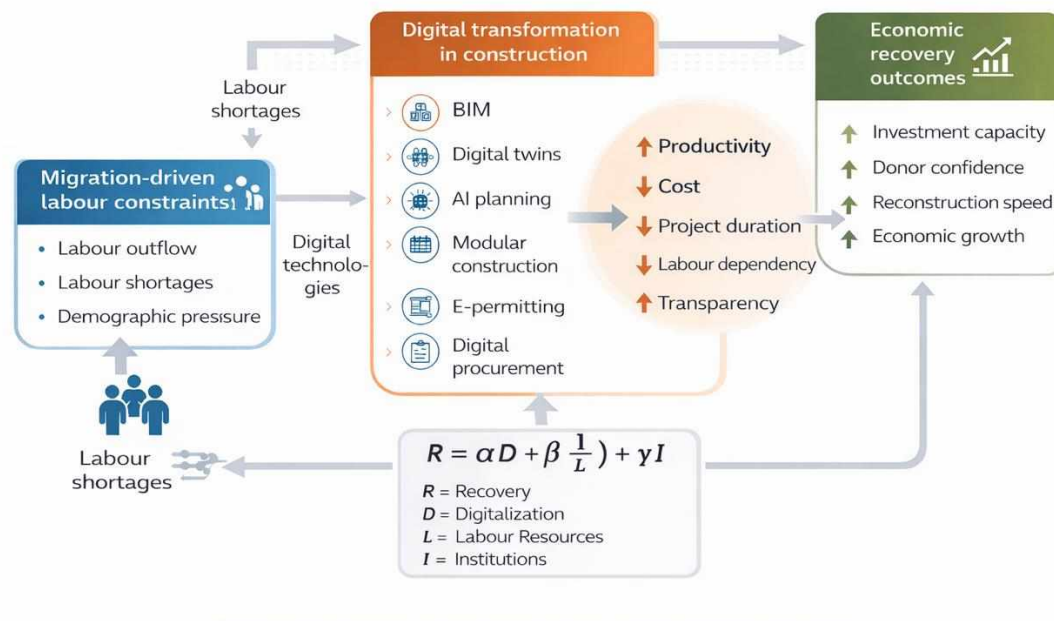
The digitalisation of permitting procedures, including the introduction of electronic permits (e-permitting), makes it possible to significantly reduce administrative barriers and improve the efficiency of regulatory processes. As research by international organisations shows, moving permitting procedures to a digital format reduces corruption risks by minimising the human factor and limiting opportunities for informal practices. In this context, digital tools serve as a mechanism for improving institutional quality, which is critically important for economies in transition.

This is of critical importance, as the scale of reconstruction is unprecedented: according to estimates by international organisations, the total cost of economic recovery already exceeds US\$500–580 billion, whilst direct infrastructure losses amount to over US\$190 billion (Shalal, 2026). Under such conditions, effective project management and transparent procedures become key factors in the use of financial resources.

The Prozorro electronic public procurement system plays a vital role in ensuring transparency, functioning as an open digital platform for conducting tenders. The system ensures competition among suppliers, open access to information and the ability to automatically detect violations through analytical tools, which significantly reduces corruption risks. In particular, the introduction of ‘red-flag’ mechanisms allows potential violations in the procurement process to be identified in real time, which boosts confidence in the system among both the business community and international donors.

Institutional transformation driven by digitalisation has a direct impact on the investment attractiveness of the construction sector. Under current conditions, a significant portion of the funding for Ukraine’s reconstruction comes from international aid, including grants, loans and investment programmes (OECD, 2025). Ukraine’s economic recovery depends to a large extent on the stability of public finances, the efficiency of public spending and the support of international partners. In this context, digital tools serve as a guarantee of greater transparency in the use of funds and a reduction in the risks of their misuse.

Figure 5. *Conceptual Model of Digital-Driven Reconstruction in Ukraine*



Source: author’s own elaboration.

Figure 5 illustrates a conceptual framework linking labour constraints, digital transformation in the construction sector, and economic recovery outcomes. The model demonstrates that migration-driven labour shortages act as a primary structural constraint affecting the construction industry. In response, digital transformation encompassing technologies such as BIM, modular construction, e-permitting, and data-driven management, serves as a central mediating mechanism that reduces labour dependency and enhances operational efficiency.

The framework further highlights that the integration of digital technologies generates a set of interconnected effects, including improved resource optimization, reduced project timelines, and increased transparency of institutional processes. These effects collectively contribute to strengthening investment capacity and accelerating economic recovery. Importantly, the model emphasizes the role of institutions in supporting this transformation, indicating that the effectiveness of digitalization depends not only on technological adoption but also on the quality of governance and regulatory frameworks. The figure conceptualizes the transition from a labour-intensive to a technology-driven model of construction development, in which digitalization acts as a key driver of productivity growth and structural economic recovery.

Digitalisation helps to create a more effective institutional environment that encourages the mobilisation of private capital. It is estimated that up to 40% of the funding required for reconstruction could potentially be met through private investment, provided that the necessary reforms are implemented and the transparency of economic processes is improved. This underscores the importance of digital platforms as tools for reducing information asymmetry and boosting investor confidence. Given the massive scale of reconstruction needs, digitalisation is one of the key factors determining the economy's ability to effectively mobilise and utilise investment resources.

5. Discussion

The findings support previous studies that identify digitalisation as a major driver of productivity growth and efficiency improvement in the construction sector. Consistent with the work of Abioye et al. (2021), Deng et al. (2021), and Nguyen et al. (2023), the results indicate that digital technologies improve resource allocation, project coordination, and overall operational performance. Similarly, the findings confirm the conclusions of Zohourian et al. (2024), who emphasise the role of modular construction in reducing labour requirements and accelerating project delivery.

The study also supports previous research linking labour shortages to technological transformation. In line with the findings of Ghodsi et al. (2024) and Tverdostup et al. (2025), the results suggest that labour constraints act as a catalyst for digital innovation. However, unlike previous studies that primarily focus on automation at the firm level, this research demonstrates the importance of digitalisation at the sectoral level within a post-war reconstruction environment.

A further contribution of the study concerns the institutional dimension of digital transformation. The results are consistent with findings by the World Bank (2020), Ataíde et al. (2023), and Rysin and Sukh (2024), which show that digital governance tools improve transparency and accountability. However, this study extends existing research by demonstrating that digitalisation not only improves administrative efficiency but also strengthens investment capacity by increasing donor and investor confidence in reconstruction programmes.

An important finding is the emergence of a technology-intensive reconstruction model. While previous studies have generally examined digitalisation, migration, and reconstruction separately, the present research integrates these dimensions into a unified analytical

framework. The results suggest that digital technologies perform not only a productivity-enhancing function but also a compensatory function by partially offsetting migration-induced labour shortages. This finding contributes to a better understanding of how post-war economies adapt to structural labour constraints.

The study additionally highlights the potential role of digital platforms in facilitating hybrid forms of labour participation. Through remote coordination and digital project management tools, highly skilled professionals located abroad may contribute to reconstruction processes without physical relocation. This expands the traditional understanding of labour mobility and opens new opportunities for engaging the Ukrainian diaspora in economic recovery.

Overall, the findings confirm hypotheses H1-H3 and demonstrate that digitalisation has a multidimensional impact on reconstruction processes through productivity improvements, labour compensation mechanisms, and institutional strengthening. These results suggest that digital transformation should be considered a central component of Ukraine's long-term reconstruction strategy.

6. Conclusions

The findings of this study demonstrate that digitalisation has become a strategic component of Ukraine's post-war reconstruction process. Under conditions of infrastructure destruction, labour shortages, and resource constraints, digital technologies contribute to higher productivity, more efficient resource allocation, and improved implementation of reconstruction projects.

The analysis confirms that technologies such as Building Information Modelling (BIM), digital twins, artificial intelligence, modular construction, e-permitting systems, and digital procurement platforms help partially compensate for migration-induced labour shortages while enhancing the operational efficiency of the construction sector. The results additionally indicate that digitalisation strengthens institutional transparency and accountability, thereby improving the investment attractiveness of reconstruction programmes.

The study contributes to the literature by integrating technological, migration, and institutional dimensions into a unified framework of digitally driven reconstruction. The findings suggest that post-war recovery increasingly depends on the transition from a labour-intensive to a technology-intensive development model, in which digitalisation functions not only as a productivity-enhancing factor but also as a mechanism for economic resilience and adaptation.

From a policy perspective, the results highlight the importance of accelerating digital transformation within Ukraine's reconstruction strategy. Expanding the use of digital construction technologies, improving digital governance instruments, and strengthening institutional transparency may contribute to more effective mobilisation of domestic and international investment resources.

Future research should focus on firm-level evidence, regional differences in reconstruction processes, and quantitative assessment of the long-term economic effects of digital technologies in the construction sector.

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ARTIFICIAL INTELLIGENCE AND TOURISM-DRIVEN ECONOMIC DEVELOPMENT IN ALBANIA

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Abstract: Albania recorded approximately 11.7 million foreign arrivals in 2024, a figure that places growing strain on infrastructure, management systems, and the natural environment. This paper examines how that tourism expansion is shaping the adoption of artificial intelligence across the sector, and what the resulting economic, environmental, and ethical consequences look like in practice. Drawing on a systematic review of academic literature published between 2019 and 2025, supplemented by secondary statistical data from INSTAT, Eurostat, and UN Tourism, we find that AI adoption is uneven: larger, urban-based businesses are realising tangible gains in efficiency and revenue, while rural SMEs continue to face significant barriers related to cost, connectivity, and skills. We argue that the question is no longer whether Albania should integrate AI into tourism, but how to do so in a way that preserves the human character of the sector.

Keywords: artificial intelligence, Albania, tourism, digital transformation, sustainable development

1 Introduction

Few places in Europe have seen the kind of tourism growth that Albania has managed over the last decade. From roughly 3.8 million foreign arrivals in 2015, the country reached an estimated 11.7 million in 2024, a 15.2% increase on the previous year alone (INSTAT, 2025). That number is startling when you consider that Albania has a resident population of around 2.8 million: the country receives, each year, nearly four times as many visitors as it has permanent inhabitants. The practical consequences are visible. During peak season, hotels, transport networks, and public services operate well beyond their designed capacity. Conventional management approaches, built for a different scale of demand, are no longer adequate (Ferhataj & Memaj, 2024).

The post-pandemic recovery in global travel has, if anything, made the situation more acute. Albania has benefited from a broader shift in tourist preferences towards less visited, more authentic destinations, and the country's combination of unspoiled coastline, mountain landscapes, and competitive prices has attracted attention from across Western Europe. Sustaining that appeal over time is not straightforward. It requires careful management of natural resources, cultural sites, and service quality, and it is in this context that artificial intelligence has begun to matter. AI is not just a tool for automating reservations; it is reshaping decisions about energy use in hotels, crowd management at heritage sites, and how operators anticipate and respond to demand (Samala et al., 2022). Serafimova and Vasilev (2024), writing in AIJES on organisational digital culture and sustainable development, show that digital culture is increasingly part of competitiveness, an insight that translates directly to tourism-heavy economies like Albania.

This paper asks, specifically, how the growth of tourism in Albania is driving AI adoption across the industry, and what the economic and sustainability implications of that

process are. The analysis draws on a systematic review of academic literature published between 2019 and 2025, together with official statistical data from INSTAT, Eurostat, and UN Tourism. Section 2 reviews the relevant literature. Section 3 sets out the methodology. Section 4 presents the results of the analysis, and Section 5 discusses the findings and practical recommendations.

2 Literature Review

AI and tourism have attracted growing academic attention since around 2019, when the volume of publications on the topic began to rise sharply (Knani et al., 2022). Most of that literature focuses on larger, well-established tourism markets. The Albanian case, and emerging Balkan economies more generally, remain underrepresented, which is one reason this paper is needed.

2.1 AI, Economic Efficiency and Visitor Experience

The economic rationale for AI adoption in tourism comes down to two things: automating what does not need human attention, and making better use of the data that the sector generates in large quantities. Reservation handling, customer queries, and itinerary generation are all areas where AI systems can take on the burden, freeing staff for the work that genuinely benefits from a personal touch (Samala et al., 2022). For Albanian hospitality SMEs, many of which operate on slim margins, even modest efficiency gains matter.

The evidence from within Albania is consistent with this picture. Godolja et al. (2025) found that hotels using digital management platforms reported measurable reductions in administrative burden and improvements in staff productivity. Demand forecasting tools are helping operators anticipate busy periods and price accordingly, reducing both waste and missed revenue opportunities (Choi & Kim, 2024). Chatbots, meanwhile, are extending service availability to 24 hours a day and removing language barriers that previously limited access to international visitors (Sousa et al., 2024).

Personalisation has become a core expectation among contemporary travellers, not just in premium segments but across the board. Tourists now routinely expect services that reflect their individual preferences, and AI makes it possible to meet that expectation at scale by drawing on data from booking histories, social media activity, and real-time feedback (Huang et al., 2022).

In Albania, one of the more instructive examples comes from Durrës. Research by Kosta et al. (2025) describes hotel recommendation platforms using Natural Language Processing and cosine similarity techniques to analyse guest reviews and refine service offerings accordingly. The commercial logic is clear: personalised services lead to higher guest satisfaction, larger per visit expenditure, and greater likelihood of return visits. Ferhataj (2024) goes further, suggesting that the most effective AI applications are those that generate experiences distinctive enough to become a reason in themselves for choosing a destination.

2.2 Sustainability, Ethics and Social Dimensions

Tourism growth and environmental protection are not straightforwardly compatible, and Albania's situation illustrates the tension well. The country's natural assets, including its Riviera coastline, national parks, and mountain ecosystems, are both the main draw for visitors and the things most at risk from poorly managed visitor pressure. AI offers several tools for managing this more intelligently.

Smart energy management in hotels is probably the most developed application: AI systems that monitor and regulate electricity and water consumption in real time can cut both costs and environmental impact (Godolja et al., 2025). Crowd prediction and visitor flow modelling allow authorities to anticipate bottlenecks at sensitive sites and suggest alternative

itineraries before problems escalate (Alrawadieh et al., 2025). Carbon accounting tools are emerging as a way of quantifying the environmental cost of different tourism patterns, giving policymakers something concrete to work with (López-Naranjo et al., 2025). The digitisation of heritage sites through virtual and augmented reality, meanwhile, offers a way of preserving access without the physical degradation that accompanies mass visitation.

AI in tourism is not without complications. Data privacy is the most immediate concern: AI systems depend on processing large quantities of personal data, and the legal and technical frameworks for protecting that data are, in many contexts, still catching up with the technology (Putera et al., 2022). For Albania, aligning with GDPR as part of the EU accession process is both a regulatory obligation and, done well, an opportunity to build the kind of trust that digital services require.

Algorithmic bias is a subtler but equally important problem. Systems trained on historical data can replicate and amplify existing patterns of discrimination if they are not carefully audited (Ma, 2024). And there is a broader question about what sustained AI adoption does to the character of hospitality. The warmth of a family-run guesthouse, the local knowledge of a guide who has lived in a place all their life: these are things that automated systems cannot replicate, and they are part of what makes Albanian tourism worth experiencing (Milton, 2023). Any serious strategy for AI integration needs to grapple with this.

3 Methodology

We used a systematic literature review as the primary methodology, supplemented by analysis of secondary statistical data. The choice reflects both the breadth of the research question and the relatively sparse literature on Albania specifically. Systematic reviews allow for a structured, transparent synthesis of what has been published, with explicit criteria for what is included and why.

3.1 Data Collection

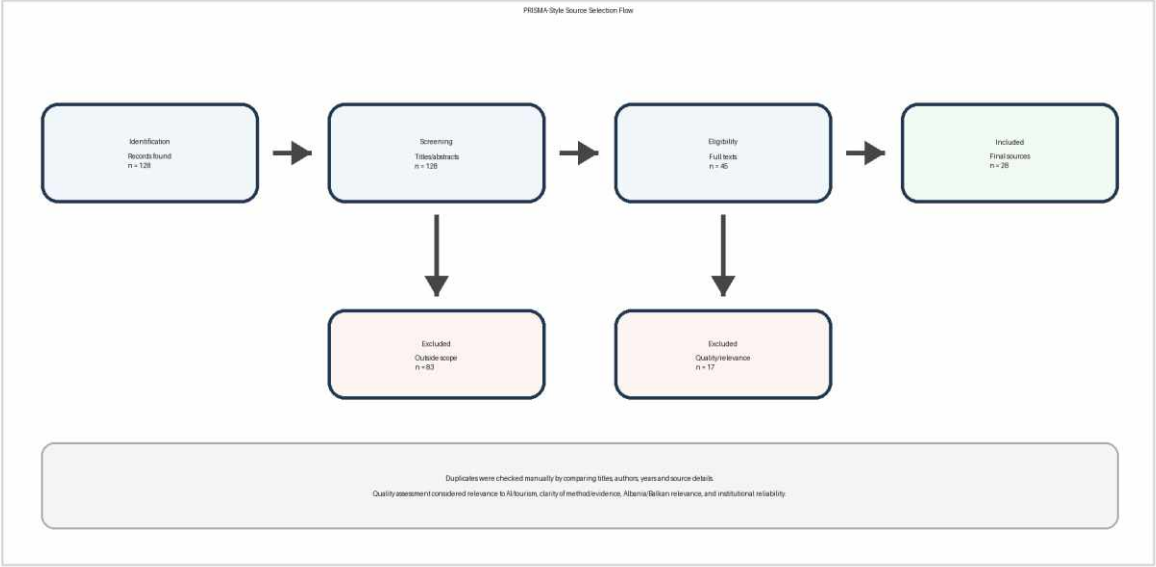
The literature search used Google Scholar, Scopus, and ResearchGate. Official statistical sources, namely INSTAT, Eurostat, and UN Tourism, were consulted to ground the analysis in verified empirical data on visitor trends and economic indicators. Search terms combined “artificial intelligence” or “AI” with “tourism” or “hospitality” and “Albania” or “Balkans,” supplemented by terms including “digital transformation,” “sustainable tourism,” and “tourism ethics.”

Inclusion required that sources be peer-reviewed articles, conference papers, or official reports from 2019 to 2025, with a clear focus on AI in tourism or hospitality and either empirical content or a well-developed theoretical framework. Studies without a socio-economic dimension, sources with insufficient methodological clarity, and papers that referred to tourism technology without addressing AI or digital transformation were excluded. Duplicate records were removed manually by comparing titles, authors, years of publication, and source details before the title-and-abstract screening stage. The screening was performed by the authors using the same inclusion and exclusion criteria; where a source was borderline, it was retained for full-text review rather than excluded at the first stage. An initial pool of 128 sources was screened by title and abstract; 45 proceeded to full-text review, of which 28 met the criteria for inclusion in the qualitative synthesis. The review process therefore followed a PRISMA-style logic: identification of sources, duplicate removal, screening for relevance, eligibility assessment, and thematic synthesis.

For quality assessment, each full-text source was checked against four simple criteria: direct relevance to AI and tourism, clarity of method or evidence base, relevance to Albania, the Balkans, or comparable tourism economies, and contribution to economic, sustainability,

ethical, or governance aspects of tourism development. This assessment was not intended as a meta-analysis, because the included studies used different methods and data types, but it helped ensure that the final synthesis relied on sources with clear relevance and sufficient academic or institutional reliability.

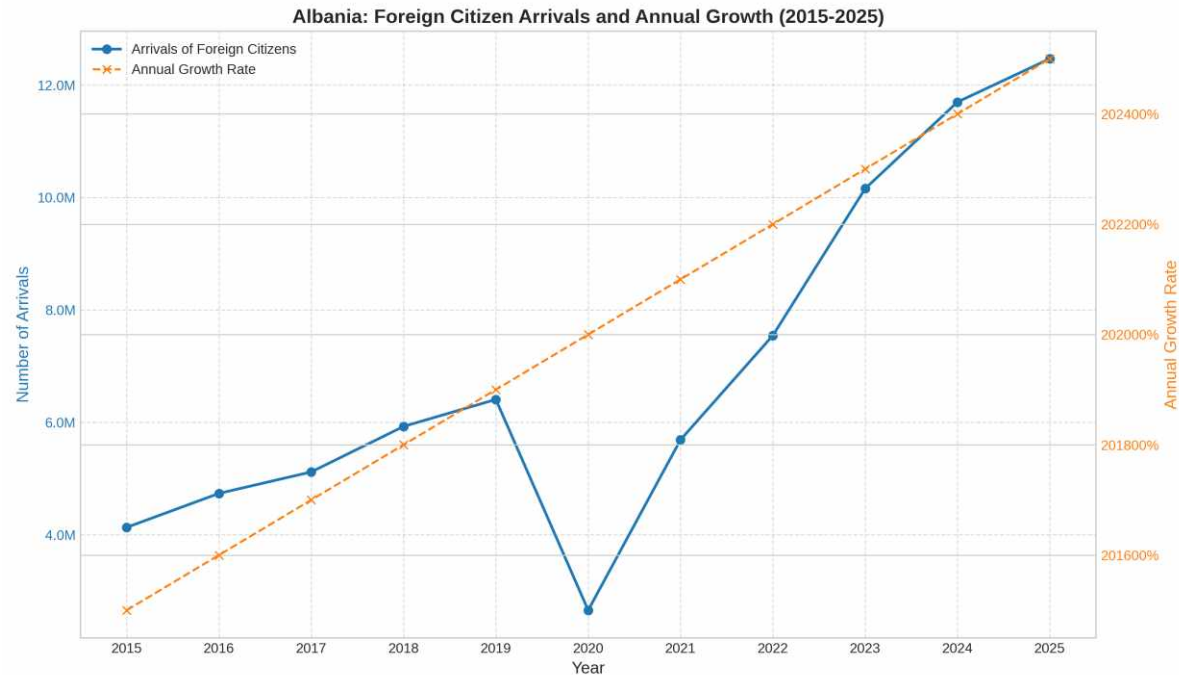
Figure 1. PRISMA-Style Flow of Source Selection



Source: Authors' methodological summary.

Figure 2 shows Albania's trajectory of foreign arrivals over the study period. The sharp contraction in 2020 reflects the COVID-19 pandemic; the subsequent recovery, and particularly the growth recorded between 2022 and 2024, provides the backdrop against which AI adoption pressures need to be understood.

Figure 2. Albania: Foreign Citizen Arrivals and Annual Growth Rate (2015–2025)



Source: Authors' compilation based on INSTAT data (2025).

3.2 Thematic Analysis

The selected literature was analysed thematically, with patterns identified, coded, and grouped into four core themes: economic impacts and operational efficiency; personalisation and value creation; sustainability and environmental management; and ethical, social, and infrastructural challenges. Table 1 provides a quantitative summary of visitor trend data that underpins several of the thematic findings.

Table 1. *Albania: Foreign Citizen Arrivals, Annual Growth, and Tourism Contribution to GDP (2015–2024)*

Year	Foreign Arrivals (millions)	YoY Growth (%)	Tourism Share of GDP (%)
2015	3.8	n/a	6.2
2017	5.1	12.4	7.4
2019	6.4	11.7	8.9
2021	4.2	-34.4	5.1
2022	7.5	78.6	9.3
2023	10.2	36.0	11.7
2024	11.7	15.2	13.4

Source: Authors' compilation based on INSTAT (2025) and Eurostat (2022) data.

4 Results of AI Integration in Albanian Tourism

Taken together, the evidence points to something that might be described as a forced digitalisation: the volume of tourism growth has created operational pressures that traditional management approaches cannot absorb, and AI is increasingly filling the gap. That process is not uniform, however, and the differences between how it plays out in Tirana versus a rural guesthouse in the Accursed Mountains are significant.

The clearest economic gains from AI adoption appear in operational efficiency. Businesses using AI-driven booking systems, demand forecasting tools, or automated customer service report reduced administrative overhead and better use of staff time (Godolja et al., 2025). Table 2 summarises the main technologies in use across Albanian tourism and the economic functions they serve.

Table 2. *AI Applications and Economic Drivers in Albanian Tourism*

AI Technology	Application Area	Economic Driver
Machine Learning	Demand Forecasting	Optimised pricing and inventory management
NLP and Chatbots	Customer Service	Reduced costs and 24/7 multilingual support
Big Data Analytics	Personalisation	Increased visitor spending and repeat visits
Computer Vision	Security and Check-in	Faster processing and enhanced safety

Source: Adapted from Kosta et al. (2025) and Samala et al. (2022).

4.1 Economic Implications and Personalised Services

Automating repetitive, high-volume tasks frees up staff time and reduces error rates during peak periods. Research on Albanian accommodation providers found that AI-enabled management systems produced measurable productivity improvements and reduced the administrative burden on employees (Godolja et al., 2025). The financial logic holds even for modest operations: lower input costs for the same service output can be redirected toward marketing, product development, or simply improved working conditions.

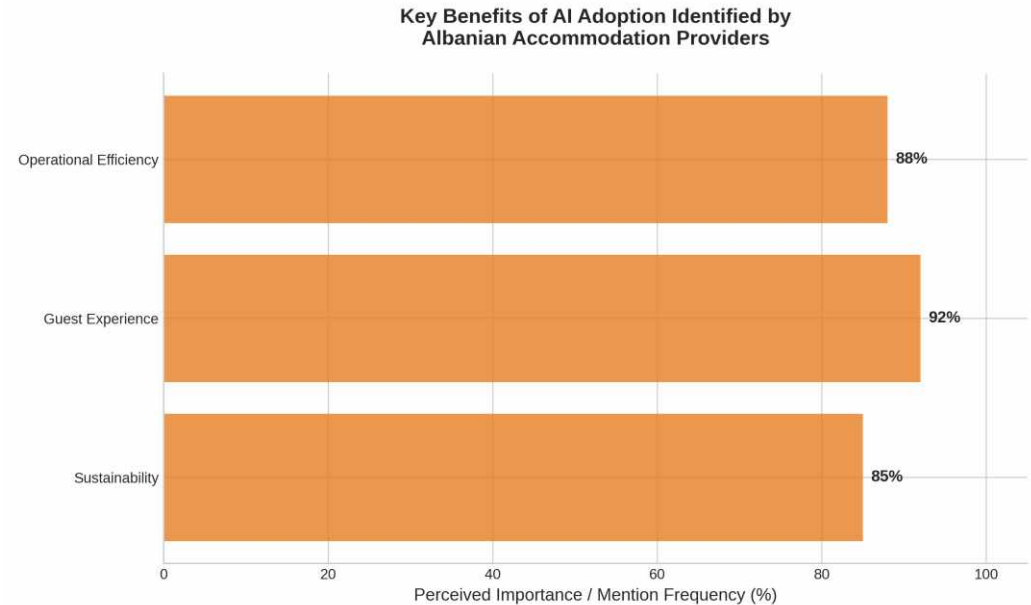
Not everyone benefits equally, though. The businesses with the most to gain from AI are also those with the resources to adopt it in the first place. This matters for how we think

about equitable development across the sector, because digital transformation can easily widen the gap between well-capitalised operators and smaller rural businesses (Sousa et al., 2024).

Personalised services tend to produce measurable revenue effects. When AI systems tailor accommodation recommendations or activity suggestions to individual preferences, guests typically spend more and report higher satisfaction, and satisfied guests come back and tell others (Choi & Kim, 2024). The Durres case documented by Kosta et al. (2025) illustrates this concretely: NLP-based review analysis allowed businesses to understand what visitors actually valued in ways that manual feedback monitoring could not replicate at scale.

Figure 3 captures the picture from the supply side. Survey data from Albanian accommodation providers indicates that improving the guest experience was the most commonly cited benefit of AI adoption, followed by gains in operational efficiency and, notably, sustainability outcomes. This ordering is worth noting: guest experience ranked above cost savings, which suggests that providers understand personalisation as a competitive priority, not just an operational convenience.

Figure 3. *Key Benefits of AI Adoption Identified by Albanian Accommodation Providers*



Source: Adapted from Godolja et al. (2025).

4.2 Sustainability, Barriers and Governance

Albania's natural and cultural heritage is the foundation of the country's tourism value proposition. Damaging it is bad economics as well as bad policy. AI contributes to its protection in several practical ways. Intelligent energy management in hotels reduces both operational costs and environmental footprint (Godolja et al., 2025). Predictive crowd management reduces pressure on vulnerable sites and, by redirecting visitors toward less-congested alternatives, distributes economic benefits more widely across the geography. AI-assisted carbon accounting gives operators and policymakers the data they need to make informed decisions about growth trajectories and land use (López-Naranjo et al., 2025).

The scope of AI in resource management extends beyond energy. Water consumption tracking, waste monitoring, and air quality assessment can all be managed more effectively with AI-driven systems than with periodic manual checks. In a context where the quality of the natural environment directly affects tourism revenue, the ability to detect environmental stress early, before it becomes visible to visitors or irreversible, has real economic value.

Overtourism tends to be self-defeating: the very popularity that draws visitors ends up degrading the things that made a place worth visiting. Albania has sites, among them Butrint, the Riviera, and the old city of Gjirokastra, where summer visitor pressure is already considerable. AI tools that model visitor flows in real time and under different policy scenarios give local authorities more options for responding proactively rather than reacting to damage after the fact (Alrawadie et al., 2025). Virtual and augmented reality platforms for heritage sites offer a complementary approach: they allow visitors to engage with culturally significant locations without the physical attrition that comes with mass presence.

The case for AI adoption is, on balance, strong. The barriers to it are also real, and underestimating them leads to policy that works for a subset of the sector while leaving others further behind. Setting up an AI-capable operation, covering hardware, software, integration, and the staff competence to run it, represents a significant upfront investment. For the small family hotels and tour operators that make up the majority of Albanian tourism businesses, that cost is often simply out of reach. The problem is compounded by infrastructure: most AI applications require reliable, high-speed internet, which is not uniformly available across Albania. Rural and mountainous areas, where some of the country's most distinctive tourism experiences are located, are often the least well-served (Godolja et al., 2025).

Even where connectivity exists, the human capacity to implement and manage AI systems is often limited. The gap between Tirana, with its growing tech sector, and smaller rural tourism destinations in terms of digital skills and literacy is marked. Albania faces a broader challenge in this respect: emigration of younger, skilled workers is substantial, and the pool of professionals with backgrounds in data science or machine learning is correspondingly thin. Training programmes exist but lack the scale and coordination needed to close the gap systematically.

AI systems in tourism collect and process large quantities of personal data. The risk of misuse, breach, or simply inadequate protection is real, and it undermines the trust on which digital services depend (Putera et al., 2022). As Albania moves toward EU membership, GDPR compliance will become mandatory rather than aspirational, which creates both pressure and an opportunity to build robust data governance from the ground up. The issue of algorithmic bias deserves parallel attention: AI systems that inadvertently disadvantage particular groups of tourists or workers are not just ethically problematic but, when they become visible, damaging to reputation (Ma, 2024). And underpinning all of this is the question of what extended AI adoption does to the feel of hospitality. The personal warmth that characterises good Albanian guesthouses and family restaurants is not reducible to an algorithm, and strategies that treat AI as a replacement rather than a complement to human service risk eroding the sector's most distinctive asset (Milton, 2023).

5 Discussion

The evidence reviewed in this paper supports a fairly clear conclusion: AI is becoming a meaningful factor in how Albanian tourism operates, and the pace of adoption is likely to increase as visitor numbers continue to grow. The benefits, including improved operational efficiency, more personalised visitor experiences, and better environmental management, are real and reasonably well documented in the local context. These findings are broadly consistent with Samala et al. (2022) and Sousa et al. (2024), who show that AI is becoming more visible across customer service, decision-making and tourism operations. At the same time, the Albanian case shows that adoption is shaped by uneven infrastructure and uneven digital capacity, which makes the transition less automatic than in mature tourism markets.

The more important question, we think, is not whether Albania should adopt AI in its tourism sector but how. An adoption strategy that prioritises cost reduction above all else risks losing what makes Albanian hospitality worth choosing over somewhere else. One that treats AI as a tool for extending what human beings can do, rather than replacing them, is more likely to produce outcomes that are both economically productive and socially sustainable. This is where the paper adds to the existing discussion: it connects AI adoption not only with business efficiency but also with the preservation of local hospitality, environmental management and regional inclusion.

On the basis of the findings, we propose five recommendations. First, the Albanian government should develop a coherent national AI strategy for the tourism sector, one that includes financial support mechanisms, regulatory guidance for SMEs, and GDPR-aligned data governance standards from the outset, not as an afterthought. Second, sustained investment in digital skills is needed at every level of the sector. Training programmes that bring together universities, vocational colleges, and industry associations have the best chance of reaching the full range of businesses, including those in rural areas where the skills deficit is most pronounced.

Third, digital infrastructure gaps in areas beyond Tirana and the main coastal strip need targeted investment, both from government and from private operators who have a stake in a functioning sector-wide ecosystem. Fourth, there is a case for supporting applied research on AI in Albanian tourism specifically, including pilot projects in heritage site management and sustainable destination planning. Evidence generated locally is more likely to be trusted and used locally. Fifth, any AI adoption strategy should be anchored in a human-centred philosophy. The aim should be to augment what people in the sector can offer, not to automate them out of the picture. AI systems that support better decision-making and enable richer interactions between visitors and hosts will serve Albania better over time than those designed primarily to minimise human involvement.

To conclude: AI cannot replace the hospitality that is Albania's most genuine competitive advantage. But used carefully, it can help the sector manage its extraordinary growth in a way that is good for the economy, the environment, and the people who work in it.

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ECONOMIC SECURITY IN THE CONTEXT OF THE SUSTAINABLE DEVELOPMENT PARADIGM: CONCEPTUAL FOUNDATIONS AND STRATEGIC TRAJECTORIES

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Abstract: *This study examines the conceptual and functional relationship between economic security and sustainable development in the context of climate change, resource scarcity, biodiversity loss, and increasing geo-economic tensions in the 21st century. It explores the contradictions between economic growth and the regenerative capacity of the biosphere, emphasizing the strategic importance of the green economy as a development priority. The research applies systemic analysis, comparative assessment, and an integrative approach, interpreting economic security as a protective mechanism against external shocks and sustainable development as the internal adaptive capacity of socio-economic systems. A conceptual framework titled the Sustainable Development Matrix of Socio-Economic Systems is proposed, integrating resource efficiency, social stability, ecological balance, and innovation-driven security indicators. The findings indicate that ecological factors should be considered an essential component of economic security. Sustainable development is framed as non-destructive progress based on a synthesis of anthropocentric and biosphere-centric perspectives. The study concludes that noospherogenesis-based development models provide a robust strategic framework for enhancing long-term competitiveness and resilience of national economies.*

Keywords: *economic security, green economy, sustainable development, resource efficiency, biosphere-centrism, strategic resilience, intergenerational equity.*

1. Introduction

In the 21st century, the intensification of global transformations, acceleration of technological progress, and increasing interdependence of economic systems have created a qualitatively new stage in the relationship between society and nature. Climate change, biodiversity loss, scarcity of energy and water resources, and rising geo-economic tensions raise fundamental questions regarding the sustainability of existing development models. Traditional growth paradigms have long measured economic performance primarily through quantitative indicators; however, such approaches have insufficiently accounted for ecological constraints and social balance. In the current context, aligning economic growth with the carrying capacity of the biosphere has become a strategic necessity. Systemic global risks demonstrate that development sustainability is determined not only by the expansion of production and consumption but also by efficient resource utilization, ecological balance, and social inclusiveness. From this perspective, a comprehensive analysis of the interrelationship between economic security and sustainable development is of both theoretical and applied significance.

1.1. Theoretical Framework

The theoretical foundation of the study is based on the concept of sustainable development systematized in the 1987 report *Our Common Future*, prepared by the World

Commission on Environment and Development (the Brundtland Report). According to this approach, development should meet the needs of the present generation without compromising the ability of future generations to meet their own needs. This concept integrates the principles of economic efficiency, environmental sustainability, and social equity. In contemporary scholarly discourse, economic security is interpreted as a system of institutional and structural mechanisms ensuring the resilience of the state and society against internal and external shocks. In this context, economic security functions as a “protective shield,” while sustainable development represents a strategic framework that shapes the adaptive and self-renewing capacity of socio-economic systems. Thus, both categories are mutually complementary and form the conceptual basis of a new development paradigm.

1.2. Problem Statement

At the current stage, the deepening of global civilizational processes, accelerated technological transformation, and the rapid expansion of production and consumption have fundamentally altered the structure of interactions between society and the natural environment. As a result, a systemic and profound contradiction has emerged between the intensity of economic growth and the ecological sustainability of the biosphere. While traditional extensive and resource-oriented development models have prioritized economic expansion, they have largely overlooked the regenerative capacity of ecosystems and the finite nature of natural capital. The central problem, therefore, lies in the imbalance between economic growth rates and the regenerative capacity of the biosphere, which leads to the cumulative increase of ecological, social, and economic risks at the global level. This issue extends beyond environmental protection alone; it concerns the long-term sustainability of economic security, national sovereignty, and civilizational stability.

2. Economic Security and Green Economy: A New Conceptual Framework of Sustainable Development

In the 21st century, the intensification of interactions between society and nature and the consequent escalation of global civilizational challenges have significantly increased risks to human security. Climate change, rapid depletion of resources, loss of biodiversity, and deepening geo-economic contradictions clearly expose the limitations of the existing development model. In this context, the question “to be or not to be?” has moved beyond the philosophical domain and has become a fundamental existential issue in global governance and strategic planning processes. In order to ensure civilizational continuity and respond adequately to global challenges, since the late 20th century important international initiatives have been undertaken to establish a new model of interaction between society and nature. As a conceptual outcome of these efforts, the idea of sustainable development was formalized and systematized in the *Brundtland Report* (1987), which defined sustainable development as meeting the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). This definition later became a methodological foundation for national strategies, institutional frameworks, and international programs, including the 2030 Agenda for Sustainable Development (United Nations, 2015).

The interpretation of sustainable development has evolved in parallel with transformations in scientific paradigms, acquiring new qualitative characteristics at each stage. In modern literature, sustainable development is characterized by the integration of economic efficiency, ecological balance, and social equity principles, forming a systemic triad of development sustainability (Elkington, 1994). At the same time, economic security is increasingly understood as a system of institutional and structural mechanisms ensuring the resilience of socio-economic systems against internal and external shocks. In this context, economic security functions as a “protective shield,” while sustainable development represents the strategic framework that shapes adaptive and self-renewing capacity of socio-economic

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systems. Thus, both categories are mutually reinforcing and constitute the conceptual foundation of a new development model (Kruglova, 2019).

From a general theoretical perspective, economic security refers to the availability of necessary resources, technologies, and institutional mechanisms that ensure the long-term stability and uninterrupted functioning of socio-economic systems. However, when the principle of continuity is considered, it becomes evident that development models based on exhaustible resources generate systemic risks in the long term. Resource degradation and the violation of ecological limits weaken the structural foundations of economic security. In this regard, sustainable resource management and green transformation become essential prerequisites for systemic stability (Pearce & Barbier, 2000).

The green economy model plays a crucial bridging role between economic security and sustainable development. By integrating resource efficiency, low-carbon technologies, circular economy principles, and environmental responsibility, the green economy establishes an ecological paradigm of economic security (Kruglova, 2019). In this framework, economic security is no longer limited to financial and productive capacity but also includes the regeneration of natural capital and the sustainability of ecosystem services. Therefore, sustainable development requires an integrated approach that combines economic, ecological, and social determinants into a unified strategic framework. The interrelationship between economic security and sustainable development can be further analyzed through several key dimensions. First, resource provision and resource efficiency highlight the transition from extensive to intensive development models. Second, financial stability and social inclusiveness demonstrate that economic resilience cannot be sustained without equitable income distribution and human capital development (Sen, 1999). Third, energy security and decarbonization underline the importance of renewable energy expansion in reducing systemic risks and enhancing long-term stability. Finally, institutional stability and adaptive governance mechanisms ensure that socio-economic systems remain flexible under changing environmental and market conditions (Daly, 1991).

Conceptually, this relationship can be described at three levels: macro-level (strategic sustainability of national economies and protection of natural capital), meso-level (sectoral and regional resource efficiency and innovation-based transformation), and micro-level (environmental responsibility and adaptive capacity of firms and households). Within this structure, economic security primarily functions as a risk management and shock absorption mechanism, whereas sustainable development defines the long-term transformation trajectory of the system. In conditions of global uncertainty and ecological constraints, ensuring economic security cannot be limited to defensive measures alone; it must be integrated with sustainable development principles that prioritize ecological restoration and social stability.

Table 1. Sustainable development matrix of social-economic systems

Conceptual Direction	Importance from the Perspective of Economic Security	Sustainability Mechanism
Resource Efficiency	Reduction of raw material dependence and import reliance	Circular economy and recycling
Social Stability	Prevention of internal unrest and social disruptions	Inclusive growth, fair income distribution, and employment
Ecological Balance	Protection from economic losses caused by natural disasters and climate change	Green technologies and renewable energy
Innovation Security	Elimination of dependence on foreign technologies	Research and Development (R&D) and development of domestic intellectual property

Source. Prepared by the author based on the studied literature sources (1, 4, 5, 11, 13, 14, 17–19, 21, 23, 26; World Commission on Environment and Development, 1987; Elkington, 1994; Daly, 1991; United Nations, 2015; Sachs, 2015; Pearce & Barbier, 2000).

Figure 1. Conceptual Model of Socio-Economic System Stability and Economic Security

The presented framework illustrates a systemic model of socio-economic stability and its transformation into economic security and sustainable development. At the core of the model lies Socio-Economic System Stability, which is operationalized through four interrelated strategic pillars: Resource Efficiency, Social Stability, Ecological Balance, and Innovation Security.

The first pillar, *Resource Efficiency*, emphasizes circular economy principles, resource sovereignty, and supply chain resilience as key determinants of reducing external dependency and strengthening domestic economic autonomy. The second pillar, *Social Stability*, is grounded in inclusive growth, equitable income distribution, and employment stability, which collectively ensure internal socio-economic cohesion and mitigate systemic risks of social fragmentation. The third pillar, *Ecological Balance*, reflects the increasing transformation of environmental risks into economic risks. It highlights the role of green technologies, renewable energy systems, and climate risk reduction mechanisms in safeguarding long-term economic resilience. The fourth pillar, *Innovation Security*, represents the technological and intellectual foundation of the system, encompassing R&D development, technological independence, and intellectual property accumulation as drivers of competitiveness and strategic autonomy.

These four pillars collectively converge into the formation of Economic Security, which functions as an integrative mechanism ensuring system-wide resilience against internal and external shocks. Economic security, in turn, serves as a transitional stage toward Sustainable Development, defined as a balanced integration of economic, social, and environmental objectives. Ultimately, this trajectory leads to Strategic National Resilience, representing the highest level of systemic stability and adaptive capacity. From a theoretical perspective, the model demonstrates that economic security is not an isolated domain but rather an outcome of multidimensional sustainability interactions. The integration of resource, social, ecological, and innovation dimensions reflects a shift from traditional growth-oriented paradigms toward a resilience-based development framework.

3. The Strategic Trajectory of Economic Security in the Context of Sustainable Development

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The sustainability of economic growth rates characterizes the dynamics of expanded reproduction with considerable precision. The continuity and efficiency of this production mode are directly dependent on resource availability. Hence, the systemic continuity of a socio-economic development trajectory as a key condition of economic security requires an adequate and high-quality resource base. This is a fundamental premise of the sustainable development concept as defined by the United Nations, which frames it as a strategic approach to socio-economic progress aimed at preserving biosphere integrity and ensuring human survival (United Nations, 2002; World Commission on Environment and Development, 1987).

Within this framework, sustainable development provides a global governance orientation for state policy, strategic planning, and decision-making processes. It implies the formation of development trajectories for socio-natural systems that may either ensure or undermine economic security depending on their structural parameters. From this perspective, civilizational trajectories can be grouped into two categories: spontaneous (unregulated) trajectories and regulated trajectories. Historically, spontaneous trajectories maintained relative system stability over long periods. However, in the modern era, they significantly increase systemic risks due to approaching critical “tipping points” of irreversibility. Current resource consumption levels exceed the regenerative capacity of the biosphere, and the ecological footprint threshold was already surpassed in 2016 (WWF, 2016). Therefore, global and national economic security increasingly depends on the transition to green technologies, embedded within regulated socio-natural-economic development frameworks (Kruglova, 2019).

The term “sustainable development” has undergone a complex conceptual evolution. Its translation into different languages is not fully unambiguous, as “sustainability” is often mistakenly interpreted as static equilibrium, whereas in reality it reflects dynamic and nonlinear processes. Some scholars emphasize terminological limitations, arguing that absolute sustainability is conceptually unattainable due to systemic variability in nature and society (Korchagina, 2008; Sachs, 2015). The conceptual foundations of sustainable development were formalized at the 1992 Rio Conference (United Nations, 1992) and further institutionalized through the Johannesburg Declaration of 2002. These principles were later consolidated in the 2030 Agenda for Sustainable Development (United Nations, 2015).

UN documents emphasize that sustainable development principles are not entirely new; they are historically rooted in traditional societies and local community practices. Even industrialized countries retain fragmented elements of sustainability within their socio-economic systems. These ecosystem-based and community-centered components now represent a strategic foundation of the modern sustainable development paradigm. In Western literature, sustainable development is defined as a development model in which the needs of future generations are not compromised by current economic activity. This reflects the principle of intergenerational equity, highlighting the risks associated with overexploitation of finite resources (Sen, 1999; Stiglitz, 2012; Sachs, 2015). More specifically, sustainable development is interpreted as the balanced reproduction of territorial potential including economic, ecological, social, and resource components ensuring long-term socially oriented development conditions (Leksin & Shvetsov, 2007). From a systemic economic perspective, sustainability and economic security are tightly interconnected. Classical models such as *The Limits to Growth* demonstrate the structural constraints of exponential growth within finite systems (Meadows et al., 1972). Later approaches, including steady-state economics, argue that long-term stability requires maintaining economic activity within ecological limits (Daly, 1991). The triple bottom line framework further integrates economic, social, and environmental dimensions of development (Elkington, 1994), while OECD and World Bank methodologies expand evaluation beyond GDP toward comprehensive sustainability indicators (OECD, 2017; World Bank, 2018). For Azerbaijan, these principles are reflected in national development

policy, particularly in the strategic document “Azerbaijan 2030: National Priorities for Socio-Economic Development,” which emphasizes green growth, environmental sustainability, and inclusive development as key pillars of long-term economic security (President of the Republic of Azerbaijan, 2021).

Table 2. Schematic Presentation of the Concept of Sustainable Development

Dimension	Main Directions	Key Mechanisms	Outcome
Economic	Sustainable economic growth, efficiency, competitiveness	Innovations, efficient use of resources, investment environment, employment growth	Economic stability, long-term development, economic security
Social	Social justice, improvement of welfare, inclusiveness	Access to education and healthcare, social protection mechanisms, human capital development	Improved quality of life, social stability
Environmental	Environmental protection, ecological balance	Conservation of natural resources, ecological standards	Sustainability of ecosystems, healthy environment
Integration	Economic–social–environmental coordination	Green economy, sustainable governance, institutional mechanisms	Ensuring sustainable development

Source. Prepared by the author based on analyzed sources (President of the Republic of Azerbaijan, 2021; Daly, 1991; Sachs, 2015; United Nations, 2015; UNDP, 1991; World Commission on Environment and Development, 1987).

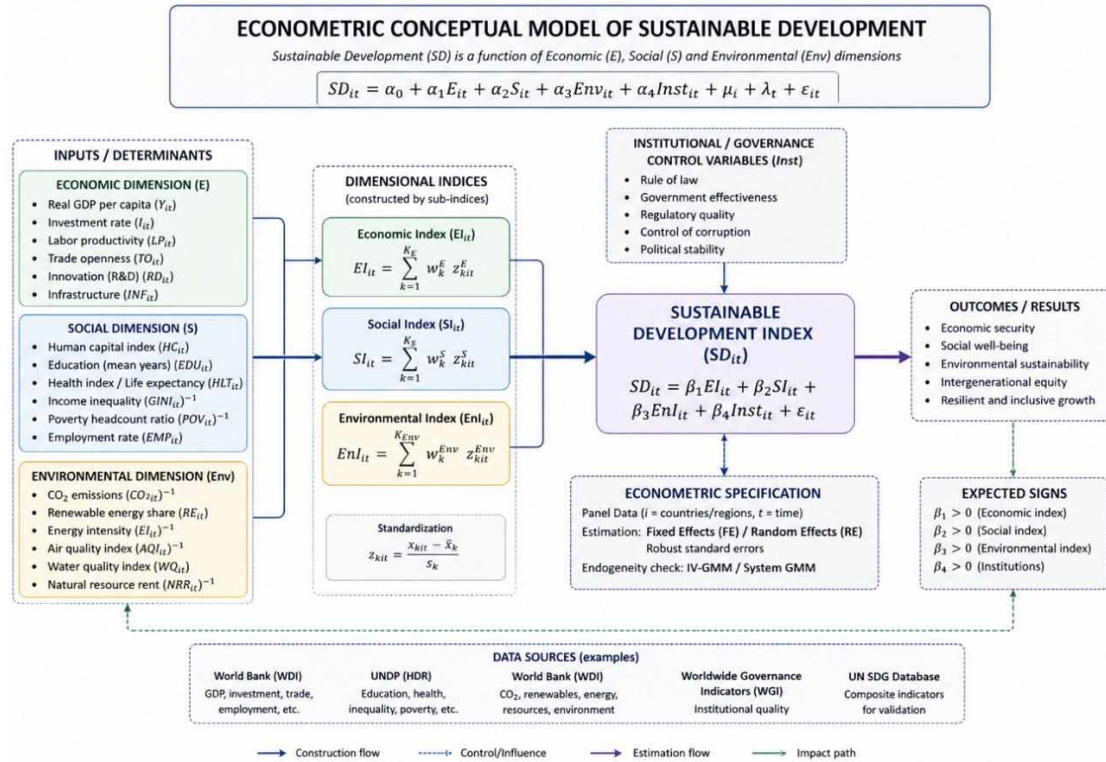
Based on the above, the main criterion is the preservation of all elements of regional potential, as well as the direct impact of quantitative and qualitative parameters on the population’s standard of living. The presented table reflects a systemic and integrative model of the sustainable development concept. The concept is formed on the basis of the interdependence of economic, social, and environmental dimensions, an approach widely recognized in modern economic theory as the triple bottom line model. The economic dimension constitutes the material foundation of sustainable development and aims to ensure long-term economic growth, efficient resource utilization, and improvement of the innovation and investment environment.

This dimension is crucial for strengthening economic security and maintaining economic stability. The social dimension is focused on improving societal welfare, ensuring social justice, and developing human capital. Expanding access to education and healthcare, as well as strengthening social protection mechanisms, forms the social foundation of sustainable development and stimulates inclusive economic growth. The environmental dimension encompasses environmental protection, efficient and responsible use of natural resources, and the maintenance of ecological balance. This dimension plays a decisive role in protecting the interests of future generations and ensuring the sustainability of ecosystems. The integrated approach involves the coordination of these three dimensions. Through green economy principles, sustainable governance, and institutional mechanisms, economic growth is aligned with social welfare and environmental security. This integrated approach represents the key outcome of sustainable development. Thus, the table clearly illustrates the goal–mechanism–outcome chain of the sustainable development concept, systematizing both its theoretical and applied nature. Based on the above conceptual approaches, it should be emphasized that sustainable development can essentially be characterized as “development without

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destruction” (Leksin & Shvetsov, 2007). This concept combines two fundamental and inseparable aspects: the anthropocentric aspect, which reflects human welfare and progress, and the biosphere-centric aspect, which emphasizes environmental protection as a prerequisite for human development. Modern socio-economic, scientific-technical, and industrial-technological transformations, along with the resulting environmental risks and global threats, have made the formation of a new development paradigm inevitable, as highlighted at the 1992 Rio de Janeiro Conference (United Nations, 1992). This paradigm is based on social justice and high economic efficiency while aiming to preserve natural ecosystems for both present and future generations.

Figure 2. Econometric conceptual model of sustainable development



The figure 2 depicting the econometric conceptual model of sustainable development explains how economic, social, and environmental dimensions jointly determine a country's sustainable development performance. It treats sustainable development as a dependent variable influenced by measurable indicators from all three pillars. The economic dimension includes variables such as GDP per capita, investment, productivity, trade openness, innovation, and infrastructure, which represent growth and efficiency. The social dimension captures human capital, education, health, income equality, poverty levels, and employment, reflecting welfare and inclusiveness. The environmental dimension includes CO₂ emissions, renewable energy use, energy intensity, air and water quality, and natural resource depletion, representing ecological sustainability.

To operationalize the relationship between economic security and sustainable development, the following conceptual econometric model is proposed:

$$ES = \alpha + \beta_1 RE + \beta_2 SS + \beta_3 EB + \beta_4 IS + \varepsilon$$

Where:

- **ES** = Economic Security Index
- **RE** = Resource Efficiency (circular economy, resource productivity)
- **SS** = Social Stability (income equality, employment, human capital)
- **EB** = Ecological Balance (CO₂ emissions, renewable energy share)

- IS = Innovation Security (R&D intensity, technological independence)
- ε = stochastic error term
- $\alpha, \beta_1-\beta_4$ = estimated coefficients showing the contribution of each dimension

To ensure system viability under ecological limits, the following constraint can be added:

$$RE \leq BC$$

Where:

- BC = Biosphere Carrying Capacity

The abovementioned condition ensures that resource use does not exceed ecological regeneration limits. For a more advanced representation of civilizational development trajectories, the following functional relationship can be introduced to describe sustainable development dynamics:

$$SD_t = f(ES_t, EC_t, IN_t, G_t)$$

Where:

- SD_t represents the level of sustainable development at time t ;
- ES_t denotes economic security at time t ;
- EC_t refers to environmental (ecological) conditions at time t ;
- IN_t reflects innovation capacity, including technological advancement and R&D potential;
- G_t represents governance effectiveness, encompassing institutional quality, regulatory efficiency, and policy coherence.

The functional specification implies that sustainable development is a dynamic and multidimensional process determined by the simultaneous interaction of economic, ecological, technological, and institutional factors.

Besides, the Sustainable Development Index (SADI) is introduced as an aggregated empirical proxy for sustainable development performance. It integrates multidimensional indicators covering economic resilience, social welfare, environmental integrity, and institutional quality. In this study, SADI serves as a synthetic measurement tool that operationalizes the theoretical model of sustainable development and enables its empirical approximation within an economic security framework. Sustainable development can be operationalized through the composite SADI index, which integrates economic, social, and environmental dimensions into a single measurable indicator. Accordingly, the model can be reformulated as:

$$SADI_t = \alpha + \beta_1 ES_t + \beta_2 EC_t + \beta_3 IN_t + \beta_4 G_t + \varepsilon$$

Where:

- $SADI_t$ = Sustainable Development Index at time t
- ES_t = Economic security
- EC_t = Environmental condition
- IN_t = Innovation capacity
- G_t = Governance effectiveness
- ε = stochastic error term

In this specification, the SADI index becomes the endogenous outcome variable, allowing empirical validation of how economic security and its determinants jointly shape sustainability performance.

As a logical result of evolutionary processes, the sustainable development model currently represents a systemic structure in which ecological, economic, social, and integration components are prioritized in optimal balance. Summarizing the presented definitions, we formulate our conceptual understanding of sustainable development as follows: Sustainable development is the ability of a socio-economic system at any hierarchical level (global, national, regional, or local) to function and evolve within defined parameters under conditions of both endogenous and exogenous negative influences. This development model must ensure

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the progressive and socially oriented interests of individuals, maintain ecological balance, create necessary conditions for the evolution of the biosphere as the foundation of life on Earth, and ultimately support the health and long-term existence of humanity. Finally, the components of sustainable development within the paradigm of economic security can be systematically presented in the following table based on the conceptual framework outlined above (Table 3).

Table 3. Components of Sustainable Development in Ensuring Economic Security

Component Name	Essence and Relation to Economic Security	Key Principles
Anthropocentric Aspect	Focuses on human-centered development, ensuring progressive and socially oriented living standards for individuals and society.	Social justice, protection of human capital, safeguarding vital interests
Biosphere-Centric Aspect	Emphasizes the protection of the environment and maintaining ecological balance as the foundation for human development.	Protection of the biosphere, ecological equilibrium, respect for nature's regenerative capacity
Technological Aspect	Involves the application of innovative, "green," and waste-free technologies that transform the resource base of the economic production system.	Smart eco-oriented impact, resource efficiency, transition to renewable energy sources
Intergenerational Equity	Ensures that current economic interests do not compromise the needs of future generations.	Balanced resource distribution across generations, sustainable (non-destructive) development trajectory
System Stability	Maintains the system's ability to function under internal (endogenous) and external (exogenous) shocks and disturbances.	Risk and threat management, enhancement of economic resilience

Source. Prepared by the author based on reviewed sources [1,6,9,15,21,23,26].

The sustainable development complex is analyzed from the perspective of ensuring economic security along two main trajectories: free and regulated pathways. Free trajectories refer to development patterns that, at the current stage, have a high probability of causing instability in the nature civilization system and leading to the deterioration of economic security. In contrast, regulated trajectories are considered an integral part of economic security and are based on the application of new technologies that keep resource consumption within the limits of nature's regenerative capacity. As a result, the interaction of these components ensures the restoration of the resource base after humanity passed the so-called "point of no return" in 2016, while also maintaining the economic system within the framework of national ecological security. At the same time, the conceptual differences between the sustainable development approach and models predicting ecosystem destabilization are comparatively summarized in Table 4. The main factor necessitating the transition to a sustainable development model is the highly risky and unstable nature of the current anthropogenic environment (Yusibov, 2026). The present situation requires the development and urgent implementation of comprehensive preventive measures aimed at stabilizing the biosphere and restoring key parameters of economic security. The comparative characteristics presented in Table 4 confirm that the sustainable development model represents a new stage of civilizational development economic and social within the constraints of planetary biosphere limits and environmental protection imperatives.

Table 4. Comparative Analysis of Sustainable Development Model and Non-Stable Development Models

Comparison Criteria	Non-Stable (Extensive) Models	Sustainable Development Model (Enduring Development)
Resource Use	Exploitation of non-renewable resources and extensive growth.	Prioritization of renewable and alternative resources.
Environmental Approach	Reactive exploitation of the environment for profit.	Proactive compliance with planetary–biosphere limits.
Nature of Development	Risk of instability and ecological crisis.	Safe and systematic civilizational progress.
Energy Base	Fossil fuels and high carbon emissions.	Renewable energy sources and “green” technologies.

Source: Prepared by the author based on reviewed sources [1,6,9,15,25].

This model, while minimizing the scale and intensity of anthropogenic pressure on the environment, also aims to transform the resource base of the economic production system. This transformation essentially implies a shift toward an alternative economic model based on renewable resources and inexhaustible energy sources, thereby ensuring the harmonization of biosphere protection with the developmental interests of civilization. Consequently, the study of the interrelationship between the transition to sustainable development and noospherogenesis as a means of realizing economic security potential is of significant scientific importance. This interrelationship is manifested in several key aspects. First, the necessity of ensuring the future existence of society and civilization as a whole will strongly stimulate scientific research and creative activity. Second, the main mechanism for implementing the sustainable development model is collective human intelligence. Thus, solving global challenges and threats facing modern civilization is impossible through the efforts of individuals or single states alone. In this regard, the global community is confronted with the necessity of adopting a development model based on intelligence and knowledge. The analysis of most normative and strategic documents on the development of the green economy shows that the formulation of unified and systematic principles for sustainable territorial development is both feasible and necessary. These principles can be summarized as follows:

- The principle of considering human needs and harmonizing human activity with nature
- The principle of developing civil society institutions and ensuring their active participation in sustainable territorial development
- The principle of strengthening social protection of families and children
- The principle of protecting the cultural, social, and economic interests of indigenous populations
- The principle of combating population decline and socio-demographic degradation processes
- The principle of increasing legal culture and fostering respect for the law among the population
- The principle of intensifying economic development through the application of advanced technological innovations
- The principle of ensuring and improving environmental quality
- The principle of improving environmental protection legislation
- The principle of developing paid nature use and natural resource management systems
- The principle of efficient and rational use of natural resources
- The principle of considering the interests and needs of future generations

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The systematic implementation of the proposed principles of sustainable territorial development has significant scientific and practical importance for forming sustainable development models at national, regional, and subregional levels, as well as for ensuring long-term economic security.

4. Conclusions

The accelerating global transformation processes of the 21st century, combined with deepening ecological and socio-economic imbalances at the planetary level, have fundamentally intensified the interaction between society and nature. This shift has made the transition toward a qualitatively new stage of the economic security paradigm both necessary and unavoidable. The conducted theoretical and conceptual analysis demonstrates that economic security is no longer limited to a defensive mechanism against internal and external threats. Instead, it has evolved into a complex systemic category that is intrinsically linked to the principles of sustainable development, ensuring self-renewal capacity, adaptability, and long-term resilience of socio-economic systems. From a systems perspective, economic security should be redefined as an integrated structure in which environmental factors are not externalities but internal and inseparable components of the socio-economic system. The stability and competitiveness of any economic system are therefore directly conditioned by the equilibrium state of its surrounding ecological environment, which functions as a higher-order supersystem. In this context, ecological security must be conceptually embedded within the architecture of economic security.

At the same time, the current global evidence of exceeding biospheric regenerative limits clearly indicates the high-risk nature of uncontrolled and resource-intensive development models. This validates the necessity of transitioning toward regulated development trajectories based on ecological constraints, reduced carbon intensity, and green technological innovation. Strategic economic planning must therefore shift from linear growth logic to adaptive models that internalize environmental limitations as core planning parameters. Sustainable development, in this sense, represents a “non-destructive progress” model that replaces the artificial dichotomy between anthropocentric and biosphere-centered approaches with a harmonized synthesis. This ensures the protection of both present and future generations while reinforcing intergenerational equity as a foundational principle of economic security. The preservation of ecosystem stability thus becomes not a secondary environmental objective but a core strategic pillar of national and global security frameworks. Furthermore, the transition to a sustainable development model extends beyond institutional restructuring and technological modernization. It requires a deeper intellectual transformation of economic thinking, driven by collective cognitive capacity and innovation-based governance. Green technologies, digitalization, and enhanced scientific research potential collectively form an intellectual self-defense mechanism of the economy against ecological and systemic risks, accelerating the shift toward a noospheric development paradigm. Overall, the analysis confirms that the harmonization of human needs with ecological constraints, efficient and rational resource governance, and the institutionalization of green economy mechanisms constitute the strategic foundation of long-term economic security. The systematic implementation of these principles strengthens the resilience of national economic systems, enhances their adaptive capacity under global uncertainties, and ensures their competitiveness in the context of global transformations. Consequently, this lays the scientific and practical groundwork for the formation of a new, sustainability-oriented model of economic security.

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MACROECONOMIC DETERMINANTS OF NPLS IN EU: A PANEL DATA ANALYSIS (2010–2023)

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Abstract: *Non-performing loans (NPLs) present a significant risk to the banking systems, and become worse during periods of economic turmoil. This study aims to identify and quantify the macroeconomic determinants influencing non-performing loans in EU member states, using annual panel data from 2010 to 2023. A Pooled Ordinary Least Squares regression approach along with robust and cluster-robust standard errors are utilized to assess the effects of GDP growth, unemployment rate, and inflation on NPL ratios. The findings indicate that unemployment is the strongest factor affecting NPLs. GDP growth is positively connected with NPLs, contrary to prevailing expectations, suggesting that economic expansion might encourage over-leveraging. Inflation has no statistically significant effect, while NPL ratios tend to rise during recessions. The study highlights the importance of macroeconomic stability for protecting financial systems.*

Keywords: *non-performing loans, macroeconomic determinants, panel data, EU, pooled*

1. Introduction

According to the European Commission, non-performing loans are defined as bank loans for which borrowers are unable or unlikely to fulfill their repayment obligations, either because of a decline in their personal financial situation, or late payments piling up (European Commission, n.d.). When banks have accumulated too many of these bad loans, their balance sheets weaken, which leads to a reduction in their profits. Since banks use these funds to give out loans this situation consequently gives them less room to provide new credit to households and firms. Thus, it negatively affects the entire economy as a whole and the future investments as well (Klein, 2013).

After difficult periods of global disruptions such as the Covid-19 pandemic, the issue of non-performing loans became more evident. Particularly, greater levels of NPL ratios can slow down the period of economic recovery after the mentioned shocks, especially in those countries that are gravely exposed to adverse macroeconomic conditions. Even after the major policy regulations that have been taken at the EU level to address these NPLs, they continue to remain a concern for the adequate functioning of the financial system (Huljak et al., 2020).

Even though macroeconomic factors are so important, the majority of the existing research focuses on bank-specific determinants of non-performing loans. While cross-country analysis for the macroeconomic drivers, especially within the whole EU countries is rather limited. Moreover, most of the studies focus on short horizons, mainly only through the crisis periods and leave longer-term trends less explored. A growing strand of research applies machine learning and explainable artificial intelligence to NPL prediction. Durand et al. (2023) state that the complexity of the NPL phenomenon, would suggest that models powered by AI could aid credit risk analysis and decisions. But crucially, the author concludes that future studies should incorporate macroeconomic variables to identify optimal predictors of NPLs. The present study directly responds to that recommendation,

providing a panel econometric analysis of macroeconomic determinants that can serve as a foundation for, and complement, such AI powered credit risk frameworks.

The objective of this study is to carefully examine these macroeconomic factors of NPLs in EU countries using annual panel data over thirteen years, 2010 to 2023. More specifically, each determinant, including GDP growth, unemployment rate, inflation, and economic recession periods, will be analyzed for their effect. In this case, the recession will be incorporated as a regression dummy variable. This research provides this way a comprehensive assessment and offers insights for financial regulators and policymakers.

1.1 Research Questions

The study is guided by the following research questions:

- What are the main macroeconomic determinants of non-performing loans in EU countries?
- How do these macroeconomic determinants affect NPL ratios?
- Do recession periods significantly influence the level of non-performing loans?

2. Literature Review and Hypotheses Development

2.1 Unemployment and Non-Performing Loans

The relevant literature identifies the unemployment rate as one of the most important macroeconomic factors affecting non-performing loans. Aqifi et al. (2025) emphasized that the central role in explaining variations happening in loan performance is held precisely by unemployment. In a similar way, Bialas and Karafolas (2025) documented that there is a strong positive relationship between unemployment and NPLs, with higher unemployment bringing a larger share of these bad loans. Even from a broader international perspective provided by Salas et al. (2024), it turns out that unemployment has a significant and positive effect on NPL ratios all over the world, no matter of the geographical location of the banks. Additionally, Masurashvili (2024) has explained this repeated result throughout the papers but by a theoretical ground stating that rising unemployment reduces household income, thereby limiting borrowers' ability to repay their debt and raising default probabilities. Consistent with this view, Zawadzki (2023) validates the same hypothesis that higher unemployment weakens households' loan repayment capacity. Overall, the literature provides strong and consistent evidence that increases in unemployment rates lead to higher non-performing loan ratios.

2.2 GDP Growth and Non-Performing Loans

In literature for many years, the link between GDP growth and NPL ratios has been widely examined and results suggest both stabilizing and risk-enhancing effects. Several studies support the counter- cyclical relationship between them, arguing that a higher GDP growth brings a reduction of NPLs as income levels improve. Goyal et al. (2023) finds that economic expansions associated with GDP growth lower the likelihood of default, meaning that they reduce the NPLs. In a similar way Ahmed et al. (2021) documents a significant negative relationship between these two variables, so credit risk would reduce in the case of GDP growth. Staehr and Uusküla (2020) further support this view by identifying higher GDP growth as a factor for lower NPL ratios in the future.

However, other studies present a rather counterintuitive result, suggesting that periods of economic expansions may be related to higher non-performing loans. Beka and Abazi (2024) found that GDP growth has a positive impact on NPLs, especially in samples that include periods of significant economic disturbances such as COVID-19. Isakov (2024) provides a possible explanation for this outcome. He argues that during economic expansions, businesses and households tend to increase borrowing to finance consumption and investment. This might lead to excessive or poorly allocated credit which then leads to

increases of the NPL ratios. Further evidence from Southeast Europe provided by Cenaj (2025) similarly finds a notable relationship between economic growth and NPL dynamics in the region, reinforcing the view that this link may be particularly context-dependent. So generally, the literature indicates that the effect of GDP growth on non-performing loans is ambiguous and may depend on the economic context.

2.3 Inflation and Non-Performing Loans

The effect of inflation on non-performing loans remains ambiguous in the empirical literature, as there are studies reporting mixed and often context-dependent results. Some of the research suggest that inflation may cause a reduction of the real value of debt and this way ease the repayment burden. Le and Le (2023) observed an inverse correlation between inflation and NPLs, supporting the idea that higher inflation can constrain the accumulation of bad loans. Likewise, Lekupanai Leleok and Makori (2024) also reported a statistically insignificant but negative effect of inflation on NPLs in the long term; however, their findings also indicate a significant positive impact in the short term. This suggests that while inflation might not serve as a major determinant of non-performing loans over extended periods of time, it can still have a temporary effect on loan performance.

In contrast, other studies emphasize the adverse effects of inflation on borrowers' financial capacity. Khoirunisa and Karnasi (2023) state that high inflation increases production costs and reduces purchasing power, leading to lower revenues and a diminished ability of firms to meet their debt obligations, thereby increasing default risk. However, empirical evidence from Kawakibi and Mustikowati (2025) also show that inflation does not significantly affect NPLs in environments where inflation remains moderate and is effectively managed through monetary and fiscal policies. Altogether, as noted by Goyal et al. (2023), the literature presents conflicting findings regarding the impact of inflation on non-performing loans, indicating that its effect may depend on the magnitude, persistence, and economic context of inflationary pressures.

2.4 Economic Recessions and Non-Performing Loans

Economic recessions are thought to be periods when credit risk increases, and as a consequence, non-performing loan ratios tend to rise as well. Huljak et al. (2020) states that high NPL ratios continue to be a major problem in a number of euro area countries, and noticed that the COVID-19 pandemic is likely to cause a spike in non-performing loans throughout the region. A statement that proves further that periods of recessions like the one the world encountered during the aforementioned pandemic, do actually affect NPL ratios. Deteriorating macroeconomic conditions lower household income and business revenues, which usually happens during recessions and as a result also increases the likelihood of loan defaults. This statement is also mentioned by Giannopoulos and Kariofyllas (2025) which explain the fact that what recessions do is that they make it more difficult for businesses, particularly those with low creditworthiness, to get extra funding needed to meet their obligations because banks tighten their credit supply.

These adverse effects that recessions have on loan performance are even more clearly visible in less diversified economies. According to Elshani (2025), the likelihood of default increases profoundly during economic downturns, with a more noticeable nuance in developing European countries that are more susceptible to external shocks. From another perspective, the policy one, Bello, Umar, and Gawuna (2020) highlight the significance of implementing measures that aim to mitigate the grave impact of domestic economic crises on banks' non-performing loans during recessions. In a similar way Kostis (2020) contends that heightened uncertainty and economic contraction impact the dynamics of the credit supply, which thereby influences how NPLs evolve. Overall, research continuously shows

that economic recessions increase the so called credit risk and contribute to higher non-performing loan ratios.

2.5 Hypotheses

Based on the recent literature utilized for this research, the following hypotheses are proposed:

- H1: Higher unemployment rates increase non-performing loans.
- H2: GDP growth has a significant effect on non-performing loans.
- H3: Inflation has a significant effect on non-performing loans.
- H4: Economic recessions are associated with higher non-performing loan ratios.

3. Data and Methodology

3.1 Data Description

A balanced panel dataset was employed in this study, comprising of European Union (EU) countries from years 2010 to 2023. Due to missing observations on non-performing loans, Germany was excluded from the dataset. The final dataset is made up from 359 country–year observations, after removing observations with a high amount of missing dependent variables. Annual data were provided by the World Bank, to guarantee uniformity and comparability across all the countries studied.

The ratio of non-performing loans (NPLs), calculated as the percentage of total loans, serves as the dependent variable. While the explanatory variables include GDP growth, unemployment rate, inflation rate, and a recession in the format of a dummy variable. Macroeconomic performance is reflected in GDP growth which is calculated as the annual percentage change in real GDP. The unemployment rate reflects both the state of labor market and the ability of borrowers to repay debt. The real value of this debt can be impacted by inflation which is defined as the annual percentage change in consumer prices. And lastly, the recession dummy which helps the model to account for the effects of economic downturns and equals one for recession years and zero otherwise.

3.2 Descriptive Statistics

The summary statistics of the variables utilized are showcased in table 1. With a maximum value of 47.75% the average NPL ratio is 6.93%, with significant variation across countries. GDP growth averages 2.22%, while the unemployment rate has a mean of 8.38%. And inflation averages 2.54%, although the studied sample includes both periods of deflation and high inflation.

Table 1. Descriptive Statistics

Statistic	N	Mean	St. Dev.	Min	Max
NPLs	359	6.93	8.13	0.15	47.75
GDP Growth	359	2.22	3.75	−10.94	24.62
Unemployment	359	8.38	4.55	2.02	27.69
Inflation	359	2.54	3.21	−2.10	19.71

The dispersion of variables indicates meaningful cross-country heterogeneity, which validates the application of panel data methods.

3.3 Correlation Analysis

Pearson correlation matrix is reported on table 2. We can observe that non-performing loans show a strong positive correlation with unemployment (0.601), which suggests to us that the worsening of labor market conditions are linked with higher credit risk. Inflation is moderately negatively correlated with NPLs (−0.249), while GDP growth shows a weak negative relationship (−0.102).

Table 2. *Correlation Matrix*

	npl	gdp growth	unemployment	inflation
npl	1	-0.102	0.601	-0.249
gdp growth	-0.102	1	-0.228	0.074
unemployment	0.601	-0.228	1	-0.292
inflation	-0.249	0.074	-0.292	1

Most importantly, the correlations among the explanatory variables remain low, indicating that there are no immediate concerns regarding multicollinearity.

3.4 Econometric Model

This study estimates a pooled Ordinary Least Squares (OLS) regression model so to examine effects of the macroeconomic factors on non-performing loans :

$$NPL_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 UNEMP_{it} + \beta_3 INF_{it} + \beta_4 RECESS_{it} + \varepsilon_{it} \quad (1)$$

where i denotes the country and t represents time. The error term ε_{it} captures unobserved factors affecting NPL ratios. Pooled OLS is suitable as a baseline specification for determining the average relationship between macroeconomic variables and banking sector risk across EU countries.

3.5 Diagnostic Tests and Residual Analysis

A number of diagnostic tests were performed to confirm the validity of the pooled OLS assumptions. These consist of checks for normality, heteroskedasticity, autocorrelation, and multicollinearity.

Stationarity: The Augmented Dickey–Fuller test or ADF was utilized in order to check if the variables have a unit root. As reported in Table 3, the null hypothesis of a unit root is rejected for all variables at the 1% significance level. This confirms us that the series are firstly stationary and also suitable to be used for the regression analysis, reducing like this the risk of sporadic results.

Table 3. *Augmented Dickey–Fuller Unit Root Test*

Variable	Test Statistic	Lag Order	p-value
Non-performing Loans (NPL)	-4.507	7	<0.01
GDP Growth	-5.011	7	<0.01
Unemployment	-4.530	7	<0.01
Inflation	-10.569	7	<0.01

Normality of Residuals The Shapiro–Wilk test in Table 4 strongly rejects the null hypothesis of normally distributed residuals ($W = 0.854$, $p < 0.001$). This indicates that residuals are not normally distributed, a violation of the classic assumption.

Table 4. *Normality Test (Residuals)*

	Test	Statistic	p-value
	Shapiro-Wilk	0.854	
			<0.001

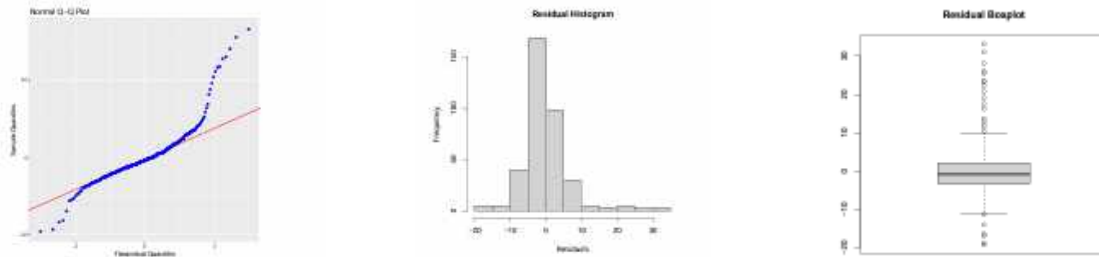
Three visual diagnostics for normality of residuals are displayed in Figure 1: a Q-Q plot, histogram, and boxplot of the residuals. The Q-Q plot shows minor deviations from the diagonal, while the histogram indicates that there is some slight skewness. The boxplot shows a few outliers, but overall the residuals are reasonably symmetric. So these graph results give the same answer as the Shapiro-Wilk test, that we do not have a normality of residuals. However, given that the sample size is quite large and over thirty, the violation of strict normality is unlikely to bias the OLS coefficient estimates due to the Central Limit Theorem.

Figure 1. Residual Diagnostics

Normal Q-Q plot of residuals

Histogram of residuals

Boxplot of residuals



Heteroskedasticity: Heteroskedasticity is detected using the Breusch–Pagan test ($BP = 58.14$, $p < 0.001$; Table 5), showcases that the variance of residuals is not constant across observations, which means that we have heteroskedasticity present in the model.

Table 5. Breusch-Pagan Test for Heteroskedasticity

Test	Statistic	df	p-value
Breusch-pagan	58.14	4	<0.001

Multicollinearity: (Table 6) shows that Variance Inflation Factors (VIFs) have a range between 1.09 and 1.83, which is well below the conventional threshold of 10, confirming that multicollinearity is not a concern for the model.

Table 6. Variance Inflator Factors

Variable	VIF
GDP Growth	1.83
Unemployment	1.72
Inflation	1.09
Recession	1.12

Autocorrelation: The Durbin–Watson test used to check for autocorrelation or differently known as serial correlation, reveals positive serial correlation in residuals ($DW = 0.386$, $p < 0.001$; Table 7), suggesting that residuals are correlated within countries over time. A statement that means we have the violation of autocorrelation present in the model.

Table 7. Durbin-Watson Test for Autocorrelation

Test	Statistic	p-value
Durbin–Watson	0.386	<0.001

Functional Form: The RESET test fails to reject the null hypothesis of correct functional form ($F = 0.048$, $p = 0.952$; Table 8), supporting the linear specification of the model.

Table 8. RESET Test for Functional Form

Test	Statistic	df1	df2	p-value
RESET	0.048	1	354	0.952

3.6 Robust Estimation Strategy

To address the violations that were detected above with the particular tests conducted; this study employs Robust standard errors and Cluster-Robust standard errors. Robust standard errors correct for the bias due to a non-constant variance, while cluster-robust standard errors account concurrently for heteroskedasticity and within-country autocorrelation.

Clustered standard errors at the country level are considered the preferred specification for inference in this study. Table 9 presents the results from the pooled OLS regression after cluster-robust standard errors.

4. Empirical Results

In table 9 it is shown the pooled OLS regression results after the cluster-robust standard errors has been applied to fix the problems with the model.

Table 9. Pooled OLS Regression

<i>Dependent variable:</i>	
Non-Performing Loans (NPL)	
GDP Growth	0.256***
	(0.098)
Unemployment Rate	1.02***
	(0.320)
Inflation	−0.214
	(0.159)
Recession Dummy	2.512*
	(1.348)
Constant	−2.181
	(2.299)
Observations	359
R ²	0.377
Adjusted R ²	0.370
Residual Std. Error	6.453 (df = 354)
F Statistic	53.525*** (df = 4; 354)
<i>Note:</i> *p<0.1; **p<0.05; ***p<0.01	

Coefficient of determination illustrates us that the model explains approximately 37.7% of the variation in non-performing loans ($R^2 = 0.377$), a number that indicates a moderate explanatory power.

Unemployment because of a high significance can be considered as the strongest predictor of NPLs ($p < 0.01$). The NPL ratio increases by roughly 1.025 percentage points for every percentage point increase in unemployment. This result leads to supporting the hypothesis borrowers' repayment capacity is reduced due to weaker labor market conditions.

GDP growth showcases a positive and statistically significant coefficient (0.256, $p < 0.01$). Although it goes against the traditional expectations of a countercyclical relationship between GDP and NPLs, this result may be a reflection of periods of credit expansion during economic upturns. And what happens in these cases is that borrowing increases leading to a breach where it can subsequently elevate default risk.

Inflation carries a negative coefficient (−0.214) but is not statistically significant, which suggests that price dynamics were not a primary driver of loan performance in the EU during the sample period. The dummy variable used consisting of recession is positive (2.512) and marginally significant only at the 10% level, which leads to the conclusion that economic downturns are related to higher levels of bad loans. This aligns well with the theoretical expectations from literature reviewed that tighter financial conditions lead to default probabilities.

Overall, the findings from the model highlight how important macroeconomic stability is in order to maintain banking sector resilience.

5. Analysis and Discussion

This section covers the analysis of the result coming from the pooled OLS regression regarding the macroeconomic determinants of non-performing loans (NPLs) in European Union countries between 2010 and 2023. The estimated model is expressed as follows:

$$NPL_{it} = -2.181 + 0.256 GDP_{it} + 1.025 UNEMP_{it} - 0.214 INF_{it} + 2.512 RECESS_{it} + \varepsilon_{it} \quad (2)$$

As aforementioned, the model explains roughly 37.7% of the variation in NPL ratios ($R^2 = 0.377$, Adjusted $R^2 = 0.370$), considered as a moderate explanatory power for cross-country macroeconomic analysis. Another important value is the F-statistic which is highly significant (53.525, $p < 0.01$), confirming the joint significance of the explanatory variables.

5.1 Discussion

H1: For unemployment, the regression coefficient is 1.025 and is statistically significant at the 1% level. Thus, assuming that all other factors are kept constant, a one percentage point increase in the unemployment rate increases NPLs by approximately 1.025 percentage points. This finding supports the first hypothesis that higher unemployment reduces the repayment capacity for borrowers which then leads to more non-performing loans. The result is consistent with the previous studies taken into account such as the ones by Bialas and Karafolas (2025), Masurashvili (2024), Ahmed et al. (2021), and Salas et al. (2024), which also identify unemployment as one of the strongest macroeconomic drivers for credit risk. This is explained by the logic that during periods of rising unemployment, households face reductions in their income and firms as well experience shortfalls in their revenues, meaning that they have little liquidity and the chance of default increases. All of these ultimately contribute to an accumulation of NPLs higher than the before situation.

H2: GDP growth, contrary to the traditional expectation which would be countercyclical, has a positive coefficient (0.256) and is considered as significant at the 5% level. This signifies that with a one percentage point rise in GDP growth, NPLs increase with a 0.256 percentage point, *ceteris paribus*. This counterintuitive result suggests that during periods of economic expansion, both households and firms may increase borrowing due to optimism about their income growth. While on one side this can initially stimulate investment and consumption, some borrowers may over-leverage leading to defaults later or an inability to pay their debts. Similar observations were reported by Beka & Abazi (2024) and Isakov (2024), particularly during periods that tend to have economic volatility such as the COVID-19 pandemic. Therefore, rapid GDP growth may paradoxically be linked to higher NPLs in certain contexts, showing that it is important to have a prudent credit management even during expansionary periods.

H3: Inflation, although having a negative coefficient (-0.214), it is not statistically significant ($p \approx 0.18$). This result tells us that inflation does not have a strong impact on NPLs in the EU during the period used in the sample. Some literature (Le & Le, 2023; Huljak et al., 2020) suggests that inflation may reduce the real burden of debt, but in our analysis, this effect appears negligible. On the other hand, high inflation could reduce purchasing power and increase default risk, but EU countries experienced relatively moderate and controlled inflation rates during the studied period. Overall, inflation appears to be a secondary factor in explaining variations in NPLs.

H4: Economic Recession used as a dummy has a positive coefficient of 2.512 and is marginally significant ($p \approx 0.06$), results that can be interpreted as NPLs increase during recession years compared to non-recession ones. This observed result aligns with theoretical expectations which state that recessions reduce economic activity, weaken business revenues, and constrain households' repayment capacity, thereby increasing defaults. Literature by Giannopoulos & Kariofyllas (2025), Elshani & Nezirai (2025), and Bello et al. (2020) all similarly show that recessions elevate credit risk and result after all in higher NPL ratios. Despite the effect being borderline significant, it emphasizes the importance of monitoring credit exposure during economic downturns.

5.2 Limitations and Future Research

The limitations of this study mainly stem from data constraints and methodological choices. First limitation was the exclusion of Germany due to a large number of missing data on NPLs which might limit the generalization of the findings to the entire EU. Additionally, the study focuses only on the macroeconomic variables that mean omitting bank specific determinants such

as liquidity, capital adequacy, and management quality, which are also factors that influence credit risk. As for the methodology, the use of pooled OLS does not fully account for unobserved country-specific effects. For future research, applying other methods such as Fixed Effects, Random Effects, or GMM models could provide more accurate results and have a better control for country-level differences. Combining macroeconomic indicators with bank-level data would also allow for a more comprehensive understanding of NPL determinants and improve the predictive power of the model. Additionally, future research could extend these findings by incorporating the macroeconomic variables validated here into deep learning or AI powered models for NPL prediction as recommended by Durand et al. (2023), potentially improving both predictive accuracy and interpretability in credit risk analysis.

6. Conclusions

Applying a panel data from 2010 to 2023, this research looked at the macroeconomic determinants of non-performing loans (NPLs) across European Union countries. The empirical results demonstrate the critical role that macroeconomic conditions have in what is called shaping the banking sector stability.

As we saw from results, amongst all the variables analyzed, unemployment was the most significant predictor of NPLs, confirming that like in the relevant literature, deteriorating labor market conditions significantly weaken borrowers' repayment capacity. GDP growth results, which were positive and highly significant in relation with NPL, showcased us that that periods of economic expansion might serve as a factor to encourage excessive borrowing and risk-taking behavior that later materializes in higher default rates. Inflation did not appear to have a considerable effect, although negatively related to NPLs, indicating that under the observed periods price dynamics were not a primary driver of loan performance. Lastly, recession episodes show signs of increases in NPL ratios, meaning that economic downturns as predicted cause banking systems to become vulnerable.

Overall, the results tell us that maintaining macroeconomic stability should be one of the focuses for safeguarding financial systems. Policymakers should prioritize labor market resilience, closely monitor credit expansion during growth periods as it might lead to bad loans as much as the good ones, and strengthen preventive regulatory frameworks to mitigate the credit risk before it escalates further. Despite providing important evidence, this study is still subject to certain limitations mentioned earlier, so future research could incorporate in models bank-specific variables and apply advanced panel techniques such as Fixed Effects or Generalized Method of Moments (GMM) to better capture unobserved heterogeneity and improve estimation robustness.

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FINANCIAL INCLUSION AND HOUSEHOLD ECONOMIC WELL-BEING: A LITERATURE REVIEW

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Abstract: *Financial inclusion has become an important topic in economic and financial research due to its potential to improve household economic well-being and promote inclusive development. This paper aims to review and synthesize the existing literature on the relationship between financial inclusion and household economic well-being. The study examines key concepts, determinants, and empirical evidence related to access to and use of formal financial services, including savings, credit, insurance, and digital financial products. The reviewed literature indicates that financial inclusion contributes positively to household well-being by improving income management, encouraging savings, expanding investment opportunities, and strengthening resilience to economic shocks. The findings also highlight the importance of financial literacy, income levels, and financial system development in enhancing the effectiveness of financial inclusion initiatives. Overall, the literature suggests that greater financial inclusion can significantly improve household economic well-being, particularly among low-income and financially vulnerable groups.*

Keywords: *financial inclusion, economic well-being, households, financial literacy, financial services.*

INTRODUCTION

Financial inclusion has become an important component of economic development strategies across the world. According to the World Bank, financial inclusion refers to access to and use of affordable and appropriate financial services, including payments, savings, credit, and insurance. Access to such services enables individuals and households to participate more effectively in economic activities and improve their financial resilience (World Bank, 2022).

The importance of financial inclusion has increased significantly during the last decade due to its potential contribution to poverty reduction, income generation, and economic growth. The World Bank reports that access to financial services allows households to better manage financial risks, cope with emergencies, and support productive investments. Despite substantial progress in expanding financial access globally, a considerable proportion of the world's population remains excluded from the formal financial system, particularly in developing economies (World Bank, 2022).

Empirical evidence further suggests that financial inclusion plays a crucial role in improving household welfare. Using data from a large number of countries, Honohan (2008) found a strong association between access to formal financial services and lower levels of poverty, indicating that greater financial access may contribute to improved living conditions and economic opportunities for households. Similarly, Demirgüç-Kunt et al. (2018) highlight that increased ownership of financial accounts has expanded opportunities for saving, borrowing, and making secure transactions, thereby strengthening the economic position of individuals and families.

The broader finance and development literature also emphasizes the distributional benefits of financial access. Beck et al. (2007) argue that financial development can reduce income inequality and improve the welfare of lower-income groups by expanding access to financial resources and economic opportunities. These findings suggest that financial inclusion can serve as an important mechanism through which households enhance their economic well-being.

Although a growing number of studies have examined the relationship between financial inclusion and household welfare, the literature presents different perspectives regarding the channels and magnitude of this relationship. Factors such as financial literacy, income levels, institutional quality, and technological development may influence the effectiveness of financial inclusion initiatives. Therefore, a comprehensive review of the existing literature is necessary to better understand the relationship between financial inclusion and household economic well-being.

The main objective of this paper is to review and synthesize the existing literature on the relationship between financial inclusion and household economic well-being. By examining theoretical arguments and empirical findings, the study aims to identify the key mechanisms through which financial inclusion affects household welfare and to highlight potential directions for future research.

LITERATURE REVIEW

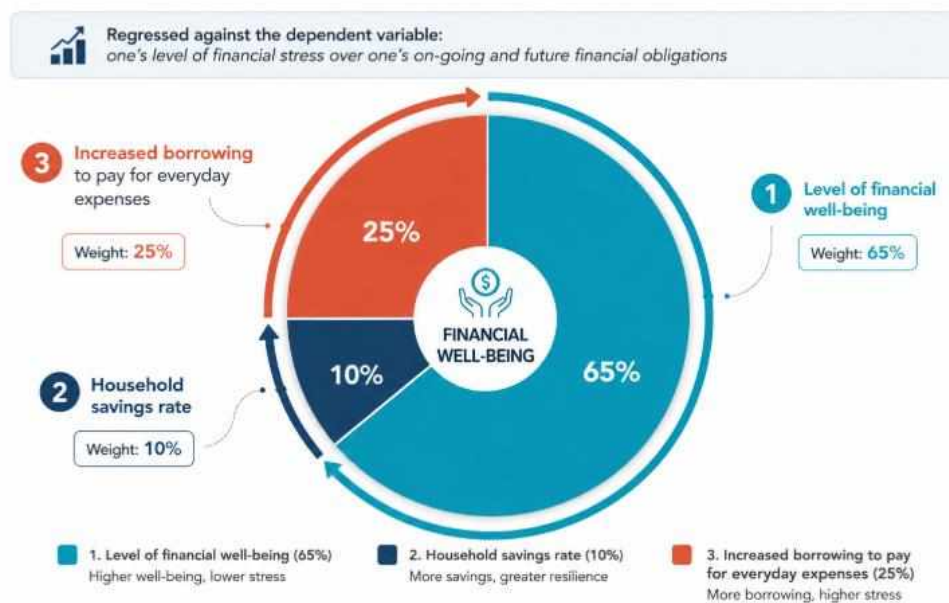
Financial inclusion has increasingly been recognized as an important factor influencing household economic well-being. The literature suggests that access to formal financial services enables households to manage financial resources more efficiently, reduce vulnerability to economic shocks, and improve long-term economic prospects. According to the World Bank (2022), financial inclusion encompasses access to affordable and useful financial products and services, including payments, savings, credit, and insurance. These services facilitate participation in economic activities and contribute to poverty reduction and economic development.

Authors Sakyi-Nyarko et al. (2022) examined the impact of financial inclusion on household well-being using nationally representative data from Ghana. The authors developed a comprehensive financial inclusion index that incorporates the availability, accessibility, usage, and quality of financial services. The results of their analysis indicate that higher levels of financial inclusion are associated with significant improvements in household well-being. Specifically, households with greater access to and use of financial services were more likely to experience better food consumption, improved access to healthcare services, higher cash income, and increased school attendance. Based on these findings, the authors argue that promoting financial inclusion can play a significant role in enhancing household economic well-being and supporting the achievement of the Sustainable Development Goals (SDGs).

Authors Marcellin and Sun (2024) examined the impact of financial inclusion on household well-being and socioeconomic outcomes by developing a financial inclusion index based on the use of financial products, financial barriers, and access to financial resources. Their findings indicate that households with higher levels of financial inclusion are more likely to have higher incomes, own homes and real estate assets, and accumulate intergenerational wealth. The study also highlights that financial inclusion is associated with improvements in psychological and social well-being, increasing satisfaction with family life and work while simultaneously reducing stress and other social problems. The authors argue that expanding financial inclusion can contribute to poverty reduction and long-term improvements in household economic well-being.

FINANCIAL INCLUSION AND HOUSEHOLD ECONOMIC WELL-BEING: A LITERATURE REVIEW

Figure 1. Conceptual Framework of Financial Wellbeing and Financial Resilience



Source: Author's illustration based on the literature review.

Figure 1 presents a financial well-being index model and the relative importance of its key indicators. The model demonstrates that the overall level of financial well-being represents the largest component of the index, accounting for 65% of the total weight, indicating its central role in determining individuals' financial security and stability. In contrast, increased borrowing to cover everyday expenses accounts for 25% of the index and is considered an indicator of financial vulnerability and financial stress. Household savings contribute 10% to the model, reflecting the importance of savings in strengthening financial resilience and the ability to cope with unexpected economic shocks. Overall, the figure highlights that higher levels of financial well-being and greater savings are associated with improved financial stability, whereas reliance on borrowing for daily expenses may negatively affect household economic well-being. Therefore, the model emphasizes the importance of sound financial management practices in promoting long-term household financial security and well-being.

One of the earliest influential contributions to this literature is provided by Burgess and Pande (2005), who examined the effects of rural bank expansion in India. Their findings indicate that increased access to banking services contributed to poverty reduction and improved economic opportunities in previously underserved areas. The study highlights the role of financial institutions in supporting economic participation among lower-income households and suggests that improved financial access can generate broader welfare benefits.

Authors Park and Mercado (2018) examined the relationship between financial inclusion, poverty, and income inequality in developing Asian countries. Their findings indicate that higher levels of financial inclusion are associated with lower levels of poverty and economic inequality. The authors argue that broader access to financial services enables households to obtain financial resources for consumption, investment, and risk management, thereby improving their economic well-being. The study emphasizes that policies promoting financial inclusion can serve as an effective instrument for fostering inclusive economic development and enhancing the living conditions of low-income households.

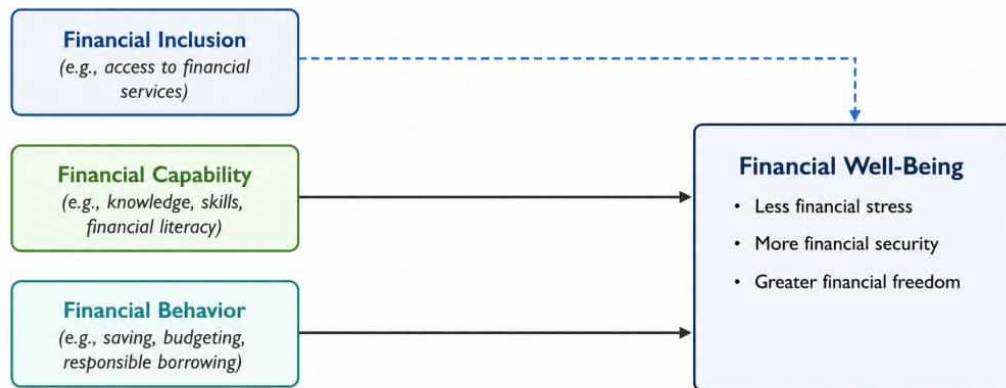
Similarly, Beck et al. (2007) argue that financial development contributes to reducing income inequality and improving the economic conditions of poorer population groups. According to their findings, a more inclusive financial system allows disadvantaged

households to access productive opportunities that would otherwise remain unavailable. Consequently, financial inclusion may enhance household welfare through increased investment opportunities, improved income generation, and greater financial security.

Further evidence is provided by Honohan (2008), who analyzed household access to financial services across more than 160 countries. The study reports a strong association between greater access to formal financial institutions and lower levels of poverty. Although the author emphasizes that correlation does not necessarily imply causation, the findings nevertheless suggest that financial inclusion is closely linked to improved economic outcomes at both household and national levels. The growing importance of financial inclusion has also been documented through the Global Findex Database. Demirgüç-Kunt et al. (2018) report substantial growth in account ownership worldwide and emphasize the role of financial services in facilitating savings, borrowing, and secure financial transactions. Their findings indicate that expanded financial access creates opportunities for households to improve financial management and strengthen economic resilience.

In addition to financial access, the literature emphasizes the importance of financial literacy as a determinant of household welfare. Lusardi and Mitchell (2014) conceptualize financial knowledge as a form of human capital that influences economic decision-making throughout an individual's life cycle. Their review demonstrates that individuals with higher levels of financial literacy are generally better equipped to make informed decisions regarding saving, borrowing, investment, and risk management. Therefore, the benefits of financial inclusion may be maximized when households possess the knowledge necessary to effectively utilize available financial services.

Figure 2: *Conceptual Framework Financial Inclusion and Financial Wellbeing*



Source: Author's illustration based on the literature review.

Figure 2 illustrates the conceptual relationship between financial inclusion, financial capability, financial behavior, and financial well-being. The framework suggests that financial well-being is influenced not only by access to financial services but also by individuals' financial knowledge, skills, and financial behaviors. Financial inclusion facilitates access to formal financial products and services, while financial capability enhances individuals' ability to make informed financial decisions. Furthermore, responsible financial behaviors, such as saving, budgeting, and prudent borrowing, contribute to improved financial outcomes. As a result, the combination of these factors can reduce financial stress, increase financial security, and promote greater financial freedom, ultimately enhancing overall household economic well-being.

FINANCIAL INCLUSION AND HOUSEHOLD ECONOMIC WELL-BEING: A LITERATURE REVIEW

Recent developments in digital finance have further expanded the scope of financial inclusion. Suri and Jack (2016), in their study of mobile money services in Kenya, find that digital financial services contributed to increased household consumption and lifted a significant number of households out of poverty. The study also reports stronger positive effects among female-headed households, suggesting that digital financial inclusion can enhance economic opportunities and financial resilience. These findings illustrate that technological innovation can strengthen the relationship between financial inclusion and household well-being by reducing transaction costs and expanding access to financial services.

Table 1. *Dimensions of Household Economic Well-Being*

Dimension	Description
Income adequacy	The ability of households to meet daily financial obligations and maintain an acceptable standard of living.
Consumption	The ability to finance current consumption needs, including food, housing, and healthcare expenses.
Savings	The capacity to accumulate financial reserves for future needs and emergencies.
Financial security	The ability to cope with unexpected financial shocks and economic uncertainties.
Debt management	The ability to manage and repay financial obligations without excessive financial stress.
Quality of life	Households' overall satisfaction with their financial situation and living conditions.

Source: Collecting data from the author (2026)

To provide a comprehensive overview of the existing literature, the following table presents a meta-analysis in a tabular format of selected studies that have examined the relationship between financial inclusion and household economic well-being. The table summarizes the main characteristics of the reviewed studies, including the authors, year of publication, study context, methodology, and key findings. By synthesizing the results of previous research, this analysis facilitates a better understanding of the current state of knowledge and highlights the main conclusions reported in the literature regarding the impact of financial inclusion on household economic well-being.

Table 2. *Summary of Selected Studies on Financial Inclusion and Household Economic Well-Being*

Author	Year	Country/Region	Methodology	Main Findings
(Dushku, 2024)	2024	Western Balkan countries	Survey and empirical analysis	Many households in the Western Balkans exhibit high financial fragility, highlighting the importance of financial inclusion and resilience.
(Honohan, 2008)	2008	160 countries	Cross-country analysis	Greater access to financial services is associated with lower poverty levels.
(Lusardi & Mitchell, 2014)	2014	Literature review	Review study	Financial literacy improves saving, borrowing, and investment decisions.
(Allen et al., 2016)	2016	123 countries	Global Findex analysis	Income, education, and employment significantly influence financial inclusion.
(Suri & Jack, 2016)	2016	Kenya	Quasi-experimental approach	Mobile money improved household consumption and reduced poverty.
(Zins & Weill, 2016)	2016	Africa	Econometric analysis	Income, education, gender, and age are key determinants of financial inclusion.
(Duvendack et al., 2019)	2019	Low- and middle-income countries	Systematic review	The welfare effects of financial inclusion vary across contexts and institutional settings.
(Kyokunda, 2024)	2024	Uganda	Cross-sectional survey	Access, quality, and usage of financial services positively affect household well-being.
(Stakic et al., 2021)	2021	Western Balkan countries	Panel econometric analysis	Financial inclusion enhances social inclusion, financial security, and household well-being across European countries.

(Federico et al ., 2021)	2021	Europe	Literature review	Financial inclusion positively affects household well-being through improved income, health, and education outcomes.
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Source: Collecting data from the author (2026)

SCIENTIFIC RESEARCH METHODOLOGY

This study adopts a qualitative research design based on a literature review approach. The primary purpose of the study is to systematically review, synthesize, and critically analyze existing theoretical and empirical literature concerning the relationship between financial inclusion and household economic well-being. Unlike empirical studies that rely on primary data collection and statistical analysis, the present study is based exclusively on secondary sources of information. A literature review approach is considered appropriate because it enables the identification of major trends, theoretical perspectives, research findings, and gaps in the existing body of knowledge. Furthermore, this approach facilitates a comprehensive understanding of how financial inclusion influences various dimensions of household economic well-being.

The study relies exclusively on secondary data obtained from a wide range of academic and institutional sources. Relevant literature was collected from peer-reviewed journal articles, books, working papers, conference papers, and reports published by international organizations. In particular, publications from reputable institutions such as the World Bank, International Monetary Fund (IMF), Organisation for Economic Co-operation and Development (OECD), European Central Bank (ECB), Asian Development Bank (ADB), and National Bureau of Economic Research (NBER) were extensively consulted. The use of these sources ensures the reliability, validity, and credibility of the reviewed literature.

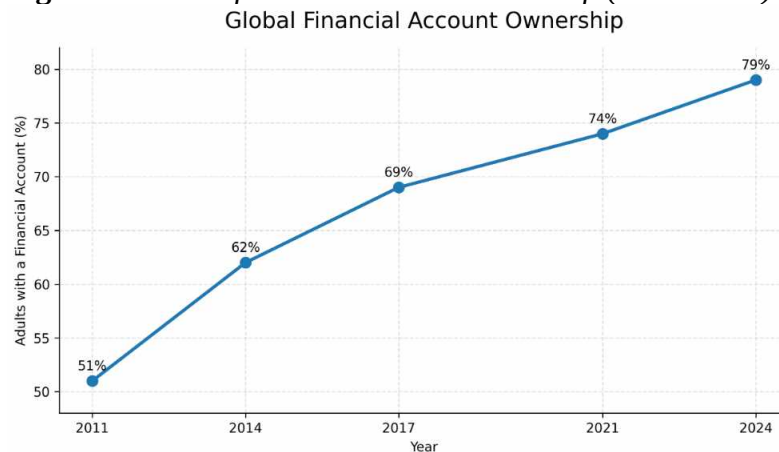
The literature search was conducted using major academic databases and search engines, including Scopus, Web of Science, Google Scholar, ScienceDirect, SpringerLink, JSTOR, and Wiley Online Library. The search process focused primarily on studies published between 2000 and 2025 in order to capture both foundational and recent developments in the field. The collected literature was analyzed using thematic analysis. This method enabled the identification, classification, and synthesis of the principal themes emerging from the reviewed studies. The analysis focused on examining the conceptualization of financial inclusion, the dimensions of household economic well-being, the mechanisms linking financial inclusion to household welfare, and the empirical evidence reported across different geographical contexts. In addition, similarities, differences, and inconsistencies among previous studies were critically assessed in order to identify existing research gaps and suggest directions for future research.

FINDINGS OF THE STUDY

To complement the literature review and provide a clearer understanding of the relationship between financial inclusion and household economic well-being, a number of illustrative figures are presented in the following section. The figures summarize important trends and indicators related to financial inclusion, including financial account ownership, the use of digital payments, formal savings, financial well-being, and financial inclusion in the Western Balkans. Although this study does not involve original empirical analysis, these visual representations help illustrate key developments identified in the literature and provide additional insight into how access to and use of financial services may contribute to improved household economic well-being. Together, the figures highlight the growing importance of financial inclusion as a mechanism for enhancing financial security, resilience, and overall welfare.

FINANCIAL INCLUSION AND HOUSEHOLD ECONOMIC WELL-BEING: A LITERATURE REVIEW

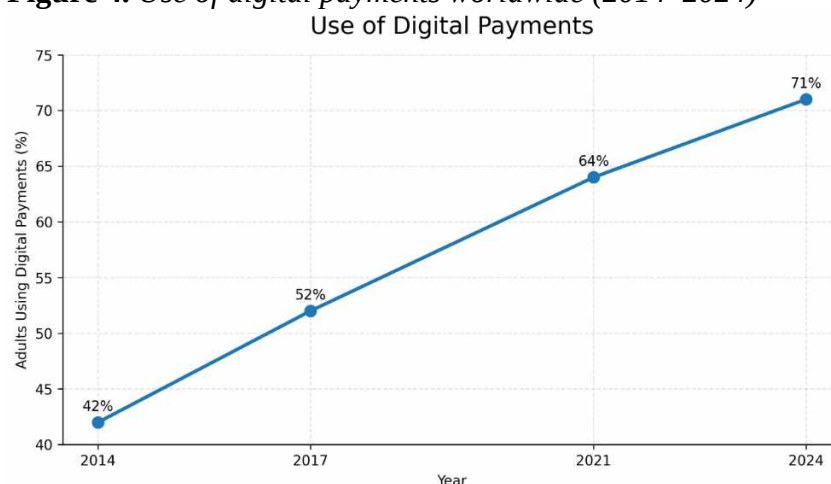
Figure 3. *Global financial account ownership (2011–2024)*



Source: Author's compilation based on World Bank Global Findex Database

Figure 3 presents the global trend in financial account ownership during the period 2011–2024. The results reveal a substantial increase in the proportion of adults owning an account at a formal financial institution or through a mobile money provider. Specifically, global account ownership increased from 51% in 2011 to 79% in 2024, indicating significant progress in financial inclusion worldwide. The most notable growth occurred between 2011 and 2017, reflecting the expansion of banking services, digital financial innovations, and policy initiatives aimed at promoting financial inclusion. The continued upward trend observed after 2017 further highlights the increasing adoption of digital financial services and mobile banking technologies. The growing ownership of financial accounts is particularly important because it represents a fundamental gateway to the formal financial system, enabling individuals and households to save, make payments, access credit, and manage financial risks more effectively. Consequently, greater account ownership may contribute to improved household economic well-being by enhancing financial security, resilience, and long-term economic opportunities.

Figure 4. *Use of digital payments worldwide (2014–2024)*



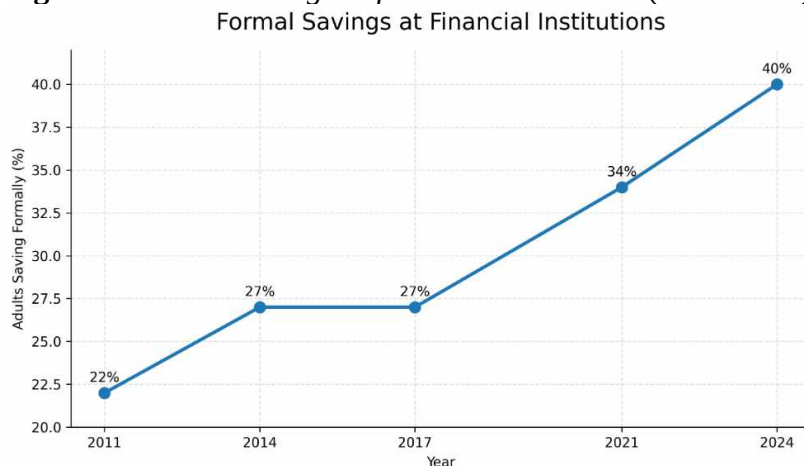
Source: Author's compilation based on World Bank Global Findex Database

Figure 4 illustrates the trend in the use of digital payments during the period 2014–2024. The results indicate a substantial increase in the adoption of digital payment services over time. Specifically, the share of adults using digital payments increased from 42% in 2014 to 71% in 2024, reflecting the rapid expansion of digital financial services and technological innovation in the financial sector. The most significant growth is observed between 2017 and 2021, suggesting an accelerated shift toward digital financial transactions. This upward trend

may be attributed to improvements in financial infrastructure, increased internet and smartphone penetration, and the expansion of digital banking and mobile payment platforms.

The growing use of digital payments represents an important dimension of financial inclusion, as it facilitates access to financial services, reduces transaction costs, and enhances household financial management. Consequently, increased adoption of digital payment systems can contribute positively to household economic well-being by promoting financial efficiency, security, and resilience.

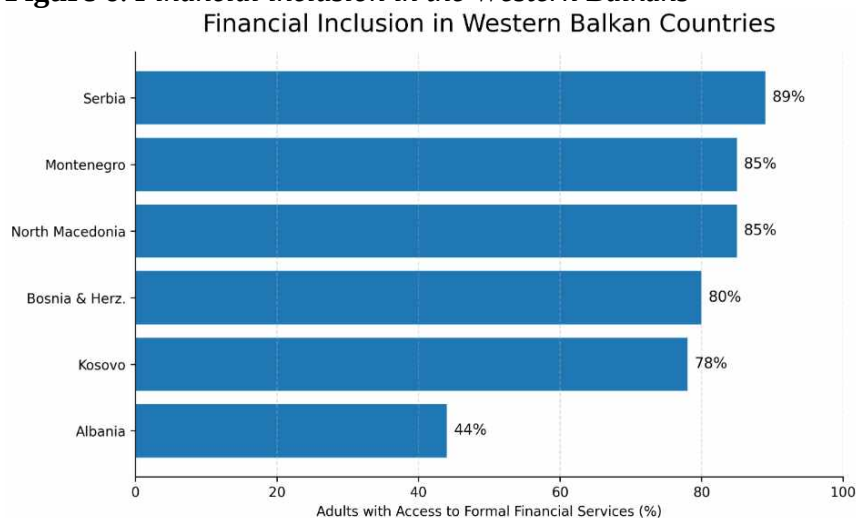
Figure 5. *Formal savings at financial institutions (2011–2024)*



Source: Author's compilation based on World Bank Global Findex Database (2025)

Figure 5 illustrates the trend in formal savings at financial institutions over the period 2011–2024. The results reveal a steady increase in the proportion of adults saving through formal financial institutions. Specifically, the share of adults with formal savings increased from 22% in 2011 to 40% in 2024, indicating substantial progress in the use of formal financial services. While the level of formal savings remained relatively stable between 2014 and 2017, a significant upward trend is observed after 2017, particularly during the period 2021–2024. This positive trend may reflect improvements in financial inclusion, greater accessibility to financial services, increased financial literacy, and the expansion of digital financial solutions. Overall, the findings suggest that the growing use of formal savings mechanisms can enhance household financial security and contribute positively to household economic well-being by strengthening financial resilience and promoting long-term financial stability.

Figure 6. *Financial inclusion in the Western Balkans*



Source: Author's compilation based on World Bank Global Findex Database

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Figure 6 presents the level of financial inclusion across the Western Balkan countries. The results indicate considerable differences among the countries in terms of access to and use of formal financial services. Serbia records the highest level of financial inclusion, with approximately 89% of adults having access to formal financial services, followed by Montenegro and North Macedonia, both with around 85%. Bosnia and Herzegovina and Kosovo also exhibit relatively high levels of financial inclusion, at approximately 80% and 78%, respectively. In contrast, Albania shows a substantially lower level of financial inclusion, with only about 44% of adults participating in the formal financial system. These disparities suggest that significant gaps in financial inclusion persist across the Western Balkans, highlighting the need for targeted policies aimed at improving access to financial services and promoting financial inclusion, particularly in countries with lower participation rates.

DISCUSSIONS/CONCLUSIONS

The review of the literature indicates a generally positive relationship between financial inclusion and household economic well-being. Across different countries and regions, access to and use of formal financial services have been associated with improved financial outcomes, including better income management, higher savings, greater financial resilience, and enhanced quality of life. The findings reported by Honohan (2008), Suri and Jack (2016), Park and Mercado (2018), and Sakyi-Nyarko et al. (2022) consistently suggest that financial inclusion contributes to poverty reduction and improved household welfare.

The literature further demonstrates that financial inclusion extends beyond simple access to financial services. Several studies emphasize the importance of financial capability, financial literacy, and responsible financial behavior in maximizing the benefits of financial inclusion. Households with greater financial knowledge are generally better able to utilize financial products effectively, make informed financial decisions, and improve their overall economic well-being.

Another important finding emerging from the reviewed studies is the growing role of digital financial services. The expansion of mobile banking, digital payments, and financial technology has significantly increased access to financial services, particularly among previously underserved populations. As a result, digital financial inclusion has become an increasingly important mechanism for promoting financial well-being and economic resilience.

Despite the predominantly positive findings, the literature also highlights that the effectiveness of financial inclusion varies across countries and population groups. Factors such as income level, education, institutional quality, and financial infrastructure influence both access to financial services and the extent to which households benefit from financial inclusion. These differences suggest that financial inclusion policies should be tailored to the specific economic and social conditions of individual countries and regions.

This study reviewed the existing literature on the relationship between financial inclusion and household economic well-being. The findings of the reviewed studies indicate that financial inclusion has become an important instrument for improving the economic conditions of households and promoting inclusive economic development. Access to and effective use of formal financial services, including savings, credit, insurance, and payment systems, can enhance households' ability to manage financial resources, cope with unexpected economic shocks, and improve their overall quality of life.

The literature consistently suggests that financial inclusion contributes positively to household economic well-being through several channels. First, it facilitates access to financial resources that support consumption smoothing, investment, and income-generating activities. Second, financial inclusion promotes savings behavior and strengthens financial resilience, enabling households to better manage financial risks and uncertainties. Third, recent

developments in digital financial services have expanded access to financial products and increased the efficiency of financial transactions, particularly among previously underserved populations.

The review also highlights that the benefits of financial inclusion are influenced by several complementary factors, including financial literacy, income levels, education, and the overall development of the financial system. Access to financial services alone is often insufficient to guarantee improved welfare outcomes. Rather, households must possess the knowledge and capability necessary to utilize financial products effectively and make informed financial decisions.

Furthermore, the literature reveals that the impact of financial inclusion is not uniform across countries and population groups. Socioeconomic conditions, institutional quality, financial infrastructure, and regulatory frameworks play a significant role in determining the effectiveness of financial inclusion initiatives. Consequently, policies aimed at promoting financial inclusion should take into account the specific characteristics and needs of different regions and social groups. Overall, the reviewed evidence supports the conclusion that financial inclusion represents an important mechanism for enhancing household economic well-being, reducing financial vulnerability, and fostering sustainable economic development.

Based on the reviewed literature, policymakers should continue to promote financial inclusion through policies that expand access to formal financial services, improve financial literacy, and support the development of digital financial infrastructure. Financial institutions should develop affordable and accessible financial products tailored to the needs of vulnerable and low-income households. Finally, future research should further investigate the mechanisms through which financial inclusion affects different dimensions of household economic well-being, particularly in developing and transition economies.

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AI CHATBOTS DRASTICALLY OUTPERFORM SECONDARY STUDENTS ON THE TEST OF ECONOMIC LITERACY

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Abstract: *This paper examines the performance of generative artificial intelligence models (OpenAI ChatGPT, Google Gemini, Microsoft Copilot) on the Test of Economic Literacy and compares their results with those of U.S. and Slovenian secondary school students. The study aims to assess whether AI systems demonstrate comparable or even superior levels of economic knowledge and to explore potential language-related differences in test performance. Descriptive statistics and item-level analysis are used to identify patterns and inconsistencies across languages when comparing AI test-takers and secondary students. Results show that AI models achieved near-perfect accuracy, while students performed significantly lower on average. The analysis also highlights differences in the length and explanatory depth of responses among the AI models. Findings contribute to current debates on assessment validity, AI use in economic education, and the future of multiple-choice testing in digitally augmented learning environments. The paper underscores the need for responsible integration of AI into educational frameworks, safeguarding the credibility of learning and the support for the sustainable development of economic knowledge.*

Keywords: Artificial Intelligence, AI Chatbots, Economic Literacy, Assessment, Economics Education.

1 Introduction

In the evolving educational landscape, the integration of technology has become essential for supporting effective learning, particularly in economics, where complex concepts often challenge students, and traditional teaching methods may not fully address individual learning needs or sustain active engagement. Artificial intelligence (AI) chatbots have rapidly become a prominent subject of empirical investigation across disciplines, including economics, education, and management. Recent studies demonstrate that models such as ChatGPT can successfully complete standardized academic and professional assessments, raising important questions about the nature of knowledge measurement and the future role of traditional testing instruments (Geerling et al., 2023; Hultberg et al., 2024; Brose, Spielmann & Tode, 2025). While much of the existing literature focuses on higher education or professional certification exams, comparatively little attention has been paid to secondary-level assessments and to cross-linguistic dimensions of AI economics test performance.

Multiple studies (Jappelli, 2010; McCowage & Dwyer, 2022) emphasize that economic literacy extends beyond the mastery of financial concepts and also encompasses an understanding of macroeconomic phenomena such as inflation, economic growth, unemployment, and public finance. Mügge (2016) argues that citizens' comprehension of macroeconomic concepts is essential, as it enables them to critically evaluate political claims about economic performance. Such knowledge is fundamental to the functioning of a democracy, since "economically literate" citizens are better equipped to participate in public debates and to form well-reasoned political preferences (Evans, 2015). As a result, standardized instruments designed to measure economic knowledge have long played an important role in

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economics education research and educational evaluation. Among these instruments, the Test of Economic Literacy (TEL) developed by the National Council on Economic Education provides a psychometrically sound instrument aligned with widely accepted content standards and has been extensively used to assess students' understanding of core economic concepts at the secondary education level (Walstad, Rebeck & Butters, 2013). Recent evidence that AI chatbots can perform at or above student level on economics tests challenges the interpretive meaning of such assessments. If AI systems can reproduce high scores on standardized instruments, it creates substantial pressure on long-standing assessment practices. One key consequence is that instructors may need to rethink their curriculum in at least three possible directions: bringing back supervised, in-person exams, integrating chatbot-supported learning activities, or expanding experiential, real-world projects that AI cannot easily imitate (Geerling et al., 2023). At the same time, students can, and arguably should, select and use appropriate chatbots to deepen their understanding of economic concepts and reasoning. AI-empowered economics education can not only enhance teaching quality but also drive innovations in this field. Wan et al. (2025) emphasize that reforms in economics education are necessary because traditional teaching approaches no longer adequately reflect the growing role of data, algorithms, and AI in modern economics.

Existing research has largely focused on English-language assessments at the tertiary education level. Cross-linguistic analyses remain rare – Wood et al. (2023) found that ChatGPT scores much higher when the exam is given in English than when it is given in a different language. The present study contributes to this emerging literature by evaluating the performance of commonly used OpenAI ChatGPT, Google Gemini and Microsoft Copilot on the TEL4 and by comparing AI-generated results with empirical data from U.S. and Slovenian secondary school students. In doing so, the paper provides empirical evidence relevant to ongoing debates on assessment validity and AI integration in education systems. By administering both the original English version and a methodologically adapted Slovenian version of the TEL4, the study also examines whether language context influences AI performance. Given that language plays a central role in both human cognition and AI model training, examining AI performance across different language versions of the same test represents an important identified research gap. Also, evidence from secondary education contexts is still limited.

1.1 Literature Review

Economic literacy is commonly defined as the ability to understand fundamental economic concepts and apply them to everyday decision-making situations. Inquiries in economics education have consistently emphasized its importance for individual welfare and societal functioning. At the secondary education level, economic literacy is shaped by curricular exposure, instructional practices, and institutional context, making reliable measurement particularly important. Standardized tests have played a key role in evaluating economic knowledge across different populations. The fourth edition (TEL4) of the Test of Economic Literacy reflects updated economic concepts and has been used in numerous national and international studies to compare student performance across school types and educational systems (Walstad, Rebeck & Butters, 2013). Prior research has demonstrated that TEL-based instruments show acceptable reliability and construct validity when applied to secondary school populations (Walstad & Watts, 2015). However, these validation efforts largely predate the widespread availability of advanced AI systems capable of generating contextually appropriate responses to multiple-choice questions. The emergence of AI chatbots therefore introduces a new dimension to the use and interpretation of standardized test results. A growing body of literature has examined the performance of AI chatbots on academic assessments.

Geerling et al. (2023) report that ChatGPT achieved high scores on the Test of Understanding in College Economics (TUCE), outperforming the average university student. Similar findings have been reported for examinations in medicine, law, and business, suggesting that the latest AI updates possess extensive domain knowledge encoded through large-scale training data and capability to solve multiple-choice tests (Newton & Xiromeriti, 2024). Importantly, these studies treat AI systems as test-taking agents rather than instructional tools. The primary focus is on score comparability, response patterns, and item-level performance rather than pedagogical effectiveness. This approach however provides a useful framework for evaluating the implications of AI for assessment validity, particularly when standardized instruments are used for high-stakes decisions.

OpenAI ChatGPT, Google Gemini, and Microsoft Copilot are large language model-based AI systems designed to generate human-like text and support knowledge-intensive tasks. ChatGPT, developed by OpenAI, is a generative transformer-based model trained on a mixture of licensed data, human-created content, and publicly available text, enabling it to perform complex reasoning, explanation, and problem-solving tasks across a wide range of domains. Gemini is a multimodal large language model developed by Google, designed to integrate text-based reasoning with advanced contextual understanding and to support analytical tasks through large-scale data. Microsoft Copilot is an AI-powered assistant embedded within Microsoft's ecosystem, leveraging large language models to assist users in information retrieval, reasoning, and productivity-related tasks. Although these systems differ in architecture, deployment environments, and optimization objectives, all three rely on probabilistic language generation and have demonstrated the capacity to perform domain-specific cognitive tasks, making them suitable subjects for comparative assessment using standardized instruments such as the Test of Economic Literacy (TEL4).

Traditional lecture-based approaches in economics education are often characterized by limited interactivity and poor student engagement, whereas the integration of AI through educational reforms can address these shortcomings by providing a more interactive, practical, and dynamically responsive learning experience (Davar, Dewan & Zhang, 2025; Wan et al., 2025). ChatGPT and other AI chatbots have the potential to transform education by providing instant, accessible support for learning and research, shifting the focus from memorization to logical thinking and conceptual understanding, thereby enhancing cognitive, creative, and problem-solving skills (Pittner, Romih & Polančič, 2023). However, overreliance on this technology could lead to a decline in these very skills, making balanced integration essential for developing competent young people. Empirical evidence indicates that students generally perceive AI systems as useful and motivating, particularly as personalized assistants that provide immediate feedback and support for academic tasks; however, concerns persist regarding the accuracy and reliability of AI-generated outputs and their potential effects on critical thinking, learning discipline, and deeper conceptual understanding (Schei, Møgelvang & Ludvigsen, 2024). While AI chatbots offer opportunities for personalized and adaptive learning, they cannot fully replicate essential dimensions of personal teaching, such as mentorship, emotional support, and pedagogical judgment, underscoring the continued centrality of educators in the learning process (Labadze, Grigolia & Machaidze, 2023). Digital platforms, AI-enhanced personalized learning improve accessibility and engagement, and it is important to develop a flexible curriculum aligned with ongoing transformations to strengthen students' adaptability to evolving economic environments (Nezhyva, Mysiuk & Zaremba, 2022; Konc, 2025). In the context of economics education, this transformation aligns with broader shifts toward data-intensive and computational approaches, which require students to combine solid foundational knowledge with innovative and analytical capacities (Hao & Zhang, 2025). Given that economics graduates are likely to enter occupations with above-

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average exposure to AI, integrating AI literacy and complementary skill development into curricula is increasingly viewed as essential for preparing students for an AI-augmented labour market (Oschinski, Spielmann & Subbu-Rathinam, 2025). In economics education, AI can help enhance values such as analytical thinking and decision-making skills by offering simulations, predictive models, and scenario-based learning. Using AI to generate and enhance case studies offers a powerful instructional tool in economics education by significantly reducing the time required to develop high-quality, practice-oriented learning materials, while enabling instructors to tailor cases to specific learning objectives and student groups (Byrd, 2025). AI-supported case studies facilitate active, student-centred learning by allowing students to apply economic concepts to realistic scenarios, engage in fruitful discussion, and explore alternative outcomes through simulations.

Nevertheless, addressing the challenges that ChatGPT poses to academic integrity requires a reconsideration of current assessment practices, particularly in relation to multiple-choice question (MCQ) based testing. MCQs are widely used in online examinations, a context in which academic misconduct was already a significant concern prior to the emergence of generative artificial intelligence. One possible response is to move away from strictly closed-book examinations and to permit the use of AI tools such as ChatGPT, thereby aligning assessment more closely with real-world professional environments in which graduates are increasingly expected to use such technologies. But this approach does not diminish the importance of foundational knowledge, which remains essential for critically formulating questions, evaluating outputs, and interpreting AI-generated responses. The assessment of basic and core economic knowledge must be conducted under conditions without direct use of AI tools. This does not necessarily require traditional in-person written examinations but may also include supervised practical tasks, oral examinations, presentations, or other real-time assessment formats that ensure academic integrity (Newton & Xiromeriti, 2024).

2 Methodology

2.1 Experimental setup

The study employs a comparative quantitative research design. Performance on the TEL4 by three artificial intelligence chatbots (OpenAI ChatGPT, Google Gemini and Microsoft Copilot) is compared with U.S. data from Walstad, Rebeck and Butters (2013) and empirical test data obtained from the sample of Slovenian secondary school students (data collected and analysed by the author of this paper, not yet published). Primary analysis is conducted at the level of total test scores, individual test items and question-answer content.

Free versions of OpenAI ChatGPT, Google Gemini and Microsoft Copilot were selected due to their widespread use and accessibility. Each TEL4 item was presented individually to the AI models, including the question stem and response options. No additional contextual cues or explanations were provided. Prompts were standardized across chatbots and languages to minimize variation in input conditions. To ensure consistency, each model completed the full TEL4 twice getting the same results (on January 8th and 9th 2026), and responses were recorded precisely. Scoring was conducted using the same answer key applied to student responses, allowing for direct comparability. The author conducted a new chat session on each of the three AI chatbots included in this analysis. Provided was one question from A version of TEL4 at a time, along with its answer choices (example Table 1 below). While it was generating responses during the chat session, the author did not provide any feedback or additional information to the AI chatbot.

Although identical test items and scoring were applied, the comparability between AI chatbots and secondary students is limited and should be interpreted cautiously. AI models do not engage in cognitive processes such as comprehension, reasoning, or dealing with

misconceptions. Their responses are generated probabilistically from training data and may reflect exposure to similar economic content rather than a genuine understanding of economics. Furthermore, AI is not affected by the same distractors that can influence students' test performance.

Table 1. *ChatGPT, Copilot, Gemini interface illustrating the question–answer methodology applied in the study*

Question 1
The opportunity cost of a new public high school is the A. money cost of hiring teachers for the new school. B. cost of constructing the new school at a later date. C. change in the annual tax rate to pay for the new school. D. other goods and services that must be given up for the new school.
ChatGPT response
Correct answer: D. The opportunity cost of a new public high school is the other goods and services that must be given up to build and operate it, since resources are limited and could have been used elsewhere.
Copilot response
The best answer is D. other goods and services that must be given up for the new school. Why? Opportunity cost is the value of the next best alternative that must be sacrificed when a choice is made. Building a new public high school uses resources—labor, land, materials, and money—that could have been used for something else. Those forgone alternatives are the true opportunity cost. Options A, B, and C describe financial or budgetary aspects, but they do not capture the full economic concept of opportunity cost. If you want, I can walk you through how to spot opportunity cost questions quickly.
Gemini response
The correct answer is D. other goods and services that must be given up for the new school. Why this is the correct answer In economics, opportunity cost is defined as the value of the next best alternative that is foregone when a choice is made. It isn't just about the dollar amount (the "accounting cost"), but rather what else society could have done with those same resources. To break down why the other options don't fit the strict definition of opportunity cost: - A and C: These represent monetary costs or financial outlays. While they quantify the expense, they don't describe the actual "thing" you are missing out on. - B: This is simply a different timeline for the same project, not a sacrificed alternative. - D: This captures the essence of the "trade-off." If a city spends \$50 million on a high school, that is \$50 million that cannot be spent on new roads, public parks, or healthcare services. Those "lost" goods and services are the true opportunity cost.

2.2. Sample

This study utilizes results derived from two prior research samples. The first student sample consists of 3,682 U.S. secondary school students from the study of Walstad, Rebeck and Butters (2013). The second sample comprises 113 students attending Slovenian general and economic secondary education schools. The same dataset is employed in a manuscript currently under review in a Scopus-indexed journal (Konc, under review). For simplicity, we analysed only results from version A of the TEL4, as the test developers found only minor differences in measurement characteristics between version A and version B. The Slovenian version of the test was developed methodologically through a translation, adaptation and validation process designed to preserve conceptual equivalence with the original English version, consistent with established guidelines for cross-linguistic assessment instruments. We deploy two samples to conduct a comparative analysis of the English and Slovenian versions and to examine potential language-related differences in AI performance.

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3 Results

OpenAI ChatGPT, Google Gemini and Microsoft Copilot achieved near perfect overall accuracy on the TEL4 (Table 2). However, question 14 seems to cause a problem for Gemini and Copilot – this question is about the exchange rate between two currencies. After we got the last response, we asked each chatbot the following question: Do you know where these questions come from (which test are they from)? Only Gemini knew the right answer, even stating the correct version of the Test of economic literacy (i.e. 4th).

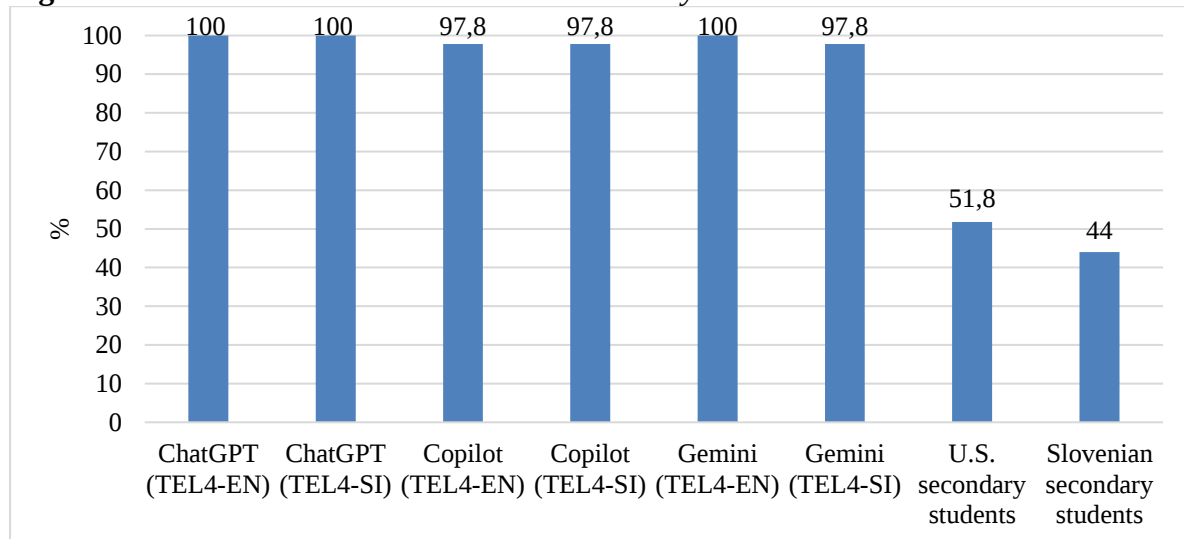
Table 2. Which AI chatbot is more economically literate?

	ChatGPT	Copilot	Gemini
Question 1	D	D	D
Question 2	B	B	B
Question 3	C	C	C
Question 4	D	D	D
Question 5	B	B	B
Question 6	C	C	C
Question 7	A	A	A
Question 8	C	C	C
Question 9	A	A	A
Question 10	C	C	C
Question 11	B	B	B
Question 12	A	A	A
Question 13	A	A	A
Question 14	B	A	B*
Question 15	A	A	A
Question 16	B	B	B
Question 17	A	A	A
Question 18	B	B	B
Question 19	D	D	D
Question 20	A	A	A
Question 21	D	D	D
Question 22	C	C	C
Question 23	D	D	D
Question 24	D	D	D
Question 25	C	C	C
Question 26	B	B	B
Question 27	A	A	A
Question 28	B	B	B
Question 29	D	D	D
Question 30	C	C	C
Question 31	A	A	A
Question 32	B	B	B
Question 33	C	C	C
Question 34	B	B	B
Question 35	C	C	C
Question 36	D	D	D
Question 37	A	A	A
Question 38	C	C	C
Question 39	D	D	D
Question 40	C	C	C
Question 41	C	C	C
Question 42	B	B	B
Question 43	D	D	D
Question 44	D	D	D
Question 45	A	A	A

*Answer incorrect only in Slovene version of the test. Note: For the full text of all 45 questions see the work of Walstad, Rebeck and Butters (2013).

Differences in scores between the English and Slovenian versions were not identified, with AI models basically perform equally on the English version of the test. There were however noticeable differences in the length and interpretation of the answers. Secondary students from the U.S. score on average just above 50% and Slovene even less (44%), indicating substantially weaker performance compared to AI chatbots. This is also presented in Graph 1 below. These findings suggest that current secondary-level economics curriculum in those two countries may be insufficiently aligned with the competencies assessed by standardized test of economic literacy.

Figure 1. *AI chatbots vs U.S. and Slovene secondary students*



We also applied the free-marginal Fleiss' kappa (Fleiss & Cohen, 1973) to assess inter-rater agreement in responses from the three AI chatbots included in this study. The coefficient ranges from -1.00 to $+1.00$, where negative values indicate agreement worse than chance, 0 represents chance-level agreement, and $+1.00$ denotes perfect agreement. The analysis yielded a moderate level of inter-chatbot agreement (free-marginal Fleiss' $\kappa = 0.492$, $Z = 5.72$, $p < .001$), despite a very high observed agreement rate. The moderate kappa value reflects the prevalence effect, whereby near-uniform response patterns inflate expected chance agreement. The accuracy of the AI chatbot's response is most important, but another notable difference between the AI models is the variation in how answers are phrased (see Figure 1 again) in the word count of their responses and the level of verbosity displayed. It should be added that Gemini added a graphic explanation in addition to the text in some of the answers. To explore these apparent differences, average wordcounts were calculated. Although the sample size was limited to the 45 questions of TEL4, the responses in English to the given prompts in these cases the response showed that ChatGPT was the least talkative (36.0 average words per question), followed by Copilot (111.9), and then Gemini with times more (331.3). In the Slovene version, Copilot replaced ChatGPT as the briefest provider (59.8 words). ChatGPT followed with 113.5 words, while Gemini once again delivered the most prolific responses, averaging 203.4 words. Whereas ChatGPT and Copilot mainly gave their answer with only a short explanation, Gemini's explanations were more exhaustive and also told why other given answer options to the question are not correct. The observed low similarity in chatbot responses, despite identical questions and prompting conditions, can be explained by the stochastic nature of artificial intelligence models, which can yield different outputs for identical inputs, as well as by structural differences in their underlying neural network architectures (Kamalov et al., 2025).

4 Discussion/Conclusion

Recent advances in generative artificial intelligence have established AI chatbots as versatile educational tools capable of supporting learning through explanation of complex concepts, instant feedback, and assistance with various academic tasks. At the same time, these systems are increasingly used by educators for content generation, assessment design, and analytical support. However, the expanding presence of AI in learning and teaching also raises important concerns related to ethical use, data protection, and the preservation of academic integrity. The ability of AI systems to perform well on standardized tests challenges existing education systems surrounding current assessment practices and the credibility of certifications. In contrast to traditional plagiarism-detection systems that rely on comparing student submissions with existing sources, ChatGPT and other AI models are capable of producing syntactically original text within seconds. Although AI-generated assignments may achieve adequate formal evaluations, they often do not demonstrate the depth of conceptual understanding typically expected in higher education and in competitive workplaces. Moreover, identifying AI-assisted plagiarism remains methodologically challenging, as generated content does not directly correspond to identifiable source materials. As generative AI tools increasingly become embedded in academic and educational environments, similarly to the preceding widespread adoption of calculators and computers in mathematics and science, schools face the challenge of adapting curriculum and assessment strategies to this evolving educational landscape.

This study provides empirical evidence on the performance of three mainstream AI chatbots on a standardized measure of economic literacy at the secondary education level. By comparing AI and human performance across English and Slovenian versions of the TEL4, the paper contributes to ongoing discussions on AI, assessment validity, and educational governance. The findings underscore the need for continued research and policy attention as AI systems become increasingly capable participants in knowledge assessment environments. Results of this study align with previous findings indicating that AI models can achieve high scores on standardized economics assessments (Geerling et al., 2023), and even achieve a perfect score – this could be due to advances in AI systems' technology and their ability to answer these kinds of questions. While ChatGPT was the only one answering all the questions of the test correctly, Google Gemini's responses were the most detailed and extensive, sometimes including explanatory graphs or videos. Extending this evidence to the secondary education level, the present study demonstrates that AI chatbots possess substantial economic knowledge as measured by the TEL4. From an assessment perspective, these findings raise questions about the continued validity of standardized multiple-choice instruments as exclusive measures of students' competence. If AI systems can reliably get high(er) scores, the interpretive meaning of test results may be altered, particularly in contexts where assessments are used for certification or selection. Therefore, educational systems will need to adapt by integrating innovative assessment methods and using AI as a tool to enhance learning, rather than viewing it solely as a painful challenge. Our study is limited by its focus on a single test instrument and a specific two-national context. Future research could extend or explore alternative assessment formats less susceptible to AI optimization, and also include more, perhaps less-known AI chatbots.

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FINTECH AND MACROECONOMIC DYNAMICS: THEIR IMPACT ON GROWTH DURING ECONOMIC UNCERTAINTY

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Abstract: *This study examines the role of FinTech integration, financial leverage, investment and inflation in growth during economic disruption. The empirical framework employs a multiple regression model estimated using Ordinary Least Squares on a balanced panel dataset of 29 countries from 2016 to 2024, incorporating a dummy variable to capture crisis consequences. Fintech-driven solutions play an essential role in managing excessive debt and investment allocation under uncertainty. The findings show that financial leverage has a significant detrimental effect on economic growth distinctly from the favorable influence of investment alongside moderate inflation supporting macroeconomic stability. Digital finance enhances economic growth through financial inclusion and investment efficiency, fostering development. The severe contractionary impact of pandemic crisis is reflected by the dummy variable. Findings emphasize the importance of FinTech adoption in finance, investment and growth policy insights.*

Keywords: *financial leverage, FinTech, growth, investment, economic disruption*

1. Introduction

The relationship between financial development and macroeconomic stability has been a widely studied topic to incorporate into government policies and long-term planning strategies in order to accomplish growth expansion according to economic circumstances. According to Akinci and Queralto (2022), the banking sector was identified as a critical component of the financial sector, with its primary technique being the management of loans given to consumers or other financial institutions through the use of leverage. Leveraging has the potential to improve loan availability, but if financial institutions manage it poorly, it can become detrimental to the economy.

However, numerous research have shown that the cost of debt is dominated by predicted advantageous returns due to investment opportunities made possible by financial leverage (Arcand et al., 2015). Even while investments have the ability to increase productivity and strengthen the economy, debt levels should not be exceeded in order to avoid unfavorable effects from future growth, especially during recessions. Inflation's help in determining its relationship to GDP growth and forecasting economic deterioration, such as a pandemic era, is necessary to maintain a balance between debt and investment. As previously stated, gross fixed capital formation, which includes contributions to tangible assets in the pursuit of output and demonstrates a nation's economic potential, is the primary growth driver.

Understandably, the impact of these components is the indicator for economic growth trend interpretation and justification. Issues related to the strategy for achieving economic growth still continue due to the fact that many countries suffer from financial management or macroeconomic instability. *However, aim of this paper is investigation of the influence of independent variables in economic development in accordance with economic downturns and moderating effect of the interaction between FinTech and investment.*

Additionally, through risk assessment and investment allocation, FinTech integration has lately been incorporated into financial development. Even if it is still in its infancy, the application of technology in finance has shown revolutionary outcomes in the management of debt structure and investment profitability. Additionally, an analysis of their impact is used to determine their link with the dependent variable in order to guarantee efficiency. Interpretation of the analysis helps in clarifying disparate assumptions that do not match statistical findings. Considering those nexuses between variables and the diverging results so far, *this study defines the following research questions:*

- *RQ1: What are the dynamics of independent variables in growth along with the contractionary impact of pandemic crisis?*
- *RQ2: How FinTech integration shapes economic growth through the mediation it makes on fixed capital accumulation?*

2. Literature review

2.1 Financial Sector Leverage role in Driving Economic Expansion

Several authors have examined the economic effects of financial leverage using a combination of panel data and theoretical analysis. Economic dynamics are influenced by financial leverage, according to conclusions derived from empirical data and rigorous interpretation. Numerous studies, especially in this area, have indicated support for leverage in banking and investment activities. However, taking on more debt than is necessary might have negative consequences and cause financial strain. Long-term valuation may be lowered by excessive debt, which would slow economic growth. Furthermore, only when capital structure restrictions are taken into account, economic stability can be established. According to Gertler and Kiyotaki (2015), leverage variations and the financial sector's inclination have a sufficient impact on macroeconomic development.

The 2008 global financial crisis severely hampered real GDP growth because of the unpredictability surrounding the banking system and its reliability. According to Zettelmeyer et al. (2008), the banking system's ambition to boost loan activity through debt improves credit availability to households or other institutions but has significant detrimental consequences on economic growth.

Financial development during the pandemic had a significant impact on the economy; however, in order to smooth the financial activity of institutions, especially in the banking system, investments had to be handled by a specific amount of debt (Demirgüç-Kunt et al., 2016). Leverage promotes economic growth, but it has a detrimental effect during economic downturns when there are few investment prospects. Real economic growth is stifled by the detrimental effects of a capital structure marked by excessive debt and as such, this study raises the first hypothesis as follow:

H₁: Higher financial leverage negatively affects economic growth

2.2 Gross Fixed Capital Formation as a Measure of Investment Opportunities in Economic Growth

The purchase of produced assets that boost investment prospects and productivity is included in gross fixed capital formation. Due to economic conditions like to the pandemic crisis, which are characterized by a decline in real GDP growth and a lack of investment possibilities, investment needs to be carefully supported and managed in order to promote resilient economic growth. The rationale for investment transformation into future growth in panel datasets was undoubtedly enhanced by the results presented, which were supported by high-level research on the impact of investment on economic growth (McGrattan & Prescott, 2014).

Findings that explain the close relationship between investment and economic growth support the conclusion that it has a favorable impact on growth (Gutiérrez & Philippon, 2017). For economic complexity, capital weight and growth investment are crucial (Bils et al., 2021). Investment lucrative cycle patterns determine growth. Even while the surge in corporate investment characterizes economic peaks, its beneficial effects account for variations in GDP growth across time. Multiple regressions based on panel datasets show that capital accumulation has a significant beneficial impact and is a driving force behind economic progress (Cerra & Saxena, 2007), as such the next hypothesis is:

H₂: Increased gross fixed capital formation positively affects economic growth

2.3 *Inflation Dynamics and Price Stability Fluctuations in Economic Growth*

Although the intricacy of their relationship is frequently discussed, economic growth is positively impacted by moderate and stable inflation, whereas excessive rates impede it. Because of the excessive demand in accordance with equilibrium, which is closely related to the situation, the central bank takes crucial steps to achieve stability. Theories suggest that high inflation is necessary for economic velocity, despite the fact that it leads to growth volatility, confusion in assessing the cost of debt, and deceptive circumstances regarding economic advancement. Inflation dynamics in macroeconomic growth are explained along with its interaction with real GDP (Reis, 2023). The positive impact of inflation, particularly the stable or moderate one in economic growth is defended by its empirical findings.

In regression analysis using panel datasets, this interaction is highly useful for identifying trends in economic growth (Hazell et al., 2022). Previous research has thoroughly examined patterns that have the potential to positively impact economic growth (Ascari & Sbordone, 2014). According to Gopinath (2017), the inflation threshold clearly outlines its beneficial effects up to the highest point of economic growth. Empirical findings from 2020 and beyond demonstrate how COVID-19 affected inflation trends (Senhadji & Khan, 2000). In order to give answer to the research question, the other hypothesis of this study is:

H₃: Moderate increases in inflation positively influence economic growth.

2.4 *The Pandemic 2020 and Its Impact on Economic Growth*

According to the macroeconomic studies model, a dummy variable must be included to the regression equation in order to capture the pandemic's effects in 2020. Specific empirical findings employing panel data models demonstrated the detrimental effects of pandemic implications on economic growth (Guerrieri et al., 2022). For an organized research and investigation of its impact, macroeconomic pandemic shocks were isolated during empirical findings (Eichenbaum et al., 2021). The pandemic year caused long-lasting effects that must be supported in a regression model, particularly for economic growth (Deb et al., 2020).

The relationship between the pandemic crisis and economic growth was evaluated rigorously, with regions that must be taken into account for growth fluctuations (Baqae & Farhi, 2020). These macroeconomic studies all support the addition of an economic dummy variable. According to Jordà et al. (2021) research, the overall effect of the pandemic crisis' long-term effects was determined. To capture once again the effect of pandemic with other macro variables the following hypothesis is raised:

H₄: Economic crisis exerts a significant negative effect on GDP growth.

2.5 *FinTech Adoption and Its Impact on Economic Growth*

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In times of economic instability, FinTech integration has been widely discussed as a means of assessing the risks associated with financial leverage, evaluating borrowing opportunities, and assisting in the allocation of investments for lucrative returns. FinTech solutions have the necessary criteria to be employed as efficient emergency tools, especially during a pandemic when the economy is characterized by financial losses, a decline in total output, a collapse of the labor market, and the need for profit or leverage to finance projects. A new area for digital financial intermediation in the economy has been created by FinTech integration in corporations and banks, which has recently produced profitable prospects from risk prediction and investment in particular assets. Additionally, by easing collateral requirements and assisting customers in investing in priceless tangible assets, FinTech lending has significantly expanded bank credit. FinTech integration, which promotes economic growth through two mechanisms—economies will rely more on digital capital, which consequently increases investment efficiency, and multiple financial facilities in underserved economies, which improve macroeconomic performance—is mentioned in this study in relation to financial inclusion (Isayev, 2025). Through credit channels derived from digital banking transactions that result in investment efficiency and risk assessment, financial inclusion boosts economic growth (Demirgüç-Kunt et al., 2016). By incorporating FinTech integration into the model to investigate its dynamic implications during economic disruption, this study supports these concepts and raises the following hypothesis:

H₅: Higher FinTech adoption positively affects economic growth.

2.6 The Synergistic Effects of FinTech Integration and Fixed Capital Accumulation on Financial Efficiency and Economic Performance

Estimating and analyzing the relationship between FinTech integration and investment is part of this study's contribution in order to produce well-organized empirical findings. Asymmetric information and transaction costs are reduced by using technology in finance. The usage of digital platforms that produce data for credit evaluation and allocation is made easier by digital banking activities. Loans and investment capital are distributed to successful projects, promoting efficiency (Beck et al., 2000). Despite its difficulties, the role of FinTech adoption as determined by digital access to financial services and products has been the focus of recent economic research studies (Aduba et al., 2023).

According to the literature review, every aspect mentioned has a major impact on economic growth. The additional research contribution carried out in this paper is defined by the inclusion of a dummy variable to clarify and interpret the effects of the pandemic crisis, taking into account that the estimated interaction of FinTech integration in investment allocation is underexplored. The model is interpreted using both financial and macroeconomic analysis, however the majority of the articles have approached them in a different way. FinTech integration significantly moderates the relationship between investment and economic growth which improves capital allocation and suggests better financial functioning, as follow:

H₆: FinTech integration strengthens the relationship between investment and economic growth by improving capital allocation and financial efficiency

3. Methodology

3.1 Model specification

To guarantee reliable findings, empirical research examines the connection between macroeconomic variables and FinTech integration in boosting economic growth using panel data estimate methodologies. Pooled OLS is used by Xing et al. (2025) to investigate the dynamic effects of independent variables as a baseline model. Pooled OLS can have econometric problems including heteroskedasticity and serial correlation, despite

its simplicity of interpretation. These problems can be resolved by using robust or clustered standard errors. Many research employ sophisticated models, such as fixed or random effects, with the Hausman test as a demonstration for proper implementation in order to overcome these restrictions. However, pooled OLS is sufficient as a baseline specification for determining the changes in the response variable arising from explanatory variables. Due to the focus in the long-term integration of financial technology and macroeconomic stability between countries, this study will use pooled OLS with clustered standard errors over one-way fixed effects analyzing within-country variation. Furthermore, the two-way fixed effect model absorbs the dummy variable because does not change over time which is one of the research objectives of this study.

In order to account for unobserved country-specific features that remain consistent across time, Cerra and Saxena (2007) employs a fixed effects model. The FE model enhances its validity and contributes to research questions and hypotheses by eliminating time-invariant heterogeneity and reflecting within-country differences. Conversely, the random effects model implies that there is no correlation between variables and that unobserved individual effects are distributed randomly. To better explain macroeconomic analysis, Deb et al. (2020) uses a fixed over random effects model. In light of these methodological strategies, a pooled OLS method with clustered standard errors will be used in this work to account for serial correlation and heteroskedasticity even though endogeneity and reverse causality remain strong limitations of this study. The conclusions about the models used in the literature review are presented in Table 1.

Table 1. *Models of the literature review*

<i>Estimation methods</i>	<i>Authors</i>
<i>Pooled OLS as a baseline</i>	<i>Xing et al. (2025)</i>
<i>Fixed effects model</i>	<i>Cerra and Saxena (2007), Deb et al. (2020)</i>

(Table 1) refers to specific models used from authors in the literature review.

3.2 Data and variable measurement

The objective of this research is to interpret financial leverage and FinTech integration in conjunction with macroeconomic consequences while anticipating economic situations from pandemic crises. For organized research and secondary data gathering, reliable sources are utilized. Information from the enormous databases of the IMF and OECD creates the panel configuration. The years 2016 through 2024 are taken into consideration for a thorough regression study.

The value generated by a nation's production over a given period of time and inside a specific nation is measured by the real gross domestic product. The real GDP growth indicator is the percentage growth rate for each year reported in constant prices and was adopted as a proxy for development by Akinç and Queralto (2022). Financial leverage is represented by the ratio of certain assets to total equity on the balance sheet of the financial institution. This ratio justifies interpretations regarding the capital structure and level of financial leverage for activity purposes consistent with Gertler and Kiyotaki (2015).

The contribution to physical assets comes from the accumulation of fixed capital, which is a vital engine of the economy and aims for productivity and growth, adopted as a variable by McGrattan and Prescott (2014). One of the most important macroeconomic indicators is inflation or price stability, typically given as a growth rate each year that aligns with the variable of Reis (2023) and Gopinath (2017). In order to understand how inflation's volatility is directly related to economic growth and support the dataset's stationarity, this study has to apply first differencing.

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With strong support from the model analysis, the inclusion of the dummy variable for pandemic belongings supported by Eichenbaum et al. (2021) and Guerrieri et al. (2022), strengthened the relationship and variance explained by COVID-19. By providing a clear explanation of their interrelated consequences, FinTech integration—represented through a proxy of digital banking transactions—and interaction with fixed capital buildup enhanced the model and were implemented in the studies of Isayev (2025) and Beck et al. (2000). In pursuance of a broad explanation related to variables and their measurements, a summary is provided in Table 2 as follows:

Table 2. Description of the variables

Variables	Expected Effect	Measurement	Source of data
Real GDP growth	Dependent	As a percentage (%)	OECD
Financial leverage	Negative (-)	Ratio	OECD
Gross fixed capital formation	Positive (+)	% of GDP	OECD
Changes in inflation	Positive (+)	As a percentage (%)	OECD
Dummy variable for 2020	Negative (-)	Binary indicator	OECD
FinTech integration	Positive (+)	% of GDP	IMF/World Bank
Interaction term between FinTech and gross fixed capital formation	Negative (-)	% of GDP	IMF/World Bank

3.3 Model diagnostic tests

Use of multiple regression analysis enhanced interpretation of independent variables impact in economic growth and estimation of regression equation in favor of accurate derived results and empirical insights. Improved regression equation, with the aim of completing standard rules ended up the sample with 261 observations. After first differencing of inflation in order to achieve stationarity, observations fell to 232. Type of data and sources are mentioned accurately (Table 2). OLS assumption fulfillment requires diagnostic tests application:

- **Normality:** Kolmogorov test in order for a normal distribution and statistical credibility.
- **Linearity:** Based on linearity detection, Ramsey test definition of independent variables by linearity is crucial for model validity.
- **Multicollinearity:** According to VIF detection test, independent variable should not be correlated with each other for multicollinearity.
- **Heteroskedasticity:** In order to ensure reliability of the model in any presence of heteroskedasticity, it should have reliable parameters according to Breusch Pagan and clustered standard errors.
- **Stationarity and serial correlation:** Data should be stationary according to ADF test. Furthermore, serial correlation is tested through Durbin Watson and Breusch Godfrey. OLS estimation method will be used for this regression equation that is presented in a correct form below:

$$\text{Real gdp growth}_{it} = \beta_0 + \beta_1 \text{financial leverage}_{it} + \beta_2 \text{GFCF}_{it} + \beta_3 \Delta \text{inflation}_{it} + \beta_4 \text{dummy}_{it} + \beta_5 \text{fintech}_{it} + \beta_6 \text{fintech}_{it} * \text{GFCF}_{it} + \varepsilon_{it} \quad (1)$$

The regression equation is based on studies of different author that analyze each of the independent variables to test their impact on dependent variable and significance of the relationship. Dilemma about the pandemic shock in economic models is clarified through several econometric theories (Deb et al., 2020).

With a methodology characterized by a strong focus in maintaining efficiency and reliable results, this paper achieves precise and accurate interpretation.

4. Results and discussion

4.1 Main findings

The dispersion of data has a huge importance to interpret the results according to the respective methodology. To determine the interconnected effects of independent variables, a summary of descriptive statistics is provided in Table 3.

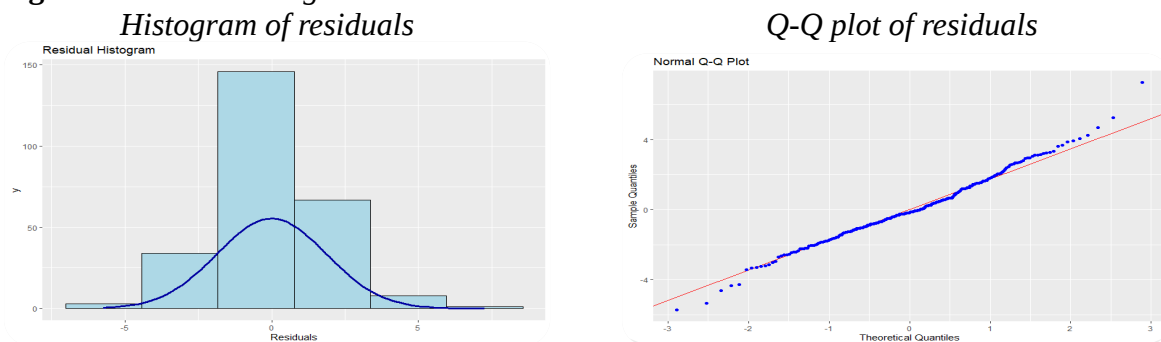
Table 3. Descriptive statistics

Statistic	Observations	Mean	Standard deviation	Sample variance
Real GDP growth	232	2.113	3.343	11.175
Financial leverage	232	17.836	11.891	141.403
Gross fixed capital formation	232	2.816	6.386	40.784
Δ inflation	232	4.115	7.334	53.791
FinTech integration	232	396.977	579.701	33.605

Econometric analysis accompanied by discussions about coefficients, tests for validity and their significance will be covered by this section. The author will derive conclusions from results about whether these variables significantly impact the dependent variable.

Moderate levels with immense volatility define economic growth that is typical for this indicator according to the summary. As shown in Table 3, requirement to capture extreme macroeconomic and financial disturbances is a consequence of fat tail characteristics beneficial to model's interpretation and analysis. Representation of economic growth by real GDP growth demonstrates the need for precise analysis conduction and determination of the relationships between variables. According to the result of the Kolmogorov test, p-value is equal to 0.2651. The fulfillment of normality condition is a consequence of failing to reject null hypothesis at 5% significance level. In order to illustrate the normality condition, residuals histogram and plot are provided in Figure 1:

Figure 1. Residuals diagnostic



As it is presented in Figure 1, the graphical presentations confirm residuals normality. To ensure that multicollinearity is not a challenge for the model, VIF results are presented in Table 4.

Table 4. Variance Inflation Factors

Independent variables	VIF test
Financial leverage	1.057
Gross fixed capital formation	2.004
Δ inflation	1.012
Dummy variable	1.12
Fintech integration	1.17
Interaction term	1.885

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As it is shown in Table 4, values less than 5 for VIF test are acceptable and disappear multicollinearity complications. Disclosure of model specification or nonlinear relationships among variables is checked through linearity or Ramsey's Reset test. According to a p-value exceeding 0.05, we conclude linearity in the model. Homoskedasticity can be proved through Breusch Pagan test and clustered standard error tests which are more conservative.

Rejection of null hypothesis in favor of alternative one at 5% level of significance concludes heteroskedasticity ($p\text{-value} < 0.05$). Redefining variables is unsuitable by means of percentage expressions and presence of negative values. In furtherance of dependability in the presence of heteroskedasticity, robust standard errors tests are necessary and presented in Table 5.

Table 5. Regression output after robust standard errors

Variables	Coefficient	Standard error	t-value	p-value	Significance
Intercept	2.193	0.2627	8.346	4.714e-15	***
Leverage	-0.0248	0.01057	-2.349	0.01961	*
GFCF	0.28	0.02983	9.539	-2.2e-16	***
Crisis dummy	-5.46	0.5304	-10.296	< 2.2e-16	***
Δ inflation	0.116	0.04093	2.364	0.01885	*
FinTech	0.000643	0.00022212	2.909	0.00395	**
Interaction term	-0.00012	0.00004246	-2.794	0.0056	**

$p < 0.001$ ***, $p < 0.01$ **, $p < 0.05$ *, $p < 0.1$.

Significance of independent variables accompanied by modest changes in inflation, financial leverage and interaction term respectively by presence of heteroskedasticity is concluded from the derivation of results on the second and more conservative test. *Despite of the presence of heteroskedasticity, the model ensures reliability and results are significant, so misleading situation caused by it is fixed (Table 5).* In accordance of analysis conducted in R studio, stationarity of the variables is proved through p-value smaller than 0.05. In order to be aware of inflated standard errors, examination tests particularly in serial correlation are applied. DW value and p-value confirmed the absence of first and second order serial correlation. *Focused on the regression model used in this study, estimated regression is as below:*

$$\text{real_gdp_growth} = 2.193 - 0.025 * \text{financial leverage} + 0.28 * \text{gross_fixed_capital_formation} - 5.461 * \text{dummy} + 0.12 * \Delta \text{inflation} + 0.000643 * \text{fintech integration} - 0.00012 \text{fintech integration} * \text{GFCF} + \varepsilon \quad (2)$$

4.2 Discussion of results

Financial leverage negatively affects economic development

Financial leverage is symbolized from significant negative influence on economic growth with the help of its capacity to develop harmful effects affecting the economy, as obviously specified in the literature review. Transformation of convenient investments into unpaid debt balances is a cause of its costs outweighing benefits. The economy suffers from insufficient capabilities to return excessive debt that leads to economic deterioration with extreme losses of real GDP. A 1 unit increase in the financial leverage ratio will decrease economic growth by 0.025 percentage points, holding other factors constant. While some studies conclude negative effects of financial leverage in the economy, others support their positive relationship through growth-focused findings. The ability of debt to

support economic activity and loan management from banking system explains its small negative effect on growth (Levine, 2003). As a consequence, enhancement of economic velocity and growth is achieved. However, boundaries of leverage should be handled effectively if it is a requirement for the economy. Similar results are presented through the connection of excessive debt and financial deterioration or cut in growth rates (Xing et al., 2025).

Fixed capital accumulation impacts positively economic development

As a contribution in physical assets to boost productivity, investment results in positive outcomes of growth. Approval for this statement is underlined from insights and conclusions derived from different papers. Gutiérrez and Philippon (2017) analyzed the effect of capital accumulation on economic growth by referring to fixed capital formation approach in economic advancements. Furthermore, investment has a crucial effect on GDP growth and a long term sustainability goal of each respective country. Related to the interpretation of this variable, a 1% increase in fixed capital accumulation growth rate, increases economic growth by 0.28 percentage points, holding other factors constant. Meaningful opportunities offered by investment to achieve economic and financial growth are expressed through its positive impact. By being a crucial part of the financial sector, rise of mobilization savings and efficiency in capital allocation is executed by investment in physical assets that flattens critical fluctuations in corporate activity. Conclusively, lending capacity of banks and other financial institutions is enhanced, furthering future economic growth.

Changes in inflation influence positively the economic development

Representing macroeconomic stability, expression in moderate levels helps in growing the economy through its significant and positive impact. The same conclusion was considered about moderate inflation effect in economic growth during studies about the evolution of inflation dynamics (Reis, 2023). According to the first differencing transformation, a 1 percentage point increase in changes of inflation increases economic growth by 0.12 percentage points, holding other factors constant. General increase in prices defined by tiny amounts is linked to economic activity and extended demand through its consistency which is explained by econometric theory. Due to the fact that moderate inflation adjusts economic growth and tremendous levels frustrate it, the effect is positive but small. Reis (2023) interprets the positive relationship between inflation and growth with the argument of not surpassing the threshold of inflation which in most cases is 3% for regular circulation of the economy. Therefore, this finding is closely associated with our idea in this study. In contrast, Khan and Senhadji (2000), Ascari and Sbordone (2014), and Gopinath (2017) argued that high levels of inflation further the decline in output and result in economic recessions.

Pandemic crisis during 2020 affects negatively the economic development

Guerrieri et al. (2022) and Eichenbaum et al. (2021) explain supply-demand downward spiral which was caused from rising infection rates and decline in income, avoiding economic surrounding for maintaining stability in welfare. Deb et al. (2020) describe the follow up effect when restrictions were dropping, supporting growth but the positive effect was smaller in magnitude than the initial negative impact in economy. On the contrary, Jordà et al. (2021) and Baqaee and Farhi (2020) described the persistent consequences of the pandemic crisis. The interpreted financial structure and economic deterioration was represented by crisis and involvement of a dummy variable to outline negative consequences consistent with Cerra and Saxena (2007). Based on the interpretation, economic growth is 5.46 percentage points lower during pandemic crisis than other years, holding other factors constant.

FinTech adoption positively affects economic growth

FINTECH AND MACROECONOMIC DYNAMICS: THEIR IMPACT ON GROWTH DURING ECONOMIC UNCERTAINTY

Digital banking transaction or digital financial intermediation as a proxy for fintech adoption tends to have a significant positive impact on economic growth due to reduction in transaction costs and financial inclusion. Furthermore, strengthens financial intermediation that connects savers with investors by improving credit allocation and efficiency of financial markets. Isayev (2025) focuses in the effect of FinTech on growth, particularly in countries where this field is still underexplored while Beck et al. (2000) suggest that fixed capital accumulation remains the crucial channel implemented by financial technology growth accomplishments. Furthermore, the alteration in the marginal effect of investment from the integration of digital finance is shown through the negative interaction term concluded by Beck et al. (2000) and Isayev (2025). Adequate evidence is provided for the FinTech impact on allocative over quantitative efficiency. As a result, higher levels of FinTech adoption are associated with a rise in real GDP growth and productivity. According to the empirical results, 1 % increase in FinTech integration increases economic growth by 0.00064%, holding other factors constant.

Fintech integration significantly moderates the relationship between investment and economic growth which improves capital allocation and suggests better financial functioning

Results are consistent with theory because the negative interaction between FinTech integration and investment explains the decrease in marginal growth effect of investment. This expresses improved allocative efficiency, reduction of misallocated investment and better financial functioning through greater reliance on digital rather than traditional capital (Md. Mominur Rahman, 2024). According to the empirical results, 1 % increase in the use of financial technology decreases the marginal effect of fixed capital accumulation in growth by 0.00012%, holding other factors constant. Results are consistent with theory because negative interaction of FinTech integration and investment explains the decrease in marginal growth effect of investment. This expresses improved allocative efficiency through reduction of misallocated investment and better financial functioning.

5. Conclusions

The effect of financial activity and macroeconomic stability integration in growth insights is analyzed by this paper. The domination of pandemic crisis needed observation in order to justify interpretation of results in the manner of literature review. Since there are not many studies that incorporate dummy variables to capture pandemic crisis and explain moderating effect of the interaction term, these will help in becoming novelties for the study. Real GDP growth, as the dependent variable, in agreement with empirical insights and descriptive analysis is expressed by multiple trends and volatility. The idea of balanced financing in order for structured future economic growth is confirmed by negative impact of leverage. Furthermore, determination of real GDP growth from leverage demonstrates the volatility as a result of inadequate risk management. Gross fixed capital formation enhances economic opportunities representing huge contributions in physical assets for productivity. Incorporation of leverage to support investment and higher returns results in expressive conclusions.

Price stability defined by moderate levels, encourages growth by reporting macroeconomic stability in the model. FinTech adoption positively affects economic growth through financial inclusion and well structured markets. The negative impact of interaction term implies a decrease in marginal growth of investment that indicates better capital allocation. To conclude, appropriate involvement of pandemic crisis, eliminates confusing situations from the model. Economic growth is illustrated from their impact in order for innovative policy constructions that enable groundbreaking improvements.

Considering that many independent variables are narrowly reported to cover longer periods, the limitation of this study was mainly lack of data for previous years. Moreover, integration of some countries in political challenges caused their absence in the regression analysis. Furthermore, inclusion of other variables as a proxy for leverage could be taken into consideration assuming that trustworthy sources did not appear missing values. Regarding the inflation, other crucial variables defined by lower volatility can be used incorporated for improved future work. To avoid heteroskedasticity barriers, use of another dataset can be applied though the model is correctly specified with reliable statistical inference.

However, variables possess high significance and explain approximately 70% of the variation in the model. Concerning complexity challenges, logarithmic transformation can be taken into consideration in the future while using data with dissimilar units of measure. In the case of economic growth, the crucial drivers of real GDP growth are applied for regression analysis but expansion of the model can be done to further research studies for improved future work. Application of fixed effect model in an adequate level of future work will enhance econometric analysis.

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ENERGY INFRASTRUCTURE AND AI-DRIVEN GROWTH IN THE EUROPEAN ECONOMY

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Abstract: *The widespread adoption of Artificial Intelligence (AI) is reshaping economic growth trajectories across the European Union. However, AI is not only a digital phenomenon, but it is also an energy-intensive one, which relies on physical infrastructure that is subject to policy, investment, and capacity constraints. This paper examines whether energy infrastructure is becoming a strategic bottleneck for AI-driven growth in the EU. It extends the endogenous growth model to incorporate energy as a separable input to AI production, developing three analytical scenarios of increasing specificity. The third and most realistic scenario demonstrates that when energy capital is insufficiently expanded relative to AI adoption, growth slows and a crowding-out effect emerges, compressing energy availability for households, industry, and other sectors. The theoretical findings are supported by an illustrative calibration, which confirms that the bottleneck and crowding-out dynamics identified in the model are consistent with observable trends in EU energy investment and data centre demand. The paper contributes a conceptual framework linking AI expansion, energy supply, and energy constraints. It also suggests directions for future empirical research on infrastructure constraints and AI-led growth in Europe.*

Keywords: *Artificial Intelligence, Energy Infrastructure, Economic Growth, Energy-Intensive Technologies, Data Centres, Endogenous Growth*

1 Introduction

Artificial Intelligence has become a central point of economic and policymaking agendas, driven by its importance and expected impact on increased productivity, new competitive advantages, and structural economic transformation, at both the microeconomic and macroeconomic levels, from individual firms' productivity to countries' economic growth. Isayev (2025) argues that AI is increasingly treated as a strategic pillar for building knowledge-based economies. Across the European Union (EU), firms increasingly integrate AI into their processes, such as production, logistics, finance, and management systems, while policymakers consider AI an important pillar of economic development.

However, it is important to emphasize that AI is not only a digital phenomenon. It is also an energy-intensive activity that relies on physical infrastructure, including data centres, electricity grid networks, and cooling facilities. AI training and processing take place in large-scale data centres. Based on ICIS (2025) projections, at the EU level, the power demand for data centres is expected to increase from 96TWh in 2024 to 168TWh by 2030, and further to 236TWh by 2035. This demand growth implies that data centres' power consumption will increase from 3.1% of total EU electricity consumption currently to 5.7% by 2035. Therefore, as AI systems and investments in AI facilities expand, the energy sector and particularly the electricity system, become a core production input with important implications. In the meantime, European electricity systems face various constraints. Grid capacity limitations and

the need for new expansions, regulatory delays, and price sensitivity affect the ability to respond to the rapidly increasing energy demand from AI. Additionally, the latest geopolitical developments, such as armed conflicts and trade wars, make the energy system in Europe even more fragile and increase the energy risk for Artificial Intelligence.

The emerging evidence in Europe suggests that the infrastructure constraints are already relevant and important to be considered. In countries like Germany, the Netherlands, and France, the top 3 AI data centre markets in the EU, electricity demand for data centres is increasing significantly and is expected to continue to rise alongside AI deployment, by a factor of 2 times, 1.5 times, and 2.5 times, respectively, based on ICIS (2025) estimates. At the same time, grid connection delays for new data centre facilities can take over several years. All this implies that infrastructure capacities, which are not expanding at the same pace as technological developments, may create a hold-up for AI-driven growth and economic benefits.

This observation raises a central question: Is energy infrastructure becoming a bottleneck for AI development and AI-driven growth in the European Union? This paper argues that it may become. It examines how the pace of AI adoption could be constrained by energy availability and infrastructure capacity rather than technological capabilities alone, and explores the crowding-out mechanism through which rising AI energy demand may compete with households, industry, and broader development objectives within the EU.

Yet the role of energy infrastructure as a potential constraint on AI-led growth remains underexplored, as existing models do not explicitly incorporate energy as a limiting input to AI production. This paper addresses that gap by asking whether energy infrastructure is becoming a strategic bottleneck for AI-driven growth in the EU. It extends the endogenous growth model to incorporate energy as a separable and constraining input to AI production, developing three analytical scenarios of increasing specificity. The objective is to establish a conceptual framework linking AI expansion, energy supply, and macroeconomic growth dynamics, and to identify the conditions under which energy changes from an enabler to a limitation. The structure of this paper is as follows: Section 2 reviews the literature on AI, energy, and growth. Section 3 develops a theoretical framework extending the endogenous growth model by adding energy. Section 4 provides a conceptual analysis of energy as a bottleneck for AI development and AI-led growth. Sections 5 and 6, respectively, provide discussions and conclusions.

2 Literature Review on AI, Energy, and Growth

Investigating the relationship between Artificial Intelligence, energy infrastructure, and economic growth requires an intersectional examination. Scholars have studied AI as a driver of productivity, or energy as a fundamental input in production and important for industrialization, or infrastructure as a determinant of competitiveness. However, these aspects are typically developed in isolation and not as intertwined. As a result, the role of energy infrastructure as a potential constraint on AI-led growth remains underexplored.

2.1 AI and Economic Growth

Regarding the relationship between AI and economic growth, most of the existing literature is built on the endogenous models of growth, which consider technology development as an endogenous variable, as a by-product of internal economic factors such as investments in research and development (R&D), knowledge, and human capital (Romer, 1990). At the time that Romer developed the endogenous growth model, the existing models (Solow, 1956; Swan, 1956) used technology development as exogenous and assumed that technological advancements were uncontrollable. Even though both models imply that technological change is important, only the endogenous one highlights that technological progress is an active driver of economic growth.

Meanwhile, empirically, studies show that AI impacts economic growth in different ways. A panel data study (Gonzales, 2023), covering from 1970 to 2019, on AI innovation implications on economic growth suggests that there is a positive and statistically significant impact of AI patenting on average long-run economic growth. Another research study (He, 2019), with cross-province panel data from 31 Chinese provinces (2003–2019), finds that artificial intelligence has a positive and significant impact on economic growth, as well. Its empirical results suggest that AI serves as a new tool for economic development, even when controlling for other economic variables such as investment, government expenditure, consumption, and inflation. Evidence from 28 Chinese provinces over the period 2005–2018 shows that AI has both a direct and positive effect on economic growth, and a mediating effect by mitigating economic slowdown through improving the industrial structure (Fan & Liu, 2021). Furthermore, Acemoglu (2024) argues that the impact of AI on GDP and productivity depends on the share of tasks it affects and the associated cost savings at the task level. According to the study estimates, these effects are expected to be positive but modest, with total factor productivity (TFP) increasing by no more than 0.71% over the next 10 years, and potentially less than 0.55% when considering the difficulty of tasks that are harder to automate. Based on the same methodology (Acemoglu, 2024), another study (Misch et al., 2025) finds that AI is likely to increase productivity in Europe by around 1.1% over the medium run. By comparison, productivity growth is higher than US estimates, mainly due to Europe's sectoral composition and AI assumptions; however, it is still considered modest.

In different sources, evidence suggests that the AI impact on economic growth differs from one economy to another. Gonzales (2023) suggests that the effect of AI on growth is stronger among advanced economies. An OECD study (Filippucci et al., 2024) points out that AI may not benefit all countries equally and could increase the economic gap between them. This is mainly because most AI development and investment are concentrated in a few countries, especially the United States and China. Productivity gains from AI vary across countries, where higher-income nations benefit more, which may slow down income convergence within Europe (Misch et al., 2025). Isayev (2025) highlights the importance of institutional frameworks, innovation governance, and public-private coordination for AI deployment and its economic impact.

Using quarterly data for Germany from 2012 to 2022, Athari et al. (2026) employ a nonlinear ARDL framework to study the AI effects on economic growth. The results suggest that positive shocks in labour force participation and AI investment stimulate gross domestic product (GDP) growth, whereas gross fixed capital formation (GFCF) does not have a significant positive effect. Meanwhile, negative shocks to GFCF and AI investment increase GDP, demonstrating an asymmetric effect. In other top AI European markets, such as France, governmental projections (French Artificial Intelligence Commission, 2024) predict that in 10 years AI could increase GDP from €250 to €420 billion, equivalent to the added value of the total industry. Similarly, in the Netherlands, Implement Consulting Group (2024) estimates that generative AI may contribute up to 1.5% annually to productivity growth in the Netherlands, with implications for surpassing current long-term GDP growth projections as early as 2028. However, these projections do not establish a causal relationship between AI and GDP growth.

2.2 AI and Energy Infrastructure

The expansion of AI in the last decade, particularly in recent years, with the massive deployment and adoption of generative AI, is transforming the world into a digital one. However, AI remains dependent on physical means.

According to the International Energy Agency (IEA, 2025), the AI lifecycle has three main energy-intensive phases: (i) hardware manufacturing, (ii) model training, and (iii) model use. Energy demand varies across these phases. The first phase is indeed energy-intensive, especially the production of semiconductors and chips; however, it accounts for a lower energy consumption compared to the operative phases. During the second phase, the AI model training relies on massive GPU clusters, making it highly energy-intensive. In the third phase, energy demand depends on different factors such as model type, query complexity, and output type. Regarding this last phase, Electric Power Research Institute (EPRI, 2024) suggests that AI models are much more energy intensive than the data retrieval, streaming, and communication applications that were previously driving data centre growth. For instance, one ChatGPT query uses about 2.9 watt-hours, which is around ten times more electricity than a normal Google search, which only uses about 0.3 watt-hours. Also, new features, such as image generation, require even more computation, with no established efficiency benchmark yet.

In order for the AI phases to happen, large-scale facilities of AI data centres are needed. AI data centres are becoming significant electricity consumers. Based on the calculations of EPRI (2024), generally, in data centres, most of the electricity is used by IT hardware, making up around 40–50% of the total demand. Cooling systems come next, using roughly 30–40% of the total, depending on the type of cooling and the density of the servers. Additionally, the remaining 10–30% is distributed among other supporting components like the lighting, office activities, monitoring, and security system. To meet all these energy needs, globally, data centres consume approximately 1.5% of total electricity use, according to the IEA (2025). Meanwhile, EU data centres consume around 2% of the total electricity used, while it varies across countries, where, for example, in Ireland, it goes up to 20% (IEA, 2025). Moreover, IEA predicts that in the next five years, this consumption will double, with AI identified as the main factor that will drive this increase.

Beyond electricity demand, the grid network presents another significant challenge for AI deployment. Many regional grid systems may struggle to accommodate the energy. For example, although the EU has one of the most developed electricity networks, it is facing several new challenges, including limited grid capacity to handle increasing connection requests from both demand (such as electricity needs from data centres) and supply sides (increase of renewable energy supply) (European Commission, 2026). Also, the average waiting time for grid connection for the new data centres in Europe could be up to 10 years (German Data Centre Association, 2026), as further explained in section 4. Another concern is that constructing new grid lines in developed economies often takes somewhere between four and eight years to be completed (IEA, 2025). This suggests that energy infrastructure constraints merit closer analytical attention, as examined in Sections 3 and 4, particularly in the absence of new investments, infrastructure expansion, or reductions in the permitting delays mentioned above.

Considering energy infrastructure as a special form of capital has examples in the infrastructure economics literature. Aschauer (1989) demonstrates that public infrastructure investment determines productivity growth, arguing that core infrastructure, including energy and utility networks, functions as a productive input rather than just a background condition for economic activity. Also, research from Calderón and Servén (2004) confirms that the quantity and quality of infrastructure have significant positive effects on long-run growth, while deficiencies in infrastructure limit economic performance. These create a theoretical basis for seeing energy capital as an input in the growth model in the following section.

3 Theoretical Framework

Based on the existing theoretical literature and its assumptions on technological progress as a by-product of internal economic factors, this paper develops an endogenous growth model.

3.1 Endogenous Growth Model

The following specifications establish the baseline endogenous growth model.

Production equation

$$Y(t) = K(t)^\alpha [A(t) \cdot L_Y(t)]^{1-\alpha}, 0 < \alpha < 1,$$

Where $Y(t)$ is the total output (or total gross domestic product), $K(t)$ is physical capital (machines), $L_Y(t)$ is the amount of labour used in production, $A(t)$ is the stock of innovative ideas (technology), α is the elasticity of inputs, and t is time.

Labour allocation

$$L = L_Y + L_A,$$

Where labour L splits into L_Y as production workers and L_A as researchers.

Capital accumulation

$$\dot{K}(t) = s_K Y(t) - \delta_K K(t)$$

Where s_K is the savings rate, and δ_K is the depreciation rate, implying that capital (K) grows when we invest a part of output (Y)

Innovative ideas production

$$\dot{A}(t) = \delta_A A(t) L_A(t)$$

$$g_A = \dot{A} / A = \delta_A L_A \text{ (growth rate of technology)}$$

These equations imply that ideas are created based on existing ideas A and from the researcher's work L_A , highlighting that (i) knowledge builds on knowledge and (ii) technology growth is self-reinforcing, as a permanent growth without diminishing returns. It is important to mention that technology serves as a multiplier of labour.

3.2 Extension of Endogenous Growth Model: Technology Replacement with AI

As a first extension of the baseline model, technology is replaced with AI as the core driver of productivity and growth. The structure of the production equation remains the same:

$$Y(t) = K(t)^\alpha [A^*(t) \cdot L_Y(t)]^{1-\alpha},$$

But here $A^*(t)$ = AI capability stock, which indicates that workers are more productive because of AI tools.

AI production

$$\dot{A}^*(t) = \delta_A A^*(t) L_{A^*}(t)$$

$$g_{A^*} = \dot{A}^* / A^* = \delta_{A^*} L_{A^*} \text{ (growth rate of AI)}$$

From the AI production equation, it follows that AI improves faster when more researchers are focused and are working on the existing AI, implying that AI helps create better AI, thus creating a feedback loop. This extended model not only highlights that the existing AI creates better AI, but it may also indicate that AI assists the researcher or even might replace them. The question of AI replacing labour in the growth model is beyond the scope of this paper.

3.3 Extension of the Endogenous Growth Model: Energy as an Endogenous Factor

Another extension of the model is to introduce energy as an endogenous factor. Before doing so, it is necessary to assess whether energy can indeed be treated as endogenous. Energy infrastructure, such as power plants, electricity grids, renewable systems, etc., can be treated as endogenous because it is generated through internal economic processes, including investment and innovation. However, energy is also subject to physical constraints. Given the nature of energy, this theoretical analysis considers three alternative scenarios for incorporating

it into the growth model: (i) energy embedded in technological advancement (AI), (ii) energy as a component of capital, and (iii) energy as a direct input into AI production, considering AI as energy capital-intensive.

3.3.1 First scenario: Energy embedded in AI

In this scenario, energy is not a factor that directly affects production, but it enables AI development and processing through computational capacity. Energy here is required to train models and operate data centres. More energy leads to greater computational capacity, which is also expected to accelerate AI progress. In this context, energy can be understood as the “fuel” for intelligence creation.

AI production

$$\dot{A}^*(t) = \delta_{A^*} A^*(t) L_{A^*}(t) E(t)^\theta,$$

$$g_{A^*} = \dot{A}^* / A^* = \delta_{A^*} L_{A^*} E^\theta \text{ (growth rate of AI when energy is embedded)}$$

Where $E(t)$ is the stock of energy infrastructure that enables AI development by providing the necessary computational capacity, and θ is the elasticity of AI production with respect to energy.

Production model

$$Y(t) = K(t)^\alpha [A^*(t) \cdot L_Y(t)]^{1-\alpha}$$

The structure of the production model remains unchanged, as energy in this model does not directly produce goods but influences growth by enabling or constraining AI development. Energy functions as an innovation input rather than a production factor, affecting growth indirectly and through AI production only.

This scenario is relevant because it captures the energy demand for AI training while keeping the model simple. However, it does not account for energy use in factories, transportation, or general production. It is particularly applicable for analyzing AI-driven growth in the short to medium term.

3.3.2 Second scenario: Energy as a component of capital

In this scenario, energy infrastructure is incorporated as part of the physical capital stock:

$$K = K_P + K_E$$

Where K_P is the traditional capital, such as machinery and factories, etc., and K_E is the energy capital, including, for instance, power plants, electricity grids, and other related infrastructure.

Capital accumulation

$$\dot{K}(t) = s_K Y(t) - \delta_K K(t)$$

In the capital accumulation equation, investments automatically include both machinery and energy infrastructure, such as power plants and electricity grids. This means that energy is treated simply as another type of capital, included in the overall stock of capital rather than modeled separately, so its role in production is captured indirectly through general investment.

Production model

$$Y(t) = K(t)^\alpha [A(t) \cdot L_Y(t)]^{1-\alpha}$$

In this scenario, the structure of the production model remains unchanged as well, as energy capital is “hidden” within total capital, thus energy capital impacts growth similarly to traditional capital. Regarding its relevance, this scenario fails to capture specific issues such as energy bottlenecks and constraints.

3.3.3 Third scenario: Energy as a direct input to AI

This scenario provides a more realistic model, assuming that energy infrastructure is part of the capital and that AI depends on energy-intensive capital.

Capital stock

$$K = K_P + K_E$$

Capital accumulation

$$\dot{K}_{E(t)} = \psi s_K Y(t) - \delta_{KE} K_E(t)$$

$$\dot{K}_{P(t)} = (1 - \psi) s_K Y(t) - \delta_{KP} K_P(t)$$

Where ψ is the share of investment going to energy, and $1 - \psi$ is the share of investment allocated to traditional capital. This setup reflects a trade-off in how the economy allocates resources between general production capacity and the expansion of energy infrastructure, and highlights that in an economy, energy investments are subject to scarcity and budget allocation.

AI production

$$\dot{A}^*(t) = \delta_A A(t) L_A(t) K_E(t)^\theta$$

$$g_{A^*} = \dot{A}^* / A^* = \delta_A L_A^* K_E^\theta \text{ (growth rate of AI)}$$

Where K_E represents energy capital, as previously mentioned.

These equations indicate that energy can act as an enabler, but it can also become a bottleneck if limited, and consequently constrain AI progress and production growth.

Production equation

$$Y(t) = K(t)^\alpha [A(t) \cdot L_Y(t)]^{1-\alpha}$$

In this scenario, the structure of the production equation remains unchanged while introducing a new mechanism without breaking the model, demonstrating that the endogenous growth model is still highly relevant. However, the sources of production growth are further explored, as energy is explicitly included as part of capital and also serves as a specific production input in AI production.

Additionally, this scenario is more realistic, as it highlights the importance of energy for AI and distinguishes energy capital from traditional capital. In this way, it helps capture the need to invest both in production capital, such as data centre facilities, and in energy capital, such as the expansion of electricity grids, for instance.

Key results

1. If $\psi \approx 0$, investments in K_E remain limited, which results in a slowdown of the rate of AI growth.
2. If ψ is high, even small increases in energy capital can generate large increases in AI growth, potentially leading to faster growth in production.
3. Unlike in the baseline model, where ideas grow without physical constraints, AI in this framework is no longer “free,” as its growth depends on the availability and expansion of energy infrastructure.

3.3.4 Comparative analysis of scenarios

Table 1 summarises the three scenarios, comparing how energy is incorporated into the model, its impact on growth, and the relevance of each scenario.

Table 1. Energy incorporation in the endogenous growth model, based on three scenarios

Scenario	Energy integration	Energy impact on growth	Scenario relevance
1 st	Part of the AI, not of the production function	Indirect effect: energy increases computational capacity → faster AI growth → higher productivity	Useful to explain AI-driven growth specifically in the short run, but ignores energy more broadly
2 nd	Part of the total capital	Indirect and unclear effect: energy affects production through capital accumulation	Useful when energy is not a constraint
3 rd	Part of both capital and an input in AI production through energy capital	Direct and indirect effects: energy supports AI development and thus drives productivity or limits growth	Useful for studying AI–energy interactions and long-run growth, and it captures energy both as enabler and bottleneck.

ENERGY INFRASTRUCTURE AND AI-DRIVEN GROWTH IN THE EUROPEAN ECONOMY

3.3.5 Illustrative Model Calibration

To test if the third scenario reflects real EU conditions, this section provides estimated values for the key parameters using some available data. The goal is not to forecast, but to show that the theoretical relationships are not abstract.

Calibrating ψ - energy investment share

EU grid investment currently stands at roughly €65 billion, against total gross fixed capital formation of €3.8 trillion (21.2% of EU GDP of €17.9 trillion), giving $\psi_0 \approx 0.017$ (IEA, 2025; Eurostat, 2025). With AI-driven data centre energy demand projected to grow by 150% by 2035 (ICIS, 2025), the required investment share rises to an estimated 0.030–0.050. Three scenarios are used, as in Table 2, below:

Table 2. *Energy Investment Scenarios Used in the Calibration*

Scenario	ψ	Interpretation
Low (<i>status quo</i>)	0.017	Current EU grid investment, no expansion
Medium (<i>partial adjustment</i>)	0.030	Energy investment 2x (EC Grid Action Plan)
High (<i>full adjustment</i>)	0.050	Energy investment 3x, sufficient for AI demand growth

Source: Authors' own elaboration based on IEA (2025), Eurostat (2025), and ICIS (2025)

Calibrating θ — energy elasticity of AI output

AI electricity consumption is growing at approximately 30% per year (IEA, 2025), while AI economic output for Europe grows at an estimated 9–18% per year (Misch et al., 2025). Dividing output growth by energy input growth gives:

$$\theta = \text{output growth} / \text{energy input growth} \approx 0.09 / 0.30 = 0.30 \text{ or } 0.18 / 0.30 = 0.60$$

A central value of $\theta = 0.40$ is used, meaning that a 10% increase in energy capital gives roughly a 4% increase in AI output. This is a conservative estimate reflecting that energy is one of several inputs to AI production.

Calibrating g_A and summary results

Applying these values to the growth equation $g_A = \delta_A \cdot L_A \cdot K_E^\theta$ from Section 3.3.3, and scaling K_E in proportion to ψ (baseline $K_E = 1$ at $\psi = 0.017$), Table 3 summarises the results across the three scenarios.

Table 3. *Calibration results across energy investment scenarios*

Parameter / Outcome	Low ψ (0.017)	Medium ψ (0.030)	High ψ (0.050)
Energy capital index (KE)	1.00	1.76	2.94
AI growth index (g_A , $\theta = 0.40$)	1.00	1.26	1.52
Cumulative TFP gain (10 years)	~1.1%	~1.4%	~1.7%
Crowding-out pressure	High	Moderate	Low
Policy implication	Bottleneck	Partial relief	Relief

Source: Authors' own calculations based on IEA (2025), Eurostat (2025), Misch et al. (2025), Ember (2025), and ICIS (2025)

Three findings are noticeable:

1. First, doubling energy investment raises cumulative TFP gains from $\sim 1.1\%$ to $\sim 1.4\%$, and tripling it to $\sim 1.7\%$ over ten years, a meaningful but not transformative difference, consistent with Misch et al. (2025) and with Acemoglu's (2024) view that AI's macroeconomic impact will be modest in the medium term.
2. Second, even under the high scenario, energy infrastructure is necessary but not sufficient for AI-led growth.
3. Third, and most critically, under current investment levels, AI data centre demand is on track to absorb all incremental EU electricity supply growth by 2030, leaving nothing for households or industry. This is the crowding-out dynamic the model predicts, now visible in real data.

These figures are illustrative, not econometric. The θ parameter in particular cannot yet be precisely estimated, as systematic data on AI capital spending and AI output at the EU country level does not yet exist. Estimating θ from EU panel data should be a priority for future empirical work.

3.4 Limitations of the theoretical model

This paper has a simplified theoretical framework and relies on assumptions that should be acknowledged:

- First, it assumes that energy supply and infrastructure adjust slowly relative to the pace of AI expansion. This assumption is motivated by the nature of energy infrastructure investment, which is highly capital-intensive, subject to administrative and permitting delays, and often requires many years to be completed. In this context, treating energy as fixed in the short and medium run provides a realistic assumption for analyzing potential bottlenecks related to rapid AI deployment.
- Second, the model does not explicitly include energy efficiency improvements. This simplification is consistent with the purpose of the framework, which is to isolate the role of energy availability as a constraint on AI-driven growth. Also, in endogenous growth models, technological progress is typically treated as the main driver of productivity growth itself, rather than modeling separate efficiency dynamics for each production input.
- Currently, the model does not empirically estimate the magnitude of the proposed bottleneck effects. So, the framework should be interpreted as an analytical tool for understanding possible mechanisms linking AI expansion, energy infrastructure, and economic growth, rather than as a predictive quantitative model.

4 Conceptual Analysis

The theoretical framework developed above, in particular the third scenario, explains the role of energy as a necessary input in AI production. From this, the following conceptual framework is built to further interpret these relationships in economic terms with more practical examples and evidence.

4.1 AI growth: Energy Demand and Supply Impact

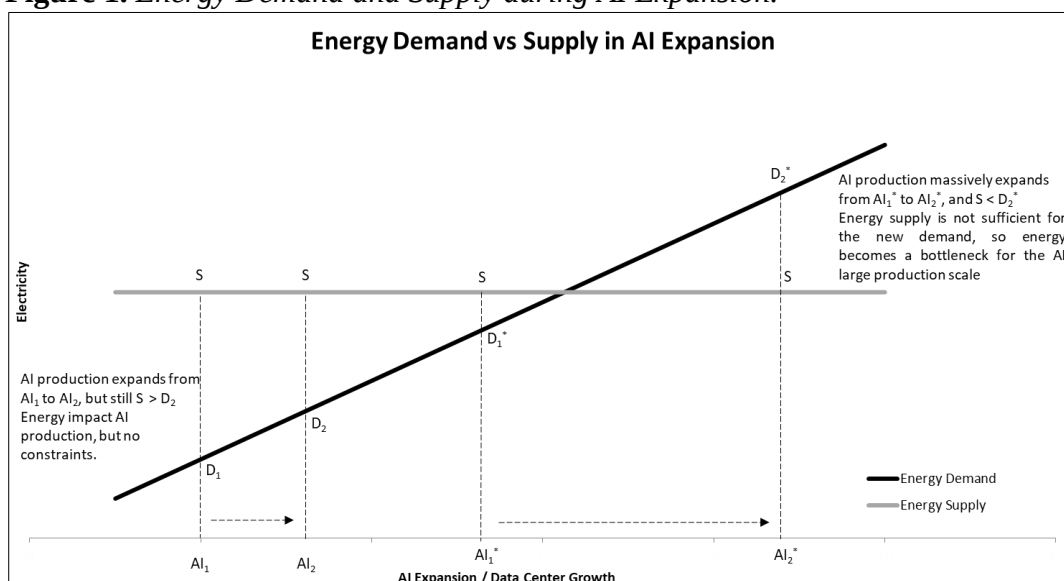
In this section, for analytical purposes, it is assumed that energy supply, including electricity grids and production capacity, remains fixed over time, without significant expansion or any change.

Even in the early stages of artificial intelligence development, energy is a very important input factor, and as AI systems expand (from AI_1 to AI_2), the existing stock of energy is still able to meet the increasing demand (from D_1 to D_2). However, if in the future the energy

supply continues to remain constant ($S=\text{constant}$), while AI continues to advance and expand in scale, new technologies or applications, the energy demand is expected to increase even more (from D_1^* to D_2^*), leading to a situation where demand exceeds available energy stock ($S < D_2^*$).

This situation would result in a supply deficiency in the energy market, creating constraints that limit the ability of economies to develop more AI and to fully benefit from AI development, and eventually turning energy into a critical bottleneck for growth. This dynamic suggests that without parallel investments in energy infrastructure, the expansion of AI may be restricted by physical energy limitations, as it is illustrated in Figure 1, which shows the gap between fixed supply and increasing demand over time.

Figure 1. Energy Demand and Supply during AI Expansion.

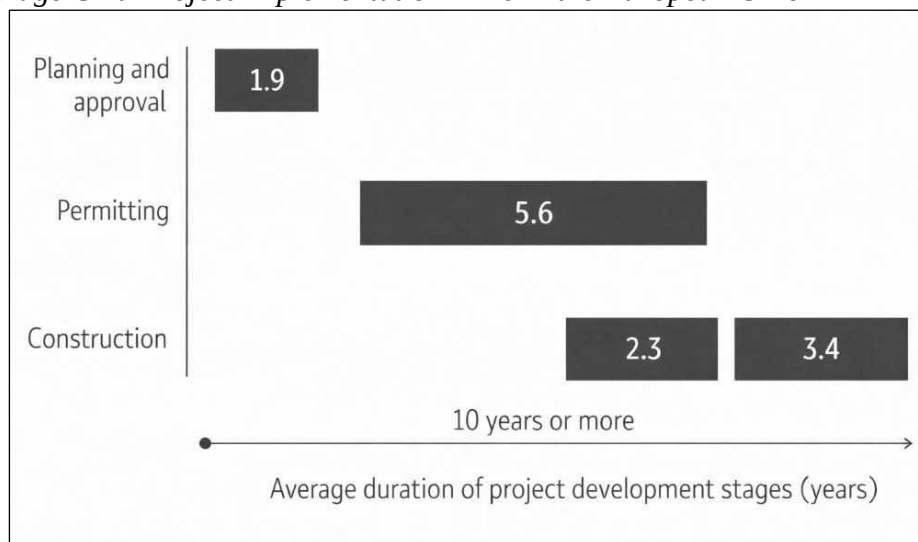


Source: Authors' own elaboration

4.2 Energy capital constraints

Figure 2

Average Grid Project Implementation Time in the European Union

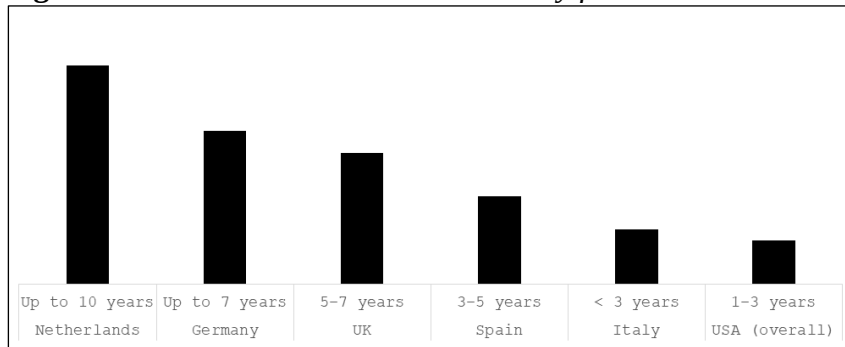


Source: EPRS, 2025

Based on the theoretical framework built above and the assumption that energy can be assumed as capital, it can be argued that capital cannot be created quickly, and it requires time to accumulate. Thus, energy capital faces limits in how fast it can expand. To bring this into practical terms with an example, what becomes most evident is the long time required for the new grid's implementation. Infrastructure projects typically take more than 10 years to be completed, with a very large share of this period being consumed by administrative permitting processes alone (European Parliamentary Research Service [EPRS], 2025), as shown in Figure 2, which presents the average grid project implementation timeline in the EU.

Apart from the time-consuming implementation of new grid projects, grid connection waiting times for data centres also represent a major bottleneck for AI competitiveness in terms of energy access. As shown in Figure 3, in leading EU data centre markets such as Germany and the Netherlands, grid connection waiting times can reach 7–10 years

Figure 3. *Estimated Grid Connection Delay for Data Centres*



Source: IEA, 2025

Additionally, capital has to be allocated between different uses, mainly between traditional capital (like infrastructure and production) and energy capital (such as grids and energy systems). This investment trade-off, introduced in Section 3.3.3, has direct practical implications.

4.3 Crowding out effect

Energy constraints turn energy into a key bottleneck, limiting sectors that use a lot of energy, such as AI, industry, transport, households, and other sectors. When different users compete for the same energy supply, which is assumed to be fixed or not experiencing significant changes over time, prices tend to increase. This situation can be described as a crowding-out effect, where the expansion of one sector reduces the energy available for others, expressed in a simple way as:

$$E_{total} = E_{households} + E_{transport} + E_{industry} + E_{AI} + E_{others}$$

When total energy supply remains fixed, an increase in energy use by AI → reduces the energy available for other sectors → creates crowding out → leads to higher prices and constrained growth.

The competition becomes concrete when considering that a single AI-focused data centre consumes as much electricity as 100,000 households, while the largest facilities currently under construction are projected to consume twenty times that amount (IEA, 2025). When total energy supply remains constrained, the expansion of even a small number of such facilities can affect the energy available for residential, industrial, and other productive uses, which is precisely what the crowding-out model describes.

In this way, energy can become a constraining factor as a result of AI expansion itself, as its high energy demand may start to limit the growth it is expected to generate. At the same time, other sectors cannot expand as needed. Overall, this conceptual analysis shows that if energy supply does not grow, it limits both AI and broader economic growth.

5 Discussions and Policy Implications

The theoretical framework developed in section 3, based on the endogenous growth model (Romer, 1990) and the infrastructure literature (Aschauer, 1989; Calderón & Servén, 2004), suggested that energy infrastructure is not merely a passive background condition for AI-driven growth. The following discussion interprets this in economic and policy terms, referring to the European Union.

- Grid connection to data centres taking up to 7 - 10 years in top EU data centre markets, such as Germany and the Netherlands (German Data Center Association, 2026; IEA, 2025), means that infrastructure decisions made today will determine AI competitiveness in the upcoming 10 years.
- Grid construction timelines of ten or more years (EPRS, 2025) suggest that the acceleration of permitting processes is as critical as the investment itself.
- The crowding-out effect becomes tangible when considered at the scale of actual infrastructure as analysed in Sections 3.3.3 and 4.3. For policymakers, the scale of AI energy consumption creates difficult trade-offs: prioritising data centres connectivity may accelerate AI-driven growth, but at the cost of household energy affordability and industrial competitiveness. This highlights that expanding energy capital investment is not optional if both AI development and broader social welfare are policy objectives.
- The investment share distributed to energy capital (ψ , as defined in Section 3.3.3) should be treated as a strategic policy indicator rather than a market result. So, policymakers need to make decisions on how much capital to invest in energy.
- The crowding-out risk underscores the need to explore mechanisms that offset data centre energy consumption. For example, Google has integrated waste heat from its Frankfurt data centre into the regional EVO district heating network, supplying an estimated 2,000 households.

6 Conclusions

The main finding is direct. When energy infrastructure does not expand with AI deployment, AI and broader economic growth slow, a result that follows directly from the third scenario of the extended endogenous growth model (Section 3.3.3), where insufficient energy capital investment constrains AI production and reduces the overall growth rate. When energy supply is constrained, rising AI energy demand competes with households, industries, and other sectors' needs, creating trade-offs (as illustrated through the crowding-out framework in Section 4). This suggests that grid investment and permitting reforms are not secondary energy policy issues but important components of any serious AI strategy in the EU.

The paper has a few limitations. It is theoretical, and its conclusions are conditional on the assumption that energy supply expands slowly relative to AI demand, an assumption consistent with current EU grid data (IEA, 2025; EPRS, 2025) but one that may not hold under accelerated infrastructure investment scenarios. It also does not consider how the energy transition, improved energy efficiency, or increased software and hardware efficiency may ease the bottleneck. The calibration exercise provides additional support for the theoretical framework by illustrating how energy infrastructure constraints may translate into differences in AI-driven growth, although it is not intended to provide precise empirical estimates. Future research should focus on empirically testing the bottleneck hypothesis and empirically calibrating the energy capital framework to offer guidance to policymakers.

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Annex - Calculations for Model’s Calibration

Baseline values

$\psi_0 = 0.017$ — current EU energy investment share (IEA, 2025; Eurostat, 2025)

$\theta = 0.40$ — central estimate of energy elasticity of AI output

$K_E = 1.00$ at baseline (set at $\psi_0 = 0.017$)

Energy capital index

$$K_E = \psi / \psi_0$$

Low: $0.017 / 0.017 = 1.00$

Medium: $0.030 / 0.017 = 1.76$

High: $0.050 / 0.017 = 2.94$

AI growth index

$$(g_A = K_E^{0.40})$$

Low: $1.00^{0.40} = 1.00$

Medium: $1.76^{0.40} = 1.26$

High: $2.94^{0.40} = 1.52$

Cumulative TFP gain ($TFP_s = TFP^{base} \times g_a$)

Baseline: 1.10% cumulative TFP gain for Europe (Misch et al., 2025)

Low ($g_a = 1.00$): $1.10\% \times 1.00 = 1.10\% \approx 1.1\%$

Medium ($g_a = 1.26$): $1.10\% \times 1.26 = 1.39\% \approx 1.4\%$

High ($g_a = 1.52$): $1.10\% \times 1.52 = 1.67\% \approx 1.7\%$

Table A1. *Summary of Formulas Used in the Calibration*

Indicators	Formulas
Energy investment share	$\psi_0 = \text{grid investment} / \text{GFCF}$
Energy capital index	$K_E = \psi / \psi_0$
AI growth index	$g_a = K_E^\theta$
TFP gain per scenario	$TFP_s = TFP^{base} \times g_a$
θ bounds	output growth rate/energy input growth rate

SMART AGRICULTURE AND ICT ADOPTION: EVIDENCE FROM AZERBAIJAN

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Abstract: *It is impossible to imagine our modern era without electronic services and digital technologies. Therefore, among the strategic tasks of our time, as well as many complex issues, as well as increasing the economic efficiency of ICT in the agricultural sector, intensifying the application of digital technologies, increasing productivity in all areas of activity due to these technologies, and making additional contributions to solving the efficiency problems of the agricultural sector as a whole is more of a priority. In the world, the processes of active use of "smart" technologies have risen to the maximum attractive level for most countries, and as a result, ICT technologies are being applied in leading fields of activity. Among the selected approaches and measures related to digitization of the agricultural sector and increasing the economic efficiency of the use of information technologies, providing necessary technological assistance to entrepreneurial and economic structures, providing advice and organizing training for the organization of effective use of ICT, modeling the use of natural resources, including land and water resources, preparation of targeted action programs, forecasting of climate changes, etc. directions are more requested. These mentioned problems and tasks are a sufficient priority for Azerbaijan. It is for this reason that the article paid special attention to the issues of increasing the economic efficiency of information and communication technologies in the agricultural field in accordance with the goals of the "Strategic Roadmap for the development of telecommunications and information technologies in the Republic of Azerbaijan" as well as "Azerbaijan 2030: National Priorities for socio-economic development". Because the agrarian sphere is an important economic sphere of strategic importance for Azerbaijan.*

Keywords: *innovation, investment, digital technologies, "smart" mechanisms, diversification, economic resources.*

1. INTRODUCTION

At a time when global risks are increasing and global threats are more evident, expanding the structure of the national economy in Azerbaijan, taking fundamental measures, and increasing the maneuverability of the economy require continuous work and the preparation of more justified mechanisms. In addition, there is a serious need for the intensification of the activity processes of various areas of the national economy, including the agricultural sector, measures to improve existing mechanisms in these directions, and to carry out improvements in this regard in a continuous manner and in accordance with modern challenges. At the same time, in-depth study of the resources of economic activity areas of the country's economy, which have more resources and are considered promising, identification and regulation of the main parameters of economic development potential, updating of standards, principles and criteria in these directions should be ensured. Already, traditional approaches and mechanisms, action strategies have undergone serious deformations in the context of global threats, under the negative effects of new complex conditions caused by global world problems, and their improvement and adjustment based on

the requirements of the current era, strengthening of their legal basis and legal base are characterized as important conditions.

On the other hand, the issues of sustainable and efficient implementation of the mentioned measures, i.e., achieving progress in the direction of achieving more appropriate and higher results by using ICT in the agricultural field, have come to the fore more prominently. Complex issues, approaches and priorities for the development of ICT across the country are expressed in the relevant strategic road map (decree of the President of the Republic of Azerbaijan on December 6, 2016).

2. ICT Development and Digitalization Processes in Azerbaijan's Agrarian Sector

In that strategic document, the near, medium and long perspectives and goals related to the development of ICT were determined based on justification, and now we are living in a period where their implementation processes are accelerating. But, let's admit that from the perspective of a researcher, despite the fact that our country has two sputnik satellites, that is, a space vehicle necessary for the expansion of ICT services, the development processes of digital technologies in Azerbaijan do not show a very high speed. Especially in the regions of the country, access to digital technologies and high-speed Internet are insufficient and it is difficult to say that there is an atmosphere of satisfaction. However, even with these, an electronic government portal, a package of electronic services, various digital platforms, and social and business-oriented electronic portals are already operating in our country. It is possible to note that the processes of expanding the use of ICT in the central government executive structures, as well as mainly in large economic entities, private companies and firms, and forming a digital service package are accelerating. It is true that ICT behavior and attitudes towards ICT in small and medium-sized enterprises are not yet in line with the requirements and criteria of the information society, and such economic subjects are sometimes not even interested in using ordinary computers in their activities. One reason for this is the traditional habit and stereotype, the other reason is the lack of information about the effectiveness of ICT and digital technologies, inexperience in the development and application of these mechanisms, as well as the lack of education in this direction.

Let's take the agricultural field and the effects and additional advantages that electronic mechanisms can provide in various fields of activity in this field are enough, from increasing the efficiency of farms to monitoring animal herds through digital technologies, taking security measures, or determining the situation through drones, real-time monitoring of farmland and plantations. organization of the mechanism, processing of important information without delay due to the data for making prompt and adequate decisions and making decisions at a high level, taking additional measures, etc. it is possible to adjust the issues. Along with financial resources, improvement of the action strategy, in-depth study and assimilation of the world experience, there should be relevant legislative acts and regulations, standards and instructions for working with various electronic tools should not contradict the laws. Currently, we are witnessing that the issue of using drones or other electronic devices anywhere is not so easy, and all these should have legal bases and regulatory mechanisms. That is, the time dictates the active use of such services to the subjects of the agrarian field.

It should be noted that it is important to make the most of ICT, to accelerate the development of agricultural fields and to create raw material resources required for agricultural processing enterprises, and to take additional measures in the direction of increasing productivity. However, necessary measures should be taken to overcome such issues. That is, there should be perfect legal bases and organizational-economic mechanisms for strengthening the infrastructure, taking more educational measures about ICT, and learning and adopting examples that reflect the practical efficiency of such mechanisms. It is

known that there are many concessions and state support mechanisms in the agrarian field, and they all arise out of a certain necessity, according to which laws are adopted, regulations are developed and approved, and when necessary, supreme orders and decrees are issued that replace laws. Therefore, it is necessary to make sure that the decisions taken are based on well-thought-out and justified mechanisms and reports, and can provide certain benefits in solving the problems of the agrarian sector and increasing efficiency.

The laws of the country adopted in the period after the restoration of independence, other legislative acts emerged out of objective necessity. So, starting from the first years of the restoration of independence, acute problems were accumulated in agriculture and in the agrarian field in general, reforms should be carried out and the agrarian policy of an independent state should be formed, and effective measures should be taken according to the world experience. In such a period, it was decided to carry out agrarian reforms in Azerbaijan, and under the leadership of the great leader Heydar Aliyev, these reforms were evaluated as the first large-scale agrarian reforms among the CIS countries. With this, important steps have been taken in the direction of increasing the efficiency of the use of land resources in our country, and useful measures have been implemented in terms of employment of the population. The Law of the Republic of Azerbaijan "On the Basics of Agrarian Reform", adopted on February 18, 1995, played an important role in these directions and provided the legal basis for the regulation of relations and mechanisms related to the implementation of agrarian reforms (Aliyev et al., 2017). On the other hand, the Law of the Republic of Azerbaijan "On Land Reform", which entered into force on July 16, 1996, strengthened the legal basis for the regulation of the use of existing land resources in the country and their efficient, intended use (Ibrahimov, 2013).

Since the beginning of the implementation of the oil strategy in our country, continuous work has been done in the direction of deep reforms in various areas of the economy, and in connection with them, the reforms in the agrarian field have been remembered for their high socio-economic efficiency. In the effective use of potential resources, including arable land, the application of state support mechanisms to small and medium-sized farmers and the provision of land shares has led to certain positive results. In this direction, legislative acts were improved, simple procedures were preferred, and the elimination of bureaucracy was one of the main goals. In addition, the creation of small and medium-sized enterprises in various directions of the agricultural sector, and the expansion of the processing network were motivated and stimulated through various state support mechanisms, including tax incentives.

As the independent state agrarian policy was formed and the problems of this field were solved, attention was paid to the development and adoption of perfect laws of the country. For example, in meeting the strategic task facing the agriculture and agrarian sector - the country's population's demand for important types of food, grain products, and first of all, wheat for food production, are of great importance. "The Law of the Republic of Azerbaijan on Grain" was adopted on June 16, 2000, and with this law, a legal framework was formed regarding the activities of the state and state institutions in the development of grain production and grain farming, supporting the activities of private subjects and investors in the development of grain, and the application of modern technologies. the mechanisms and legal bases of the regulation of the processes of keeping issues in focus have been raised to a new level [8]. In addition to these, various measures were taken by the state in order to stimulate more efficient work of agricultural and agricultural enterprises, small and medium-sized business entities, farms, expanding the structure of production and increasing the volume of production in that period, and the same at that time, a special law on tax benefits was adopted. For example, on November 27, 2001, the Law of the Republic of Azerbaijan "On granting temporary tax concessions to producers of agricultural products" came into force.

After the adoption of this law, the number of economic entities operating in various directions of agriculture and the agrarian sector in general increased, and it was possible to intensify the development of investment-oriented entrepreneurs and take stimulating measures. Thanks to the introduction of various financial instruments and new mechanisms, the possibilities of stimulating the activities of agricultural subjects have been expanded. For example, by the decree of the President of the country dated October 23, 2004, the legal basis of the mechanisms for applying leasing tools in the agrarian department was created and the necessary measures were taken in this regard (Decree of the President of the Republic of Azerbaijan on additional measures in the field of leasing expansion in the agrarian division. - Baku: city, October 23, 2004). On the other hand, in order to support the activities of agricultural producers, increase their motivation to work more efficiently, and increase their production capacity, the President of the country issued a decree dated January 23, 2007 "On state support to agricultural producers" (Badirzadeh, 2021). In connection with the implementation of this order, a mechanism of preferential loans was created to increase the production of agricultural products, subsidies were determined for many products, measures were taken to strengthen the material and technical base for the development of the field on the basis of high technologies.

Since the 2000s, special attention has been paid to the strengthening of the legislative base in our country in the direction of adopting and applying electronic mechanisms, taking into account modern global challenges. Measures for the transfer of high technologies and the application of progressive world experience have already begun to expand in various areas of the economy, including the agricultural sector. Staff training and training of specialists in this field, bringing electronic devices to the country, as well as stimulation of local production in this field, bringing electronicization to the fore in product production and sales have become the center of attention.

Taking into account that one of the important issues in increasing the efficiency of the agricultural sector is the cost-effective delivery of the grown and processed products to the final consumers, their introduction to similar sales markets, and the minimization of losses in these processes. At the same time, the creation of the legal basis for the implementation of electronic resources and trade deals on electronic resources was of great importance.

3. Legal and Institutional Framework for ICT-Based Digital Transformation in Azerbaijan's Agrarian Sector

On May 10, 2005, the Law of the Republic of Azerbaijan "On Electronic Commerce" came into force based on the mentioned factors, and this law ensured the formation of legal bases for the introduction of electronic commerce and new technologies (Law of the Republic of Azerbaijan on electronic commerce. - Baku: - May 10, 2005, No. 908-IIQ). At the same time, the role of high technologies and progressive methods of operation is great in expanding the production of environmentally friendly agricultural products and exporting them to foreign markets while meeting local demand. That is, the purchase of environmentally friendly agricultural products by increasing productivity is a priority in modern times, and these issues are regulated by the relevant country's law in Azerbaijan (Ismayilov, 2017).

The issues of regulating the development of the agricultural field in accordance with the requirements of the time and evaluating scientific innovations using ICT in these directions, developing the field on scientific basis are of great importance. It is extremely important to consider these factors in practical processes and to have legal bases for regulation. In this regard, the Decree of the President of the country dated April 16, 2014 "On measures related to the improvement of management in the agricultural sector and acceleration of institutional reforms" was effective in realizing the intended issues and making improvements (Ismayilov,

2017). As a result, the existing mechanisms of action were maximally updated, institutional and structural reforms were carried out, attention was paid to transparency issues, and expansion of the scope of electronic services was a priority. The Decree of the President of the Republic of Azerbaijan dated April 16, 2014 on "Establishment of the Electronic Agriculture System in the Ministry of Agriculture" has caused fundamental changes in this field.

Thus, electronicization processes have been accelerated and due to the expansion of electronic services, the efficiency of management, control and implementation processes has been increased in various areas of agriculture and in the agrarian field in general (Ilyasov, 2013). At the same time, the creation of the "Electronic agricultural information system" has also created additional opportunities for increasing productivity. The operating principles of this system include transparency, organization of efficient management, acceleration of the introduction of innovations, expansion of business processes, etc. they attract more attention (<https://www.agro.gov.az/az/ekt/ektis-de-sistem-in-integrasiyasi-ve-movcud-funksiyonalligi>). Various ICT mechanisms and digital services in the agricultural sector are already effective and these issues have been raised to the level of priority.

In general, in increasing the socio-economic effect in agriculture and the agrarian field, in creating new jobs, in creating farms and agricultural enterprises taking into account traditional and common interests, in the productive use of various economic forms, as well as in the renewal and improvement of cooperative relations based on ICT mechanisms in the legislation detection and elimination of existing gaps is one of the important conditions. In terms of the mentioned factors, the Law of the Republic of Azerbaijan "On Agricultural Cooperation" adopted on June 14, 2016 has given a new breath to the cooperative movement and cooperative relations.

At the moment, the main goal is the effective integration of farms and other entrepreneurial subjects, individual entrepreneurs engaged in the agricultural field, citizens in various forms of subjects, public associations, as well as cooperatives, the creation of effective collectives and teams, the effective use of modern high technologies to achieve the set goals, and ICT-based it consists of giving preference to action mechanisms. Such approaches are the demand of the times. (<http://mincom.gov.az/az/view/news/615/reqemsal-iktisadiyyatin-esasi-kimi-ikt-infrastruktur-movzusunda-beynelxalq-seminar-kechirilib>).

It should be noted that the continuous visits of the President of the country to the regions, familiarization with the existing problems on the spot, the creation of necessary infrastructure, the acceleration of socio-economic development and the allocation of additional funds from the reserve fund of the President for the implementation of priority projects, as well as the issuance of relevant presidential orders and decrees, will increase economic activity in the regions. , at the same time, it made it possible to create a solid foundation for expanding the use of modern technologies. In this regard, the need for our citizens to operate in a more transparent environment, to sufficiently benefit from their labor and citizenship rights, and to take necessary steps to ensure the openness and transparency of the society and the economy, has greatly increased the demand for an honest and transparent information society.

Accelerating the implementation processes of the "State Program for the Implementation of the National Strategy for the Development of the Information Society in the Republic of Azerbaijan for the Years 2016-2020" approved by the Decree of the President of the Republic of Azerbaijan dated September 20, 2016, in increasing the activity of civil society in our country and forming new sources of economic development. , played an effective role in identifying problems and determining their solutions.

In addition, in the Agrarian Research Center under the Ministry of Agriculture of the Republic of Azerbaijan established by the Decree of the President of the country dated May

22, 2018, purposeful work and scientific research are being carried out in the direction of the development of the field on a scientific basis. The decree of the President of the Republic of Azerbaijan dated December 14, 2018 "On the establishment of the Agricultural Supply and Supply Open Joint-Stock Company" was issued for the purpose of maximally efficient supply of products produced in the agricultural sector, elimination of defects in the processes of creation of reserves and delivery to final consumers, regulation of retail (Decree of the President of the Republic of Azerbaijan on the establishment of the Agrarian Research Center under the Ministry of Agriculture of the Republic of Azerbaijan. - Baku: - May 22, 2018) . At the same time, it is a priority to evaluate the use of ICT mechanisms in the development and modernization of management bodies in the agricultural sector (decree of the President of the Republic of Azerbaijan on December 6, 2016).

It is important to regulate the activities of agricultural subjects in accordance with the requirements of the time, to obtain necessary information about scientific-technological and digital technologies and to adopt progressive experience, to apply advanced technologies and effective methods, models, to provide agrarian services in order to increase productivity and reduce losses.

Based on these factors, the priority tasks, functions and rights of the new and important central state institution were determined by the Decree of the President of the country dated May 21, 2019 "On the approval of the Regulation on the Agrarian Services Agency under the Ministry of Agriculture of the Republic of Azerbaijan" (Aliyev et al., 2017) . Such services have already been actively provided in the regions of the country.

We would like to touch on one issue. As is known, forecasting of activities in the agricultural field, implementation of projects, etc. the issues are quite complex, this field is also associated with various risks, and for these reasons, potential investors have difficulty and hesitate to invest in the agricultural field. Therefore, the functioning and transparency of insurance mechanisms, as well as their effectiveness, are considered important.

Drought, natural disasters, etc. The role of the insurance service in covering a significant part of the losses of agricultural subjects can be very effective. At the same time, the presence of effective insurance mechanisms would further increase the motivation for the increase of economic activity in the agricultural sector, the transfer of high technologies and the application of ICT mechanisms. In general, the creation of the legislative framework of the insurance mechanism in the agricultural field has attracted attention as a subject of discussion for many years.

Finally, on August 19, 2019, the Law of the Republic of Azerbaijan "On Agricultural Insurance" was adopted (Aliyev et al., 2017). There are facts that the first insurance payments have already been made to the affected farmers and rural households, and these should be considered commendable. New opportunities are opening up for the more reliable organization of activities in the agricultural field, as well as the expansion of risky, but profitable areas of activity using ICT, and in the near future, these may give their results.

Another historical and important issue for our country is the liberation of our lands and brutally destroyed villages, towns and cities that have been in the hands of the enemy for nearly 30 years. Already, large-scale revitalization and rehabilitation projects are being implemented in these areas, infrastructure is being created, housing estates are being built, roads and bridges are being built, and the restoration of economic areas has begun. Two new economic regions - Karabakh and Eastern Zangezur economic regions were created in the territories freed from occupation, and both regions have strong agricultural potential. It is gratifying that the pilot projects implemented in the liberated territories are based on "smart" technologies.

The application of high technologies on a large scale is the highest priority, and already the commissioning of Fuzuli International Airport, the laying of the foundations of the

"Aghdam industrial park" and the "Araz Valley Economic Zone", the intensive implementation of the "Smart village" pilot project in the area of Agali villages of Zangila, and a - the holding of groundbreaking ceremonies for other projects one after the other suggests that the demand for ICT in the territories freed from occupation will increase even more in the near future. (www.economy.gov.az)

Taking into account the negative effects of the COVID-19 pandemic on the agricultural sector in the liberated territories and other regions of the country, development priorities and directions of action require the application of ICT-based mechanisms in a wide format. The efficient operation of automated livestock farms and complexes, irrigation systems, management forms seems to be the most realistic at the expense of ICT, and since these issues are justified in the world experience, the ICT factor must be seriously considered and evaluated in practical processes. At the same time, taking into account the territories freed from occupation, specifying and defining the ways of increasing the economic efficiency of ICT in the agricultural field can be more effective.

No matter how fast Azerbaijan develops in terms of industry, even if it has the strongest industrial sector in the region, as well as the world-class high-tech oil and gas industry, it is not necessary to forget that Azerbaijan is also an agrarian republic, half of our population lives in rural areas. Traditionally, strong agricultural fields and agro-industrial complex have been formed and developed in Azerbaijan. In the context of global threats and in the provision of food security, which is one of the most complex problems of the millennium, the multiplier effect of the agricultural sector is great in reducing the level of hunger and poverty, as well as unemployment.

However, over time, the problems are also increasing, as due to global warming, land areas are decreasing and becoming flooded, salinized, drought levels are increasing, agricultural development is depleting resources, and the constant growth of the world's population is making the demand for new food resources even more acute. All this sets new tasks for the agrarian sector, giving greater priority to science and technology-based development in solving the problems of increasing productivity, ensuring productivity through extensive development, increasing the caloric value of important food products, increasing their quality, reducing losses, and making processing processes more efficient. organization etc. it requires a complex and systematic solution to such issues.

The agrarian field consists of complex elements and mechanisms due to its formation and development characteristics. It is known that humanity is faced with global hunger and food security, which is one of the most serious and acute problems of the millennium. The efforts of the leading world states and international organizations in this field are still not at the desired level and the expected results have not been achieved. On the contrary, the COVID-19 pandemic has made the problems in this direction even more complicated. In view of the above, increasing the efficiency of ICT use in the agricultural field can allow to eliminate a certain part of the mentioned problems. Thus, the active application of digital technologies increases efficiency and efficiency, and creates conditions for making adequate and preventive decisions. Digitization refers to the complex and integrated application of information and communication technologies in the economy and society. Digital technology has great potential in saving production resources, simplifying documentation and improving the quality of decision-making and farm management.

Digitization aims to help make agriculture productive, sustainable, efficient and environmentally friendly, i.e. purposeful use of production resources with minimal loss to produce food products of high quality and minimal impact on the environment. Agriculture mostly produces under the open sky and works with living organisms, which means that it is characterized by complex and dynamic production conditions that are difficult to predict and regulate, which creates additional problems in production processes (<http://mincom.gov.az>)

gov.az/az/view/news/615/reqemsal-iktisadiyyatin-esasi-kimi-ikt-infrastrukturu-movzusunda-beynelxalq-seminar-kechirilib).

Approaching from the importance of modeling the development of the agricultural sector in Azerbaijan, improving it in accordance with the requirements of the global era, as well as in the conditions of the justified determination of strategic goals, it is possible to note that the disclosure of the real potential in the activity of the agricultural sector, the important aspects of bringing global approaches and the use of high technologies to the fore in a wider scope being understood and implemented. The point is that the implementation of these strategic approaches and priority tasks, the acceleration of the development of the agricultural sector on the basis of ICT, as we mentioned at the beginning, is a very complex issue and requires the solution of many problems. We have also seen from the international experience that due to the efficient use of ICT, extensive development of the agricultural sector, increase in productivity, reduction of manual labor, higher results can be achieved by using "smart" technologies in animal husbandry and crop production, optimization of the cost of the products to be produced, it is possible to increase the level of profitability (<https://www.agro.gov.az/az/ekt/ektis-de-sistemin-integrasiyasi-ve-movcud-funksiyonalligi>). In addition, the issues of activating the use of ICT during the development of agricultural areas, increasing the variety and volume of food products, and determining the solutions to the problems of reducing the level of hunger and poverty have also become very relevant for the agrarian sector of our country, and especially in the projects that are currently being implemented in the revitalization of territories freed from occupation. is a much sought after tool. For example, construction of residential areas based on "smart" technologies, creation of agro-industrial infrastructure, preference for digital technologies in entrepreneurship and business development can be examples of this.

4. The Role of Agrarian Reforms and Digital Technologies in Strengthening Food Security and Economic Growth

Under the conditions of the development of economic forms based on private property in the agrarian field, entrepreneurial activity was rapidly formed, free production-economic relations were established, interest in the proper realization of the produced products, the effective use of financial results, and the improvement of the living conditions of the population increased. The agrarian reforms carried out in the republic were of a complex nature and included both agricultural enterprises and processing and service enterprises. The results achieved during the agrarian reforms implemented in Azerbaijan are generally positively evaluated by both local experts and experts of international organizations. The goal of the agrarian reforms carried out in the Republic of Azerbaijan as well as in the post-Soviet countries at the initial stage of the transition from the administrative - emirate economy to the market economy can be formulated as follows: to achieve the development of private ownership in the agricultural sector and the establishment of an economic system based on market relations in general, to bring the agricultural sector out of the crisis situation and creation of food abundance in the country. In accordance with these goals, the structure of the agrarian field was renewed, the plots of land were privatized and the agricultural production units were reorganized. The infrastructures of the agricultural sector have been created, the market has been liberalized. The level of payment of the country's demand for argar products at the expense of domestic production has been significantly increased.

Taking into account the importance of the agricultural sector, agrarian reforms in this sector should be continued, these reforms should be continued on the basis of new, modern information technologies. Reforms carried out on the basis of modern information technology have created a certain revival in the field of agriculture as well as in other fields of the Republic of Azerbaijan. This is evidenced by the stabilization of the level of investment in

agriculture and the increase in competition between agricultural producers. At the same time, the volume and quality of the use of modern technologies, including data collection, storage and processing systems, in the agro-industrial complex is also increasing. At the same time, both the volume of data and the need for high-quality processing and reliable results that can be relied on for decision-making are increasing. As a result, there is a demand for analytical systems and especially deep analytics for rural agriculture.

There are areas of the economy in which it is absolutely necessary to adopt innovations, for example, agriculture and the agrarian sector can be a clear example of this. The great role of the agricultural sector in solving the problems of solving food security problems, creating food abundance, strengthening food security, providing access to important food products, providing food in a stable form in accordance with the financial capabilities and consumption level of all sections of the population for a sustainable and long-term period and has multifaceted functions.

In this area, both food products are grown and the economic activity of rural regions is increased, new opportunities are formed for increasing the income of the population, the potential for strengthening employment is created, the threat of forced migration of labor resources is reduced, and in general, the opportunities for solving the socio-economic problems of the territories and regions are expanded. To a large extent, accelerating the development of the agricultural sector based on new technologies has a positive effect in a number of directions and has a multiplier effect on other areas of the country's economy as a result of mutual relations:

- 1) diversifies the structure of the national economy;
- 2) ensures effective use of existing natural and economic resources of the regions;
- 3) makes significant contributions to the development of the non-oil sector;
- 4) plays an important role in increasing non-oil exports;
- 5) the development of the agricultural sector has a strong impact on increasing the economic activity of the country's regions;
- 6) strong potential is realized in solving employment problems of agricultural fields and agrarian sector;
- 7) the balanced development of the agricultural sector is one of the important activities of the country's food security and acts as a guarantor of national economic security and food security;
- 8) the development possibilities of the agrarian field are suitable for the application of new technologies and there is a great need for this;
- 9) the formation and development of innovative entrepreneurship is accelerated due to the application of agrarian ICT, etc

On the other hand, it is important to have an internet infrastructure that allows for a more efficient solution to socio-economic development issues and to form an internet network, especially high-speed broadband internet opportunities and provide services. If we approach these problems in the example of Azerbaijan, we should note that our country is just forming conceptual approaches and operational mechanisms related to ICT, we still need to study the world experience at a high level and look at the issues of application in accordance with the economic goals of our country.

If this is the case, we hope that our country's continuous ICT-related policy and measures taken will bear fruit, and it will be possible to effectively use the opportunities of ICT in various areas of the economy, including the agricultural sector. Only after that, a solid foundation can be created for modeling the development of ICT on a wider level in our country, and for the implementation of large-scale investment-innovation and technological-digital projects. Along with these, measures should be taken to build confidence in the use of ICT services, prevent inequality in the distribution of information resources, organize the

effective use of ICT to strengthen the safety of people's lives and the stability of society, update the currently used technologies, and basically form new generation networks.

These factors and approaches to the mentioned issues are considered very important for all areas of society and all sectors of the economy, including the agricultural sector in our example. Solving the efficiency problems of the agricultural sector is one of the important factors in the production and creation of reserves of important types of food products in the country, and also, as we said earlier, the development of the agricultural sector based on ICT could have a great effect in eliminating dependence on imports, and it is possible to note that these processes have already begun.

The problems and solutions of the diversification and diversification of the country's economy require a complex and systematic approach, and here the main priority is the involvement of the possible resource potential of the economy in the economic and financial circulation, the creation of fertile conditions for investments, and the application of mechanisms and tools that allow ensuring economic efficiency. . The main goal of these approaches and priority activities is to minimize the dependence of the economy on the oil and gas factor. In a word, the creation of effective mechanisms for the productive and innovative development of the economy, as well as increasing the efficiency of those mechanisms due to the application of ICT, attract more attention. On the other hand, it requires the creation of a business environment that allows for innovative and intensive development in the country, increasing the attractiveness of investment and innovation, as we mentioned earlier, the creation of appropriate ICT infrastructure in the regions of the country as well as in the central cities. In addition, taking into account that the measures taken regarding the effective use of ICT are at the initial level, special attention should be paid to the issues of training high-level and qualified personnel and training specialists in this field along with the relevant infrastructure.

It should be noted that in the current conditions, it is impossible to imagine effective economic development and progress without ICT. The Internet and electronic resources have laid the foundation for revolutionary changes in society and economy, and these processes are deepening to the maximum. In particular, the great importance of ICT resources and infrastructure can be shown from the point of view of the rapid spread of progressive practice at the global level, as well as from the point of view of information exchange. Realizing the importance of maximum acceleration of ICT infrastructure development, at the same time, they are striving for the development of technologies, their development and application, and the spread of digital mechanisms and tools with greater intensity in areas of economic activity. It is believed that ICT resources will be in greater demand in the near future as one of the most productive tools for increasing the efficiency of the economy. These resources allow entrepreneurs, every specialist, tradesman and citizen to form and develop their socio-economic relations (Badirzadeh, 2021). We are also of the opinion that ICT has a strong influence in terms of realizing the existing potential of various sectors of the economy and stands out for its strong potential in eliminating problems in this field with its multifunctional capabilities, in developing more effective and productive mechanisms and operational tools in accordance with the requirements of the time.

5. Strategic Roadmaps and ICT-Based Modernization of the Agrarian Sector in Azerbaijan

In recent years, new mechanisms and tools for the development of the agricultural sector and the realization of the strategic goals of agriculture have been defined in our country, and continuous measures are being taken in these directions. Even in the decree of the President of the country dated April 16, 2014 "On measures related to the improvement of management in the agricultural sector and the acceleration of institutional reforms", it is envisaged to improve the management processes in this field in accordance with the

requirements of the modern era, and to accelerate the application of new technologies [4]. It is as a result of the implementation of this decree that preference was given to development on scientific grounds in the agrarian field and in the leading directions of agriculture, and attention was paid to the application of new technologies and electronicization. On the other hand, in the "Strategic Roadmap for the perspective of the national economy of the Republic of Azerbaijan" approved by the decree of the President of the country dated December 6, 2016, along with a number of goals, the application of new technologies, including digital technologies, was given serious importance in almost all directions. In addition, in the "Strategic Road Map for the Development of Telecommunications and Information Technologies in the Republic of Azerbaijan", approved by the decree of the President of the country dated December 6, 2016, the issues of expanding ICT services and actively applying digital technologies in all areas of society and economy are specifically addressed. found the opposite. In another strategic road map, the "Strategic Road Map for the production and processing of agricultural products in the Republic of Azerbaijan" approved by the same decree, a wide range of measures were provided and the goals of electronicization were mainly prioritized. As one of the sectors of the economy where the impact of ICT can be significantly positive, it is justified to take systematic measures in the agricultural sector in recent years. Thus, with the productive use of ICT in the agrarian field, as well as in various areas of agriculture, including the active application of new technologies, additional opportunities arise to achieve productivity growth, sale and export of cultivated products under more favorable conditions.

We are of the opinion that there is a greater need for new formats and approaches in the development of the agricultural sector in our country and its modeling in the regional aspect, and we consider it important to give more importance to the issues of increasing the economic efficiency of ICT in these processes. This necessity is also directly related to the new objective realities, as we stated at the beginning. In all regions covered by the agrarian sector of our country, including the territories freed from occupation, and in its agro-processing enterprises, high technology-based approaches should be unequivocally and intensively dominated, and serious importance should be given to the wider application of electronic and digital mechanisms, and as a result, the development of the agrarian sector intensification, increasing the economic efficiency of ICT should be achieved.

In order to model and improve the development of the agrarian field in the context of the goals arising from the strategic road maps, and in order to increase efficiency, we are of the opinion that in our country, first of all, in the regions, in the subjects of agriculture and the agrarian field in general, in rural districts and rural settlements, even in remote villages, computers and Internet networks, more measures should be taken to actively use various ICT products and programs, accessibility of these technologies and services should be ensured. At the same time, on the basis of such technologies, it is possible to take effective measures in a number of important areas of activity in the agricultural field:

- systematically analyzing the activities of farms and taking complex measures, establishing a "smart" management system;
- regulation of activity processes in remote form, assignment of additional tasks and monitoring of resource use;
- greater emphasis on intelligence in the management of agricultural production areas, detection and evaluation of cost reduction resources;

In modern times, ICT development problems should be the highest priority for our country, and the amount of financial resources directed to this field should be increased. So, in order to achieve high results in these directions, the market of technologies and innovations should be developed, the factors of freedom and freedom of the economy should be taken into account, the institution of free economic zones should be formed, more high

technologies - ICT-based technoparks, agricultural industrial parks, agricultural science and industry parks, special economic zones, agrarian clusters, etc. should be organized.

Currently, 51 agrarian parks have been established and are in the process of being established in most regions of our country, and these parks are given ten-year tax and customs concessions by the state, but we believe that although these steps are a progressive approach, the agroparks created and operating are mainly those of ordinary farmers and agricultural enterprises. They are not so different. One of the main reasons for this is the lack of widespread use of ICT mechanisms.

The attitude towards digital technologies is becoming conceptual, and focusing not only the central links of state structures, but also structural units at the regional and local level, private sector subjects and state enterprises on expanding the use of ICT is becoming a priority task. For this, the current situation in our country should be viewed and evaluated in the context of global changes and risks. At the same time, in terms of the new situation and realities, it is important to determine more favorable ways of increasing the economic efficiency of ICT in the agricultural sector, taking into account our territories freed from occupation, and we will focus on these issues in the last paragraph.

There is a great need to increase the economic efficiency of the agricultural sector, increase productivity and rationally use the resources in this field, to update and improve the mechanisms, to develop and implement more efficient mechanisms using proven and tested technologies in the world experience. When we looked at the world experience, we noted different aspects of approaches related to them and focused on the adaptability of the experience of certain countries for Azerbaijan, and we will express their summarized content in the final part of the work. However, we believe that in the coming years, a more advanced stage of economic reforms and transition to technological innovation should be started in Azerbaijan. In addition to the leading oil and gas sector of the country's economy, other economic sectors should be modernized at a high level, the application of ICT should be deepened to the maximum, and the use of digital mechanisms should be intensified (Azerbaijan 2020: a vision of the future Development Concept).

It is very important to model the activity of the agricultural sector, to develop more profitable and attractive mechanisms of action, to increase the level of profitability of this sector. There are certain stereotypes, lack of treatment, etc. ways to get rid of such factors and situations should be sought and determined at a more fundamental level. In other words, the agricultural sector should not be understood as subsidies, preferential state support mechanisms, we also agree that such approaches are widespread in the world experience, but there is also a truth and reality that Azerbaijan is also a part of the world, has moved to a market economy and as a basic principle efficiency of the economy is accepted. In other words, the agrarian sector should be developed to such an extent that more technological innovations and ICT should be used so that the optimization of costs incurred, i.e. reducing costs, and balancing the incomes of the participants in production - production subjects, become possible, which in turn are important increase the interest in the production of food products - agricultural products, motivate and form additional incentives for efficient operation. Of course, all these are complex processes and require the further intensification of institutional and structural reforms at the country level, the maximum updating of economic development priorities in the regional aspect and their adaptation to current challenges, the determination of multiplicative goals taking into account prospective development determinants, that is, approaches to the development of the agricultural sector, applied ICT and other models based on digital mechanisms, "intelligent" technologies, as well as allowing the discovery of the potentials of creating added value and forming financial sources of this area and other related economic areas, and being involved in economic, commercial and financial circulation, as well as accelerating the economic development of the agricultural

sector, social development in the regions and in our country - it is possible to make additional contributions to economic development processes. Therefore, while accepting that science and technology are the main factor of economic development and progress of the 21st century, it is necessary to master the ways and methods of sufficiently benefiting and using this factor effectively. mechanisms, action strategies and models that can realize their potential should be defined, developed and actively used in them.

Formation of the material and technical base for the development of large-scale infrastructure, rehabilitation and revival, social and production areas in Karabakh, Eastern Zangezur economic regions, implementation of local, republican, regional and world-level projects on various types of transport, reconstruction of the railway network, a putting into operation the international airport - Fuzuli International Airport, laying the foundations of Zangilan and Lachin International Airports, conducting intensive work at the international level in connection with the opening of the Zangezur Corridor, which will connect Azerbaijan with the Nakhchivan Autonomous Republic, which is part of it, and the development of various directions of the hemp industry in these economic regions and as a whole starting the implementation of measures for the evaluation and efficient use of the development resources of the agrarian area, for example, the intensification of the processes of creating the Agdam industrial park, which will consist mainly of agro-industrial processing enterprises, the foundation of the "Araz Valley Economic Zone" in Jabrayil district, the electricity of the lands freed from occupation, formation of stable supply systems with drinking water and natural gas, construction of new networks and substations, establishment of enterprises, construction of residential areas, taking measures to ensure socio-economic development in various directions, giving priority to the creation of effective and multifunctional ICT-based action mechanisms in the agricultural field draws attention. We believe that in these processes, the rapid adoption of new technologies, especially in the socio-economic development of the region and the acceleration of the solution to the employment problem after the return of the "Great Migration", the expansion of the activities of agricultural fields and the increase of the role of the agricultural sector in the economy of the region in general will play an important role. Therefore, it is important to use these mentioned directions of activity more productively due to increasing the economic efficiency of ICT in the agricultural field. It is true that different types of state programs and strategies are implemented in our country and national priorities are targeted. Currently, the "State Program for Socio-Economic Development of the Regions of the Republic of Azerbaijan in 2019-2023", approved by the order of the President of the country dated January 23, 2019, is being implemented, and in this program, increasing economic activity in the regions of the country, especially the main non-oil sector of the agricultural sector, is being implemented.

CONCLUSIONS AND SUGGESTIONS

The directions of modeling the priorities of increasing the efficiency of the use of ICT in the agricultural field and determining the areas in which such technologies bring more benefits have been fundamentally analyzed and theoretical-methodological approaches have been systematized and evaluated in accordance with the challenges of the modern era. In addition, taking into account the strategic role of the agricultural sector and the agro-industrial complex in the formation of the long-term reliable supply of the country's population with important types of food, conceptual approaches to the use of ICT in the agricultural sector were determined and efforts were made to enrich them with author's approaches.

The materials we have prepared for the study of the directions of increasing the economic efficiency of ICT in the agricultural field, the researches we have made possible to formulate a group of results, and they are as follows:

1. The efficiency issues of ICT in the development of the agrarian field have not yet entered an intensive phase, and the implementation of targeted programs in these directions, there is a serious need to develop the development of the agricultural sector on the basis of more sustainable and different mechanisms and to expand the role of ICT in those processes.
2. Complex measures related to the creation of a more productive activity environment in the agricultural field and the introduction of mechanisms, the cultivation and collection of products and the reduction of losses to a minimum level, the creation of reserves, the development of more effective action strategies, the increase of the efficiency of ICT in the processes of delivering competitive agricultural products to consumers, and including institutional measures should be implemented, state policy should be improved and state support mechanisms should be in line with the challenges of the modern era.
3. Sufficiently benefiting from the ICT experience of technologically developed countries and the mechanisms of using digital technologies are important conditions, and if we proceed from these factors, we believe that in the near future, a deeper study of the world experience, taking effective measures to increase the economic efficiency of ICT, especially in the agricultural field, the application of digital technologies in a wider spectrum, the justification and implementation of projects on the basis of "smart" technologies, the wide use of the opportunities of ICT in increasing the attractiveness of the investment-innovation environment in the country should be systematic, and optimal control and implementation mechanisms should be developed.

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ARTIFICIAL INTELLIGENCE IN MARKETING: AN ANALYSIS OF CONSUMER DEMAND MANAGEMENT IN AZERBAIJAN'S LIGHT INDUSTRY

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Abstract: *This study analyzes the role of artificial intelligence in marketing strategies aimed at managing consumer demand in Azerbaijan's light industry. The research focuses on innovation-oriented marketing practices and their contribution to improving enterprise performance and enhancing market competitiveness. Particular attention is given to the processes of introducing, commercializing, and diffusing innovative products, where data-driven decision-making and demand forecasting play a crucial role. Using the cases of "Azarxalcha" JSC and "Gilan Textile Park" LLC, the study examines the application of digital and AI-based marketing tools, including consumer behavior analysis, market segmentation, and predictive analytics. The empirical findings demonstrate that the integration of artificial intelligence into marketing strategies supports more accurate demand management and strengthens strategic planning capabilities. The results also reveal persistent structural challenges within the sector, such as a high degree of import dependence, limitations in domestic production capacity, and the need for technological modernization. In response to these challenges, the study highlights the importance of state support mechanisms, cluster-based industrial development, and the wider adoption of artificial intelligence and analytical technologies to improve managerial effectiveness and market adaptability.*

Keywords: *Artificial intelligence, marketing strategies, consumer demand management, digital marketing, Azerbaijan's light industry*

1. INTRODUCTION

The light industry constitutes an important component of Azerbaijan's economic structure, playing a significant role in meeting domestic consumer demand and expanding export-oriented production. Sustainable development in this sector increasingly depends on the adoption of effective marketing strategies, innovation-driven product development, and systematic analysis of consumer demand. In the context of intensifying global competition and rapidly evolving market conditions, the application of artificial intelligence (AI) in marketing has emerged as a critical tool for enhancing strategic decision-making and improving market responsiveness.

Recent state-led initiatives, including the establishment of industrial parks, support for export-oriented manufacturing, and the expansion of digital distribution channels, have contributed to the modernization of textile production, garment manufacturing, and carpet weaving. Despite these positive developments, the sector continues to face structural challenges such as limited integration of marketing functions into enterprise management systems, insufficient use of consumer-oriented analytical tools, and underdeveloped branding and positioning strategies.

Against this background, the present study focuses on the analysis of AI-supported marketing strategies in managing consumer demand within Azerbaijan's light industry. The research applies a data-driven analytical framework combined with case study evidence to assess existing marketing practices, identify key constraints affecting demand management,

and evaluate the potential of artificial intelligence technologies in improving strategic planning processes. Particular attention is paid to the role of consumer behavior analysis, demand forecasting, and digital marketing tools in strengthening enterprise competitiveness.

2. Digital Transformation and AI in Industrial Marketing

The expansion of digital technologies has significantly reshaped interactions between enterprises and consumers. Tools such as social media analytics, search engine optimization, and content-based marketing strategies contribute to increased market visibility and stronger customer engagement. AI-driven systems further strengthen these processes by detecting behavioral patterns, refining campaign performance, and forecasting demand dynamics. Nevertheless, despite the evident benefits, the adoption of digital and AI-based marketing practices among many Azerbaijani light industry enterprises remains limited.

Academic research on Azerbaijan's light industry has predominantly concentrated on macroeconomic regulation, state support policies, and export promotion measures. In contrast, relatively little attention has been paid to firm-level marketing strategies, branding processes, and the digital transformation of marketing activities. Closing these research gaps is critical for ensuring closer alignment between enterprise practices, national development objectives, and international competitiveness benchmarks.

A detailed examination of marketing practices in Azerbaijan's light industry reveals a set of enduring structural barriers that continue to limit operational efficiency and competitive performance. Among the most prominent challenges are the insufficient recognition of marketing as a strategic management function, the absence of advanced marketing information systems combined with restricted access to dependable market data, and weaknesses in the material and technical base required to support innovation-oriented production processes.

These constraints highlight the importance of coordinated, evidence-based managerial decision-making. Product strategy formulation should not occur in isolation but rather as part of an integrated system that combines pricing mechanisms, distribution channels, and communication instruments into a unified marketing framework. As emphasized by Armstrong et al. (2018), marketing should be conceptualized as a comprehensive decision-making system that aligns production and sales activities, rather than as a standalone operational function.

Strategic product-related decisions should therefore focus on expanding product variety, introducing innovation-driven product lines, strengthening branding and packaging practices, and enhancing overall market competitiveness. Although certain enterprises within Azerbaijan's light industry have initiated steps in this direction, the adoption of such strategies remains fragmented, and their outcomes vary considerably across firms.

According to the "Azerbaijan 2020: Vision for the Future Development Concept" (President of Azerbaijan, 2012), the light industry—rooted in long-standing economic traditions—possesses substantial potential for sustainable growth. In recent years, institutional reforms and organizational restructuring of production enterprises have contributed to observable improvements in both the scale and quality of innovative output. Positive developments have been recorded across several sub-sectors, including raw material processing, textile manufacturing, apparel production, and leather goods, reflected in higher product quality standards and increased diversification.

Particularly noteworthy is the revitalization of the carpet weaving sub-sector, where the establishment of numerous workshops and production facilities across different regions has stimulated renewed growth. Future strategic priorities in this area include strengthening domestic raw material supply chains, upgrading production technologies, and further improving product quality (Hajiyeva et al., 2024).

In the context of intensifying global competition, the advancement of Azerbaijan's non-oil economy cannot rely solely on the modernization of traditional industries. Instead, emphasis

must be placed on the development of contemporary industrial branches capable of producing technologically advanced and innovation-intensive goods. Achieving this objective requires targeted investment in research and development activities, the promotion of knowledge-based products, and the strengthening of innovation capacities at the enterprise level (Aliyev, 2020).

The transition from a resource-dependent economic model to an innovation-driven growth paradigm represents a strategic priority for the light industry. Within this process, the establishment and continuous support of industrial parks and technoparks play a critical role. These structures facilitate the commercialization of scientific knowledge and technological advancements, foster the growth of high-technology enterprises, support industrial restructuring, contribute to balanced regional development, generate employment opportunities, and accelerate the diffusion of advanced production technologies.

The subsequent section presents empirical evidence on marketing expenditure structures and allocation patterns within Azerbaijan's light industry, with particular attention to the textile and carpet manufacturing segments. This analysis aims to assess the extent to which current marketing investments are aligned with long-term strategic objectives related to innovation and competitiveness.

Table 1. Annual Distribution of Marketing Expenditures in the Light Industry Sector

Year	Marketing Budget (thousand AZN)	Share in Total Expenditures (%)	Advertsing and Branding (%)	Exhibitions and Presentations (%)	Digital Platforms and Social Media (%)
2020	520	4,2%	45%	35%	20%
2021	610	4,7%	42%	33%	25%
2022	730	5,0%	38%	32%	30%
2023	860	5,4%	35%	30%	35%
2024	980	5,8%%	32%	28%	40%

Source: Author

3. Trends in Marketing Expenditures and Strategic Gaps in Azerbaijan's Textile Sector

Between 2020 and 2024, marketing expenditures in Azerbaijan's light industry exhibited a consistent upward trajectory. Total spending on marketing grew from 520,000 AZN in 2020 to 980,000 AZN in 2024, reflecting an 88.4% increase. At the same time, the share of marketing costs relative to overall company expenditures rose from 4.2% to 5.8%, indicating a growing acknowledgment of marketing as a strategic organizational function.

A breakdown of these budgets reveals notable shifts in priorities. Investments in traditional marketing channels, such as advertising and branding—which accounted for 45% of marketing expenses in 2020—declined to 32% by 2024. Conversely, digital marketing activities, including social media engagement and online platforms, expanded from 20% to 40%, underscoring the rising centrality of digital strategies. Spending on exhibitions and product demonstrations decreased from 35% to 28%, reflecting a post-pandemic transition toward virtual marketing initiatives.

Within the light industry, textile manufacturing represents a strategically important sub-sector, encompassing the full value chain from raw material processing to finished products. Internationally, the textile industry contributes significantly to both trade balances and economic growth (Gereffi & Frederick, 2010). Azerbaijan's advantageous geographic location

and rich natural resources, particularly cotton and wool, provide a solid foundation for scaling textile production.

Despite these favorable conditions, effective marketing strategy development in the textile sector remains limited. Key constraints include a relatively small domestic market, high dependence on imports, low levels of production-stage innovation, and underdeveloped branding practices. Marketing efforts continue to focus primarily on product quality and pricing, while opportunities for differentiation, strategic positioning, and value-based marketing remain insufficiently leveraged (Kotler & Keller, 2016).

Emerging consumer trends and the growing influence of digital technologies highlight the need for integrated marketing strategies that consider both psychological and sociocultural dimensions of demand. However, many textile firms still lack structured approaches to market segmentation and targeting, resulting in offerings that are often misaligned with actual consumer needs. This misalignment can lead to lost sales opportunities and weakened competitive positioning.

Export-oriented marketing strategies are similarly underdeveloped. Engagement in international trade fairs, B2B marketplaces, and strategic brand development for global audiences remains limited, despite the availability of government-supported mechanisms. Adoption of digital marketing tools—including search engine optimization, content marketing, and e-commerce solutions—lags behind international benchmarks, constraining both brand visibility and market penetration (Mammadov, 2021).

Addressing these challenges requires focused interventions, such as specialized marketing training, the implementation of innovation-led product policies, and strengthened collaboration between public institutions and private enterprises. These measures are essential for establishing long-term resilience and competitiveness within Azerbaijan's textile industry.

In conclusion, although the increase in marketing investment and the shift toward digital strategies have generated tangible improvements, significant strategic gaps persist. Comprehensive reforms in marketing education, innovation policy frameworks, and export-oriented practices are crucial to securing sustainable growth and enhancing the global competitiveness of Azerbaijan's textile sector.

Table 2. Current State of Marketing Strategies in the Azerbaijani Textile Industry (First Half of 2022)

The Current State of Marketing Strategies in the Azerbaijani Textile Industry (First Half of 2022)	
Indicator	Amount or Growth (%)
Orders via Portal	248.4 million USD
Domestic Production (6 months)	160.5 million USD
Textile and Leather Products Production	272.8 million USD
Growth in Clothing Production (2022/2021)	59%
Growth in Leather and Footwear Production (2022/2021)	12.9%
Import of Fabric, Yarn, Thread, etc. (6 months)	86 million USD
Import of Knitwear Products	66.5 million USD
Import of Ready-made Garments	51.5 million USD
Import of Second-and Clothing	18,9 million USD
Import of Footwear	44 million USD

Source: Author

4. Import Pressures and Strategic Perspectives in the Carpet and Textile Subsector

Statistical data indicate that during the first half of 2022, Azerbaijan's domestic textile production reached USD 160.5 million, a figure substantially lower than the value of imported textile goods. In particular, imports of essential raw materials—including fabrics, yarn, and threads—amounted to USD 86 million. These figures highlight the domestic industry's vulnerability to foreign competition, especially from low-cost producers such as China.

Although domestic output experienced notable growth—59% in garments and 12.9% in leather and footwear—this expansion had only a modest impact on overall market share. A persistent challenge is the price and perceived value competitiveness of local products. Imported goods, often sold at significantly lower prices, continue to dominate the domestic market. For example, a locally manufactured pair of shoes may wholesale for 15 AZN, whereas comparable imported items are available at 3–4 AZN, giving foreign products a pronounced cost advantage.

Marketing practices in Azerbaijan's textile sector remain largely traditional, with limited focus on brand development, consumer behavior analysis, or product differentiation. This misalignment diminishes the effectiveness of local marketing initiatives and weakens sectoral competitiveness. To overcome these challenges, strategic marketing frameworks should prioritize the following areas:

- **Branding and Product Positioning:** Local firms should distinguish their products through superior quality, innovative design, and enhanced functionality rather than competing solely on price. Establishing strong brand identities and fostering customer loyalty are essential steps.
- **Digital Marketing Expansion:** Utilizing online platforms, social media channels, and e-commerce solutions can improve market visibility and boost sales.
- **Consumer Behavior Analysis:** Systematic study of purchasing patterns enables targeted promotional campaigns and more effective product strategies aligned with consumer needs.
- **Government Support and Regulatory Measures:** Tariff policies, subsidies, and tax incentives play a critical role in leveling the competitive environment for domestic producers.
- **Export-Oriented Marketing Strategies:** Participation in international trade fairs, product certification, and logistics support can enhance the export capacity of local enterprises.

Certain subsectors within Azerbaijan's textile industry demonstrate strong growth potential, including:

- **Carpet Manufacturing:** Integrating traditional craftsmanship with contemporary marketing approaches can increase international appeal.
- **Corporate Uniform Production:** A niche market characterized by steady domestic and institutional demand.
- **Home Textiles:** Rising consumer interest in domestic and personalized products creates new market opportunities.
- **Outerwear Manufacturing:** Combining locally sourced materials with innovative design provides opportunities for regional and international competitiveness (Kerimova et al., 2024).

In summary, addressing the pressures from imports requires a strategic focus on innovation-driven marketing, adoption of digital tools, and effective brand positioning. These measures are critical for strengthening the competitiveness, sustainability, and global relevance of Azerbaijan's textile and carpet subsectors.

5. Carpet Production as a Strategic Subsector in Azerbaijan's Light Industry

Carpet production stands out as a sector with profound historical roots and significant growth potential. The 2018–2022 State Program for the Preservation and Development of Carpet Art in Azerbaijan emphasizes the strategic objective of promoting Azerbaijani carpets as a national brand in global markets. Today, Azerbaijani carpets are marketed internationally under the “Azerbaijan Carpet” brand, with major export destinations including the United States, Japan, the United Arab Emirates, the United Kingdom, Canada, Italy, and Switzerland.

Established by Presidential Decree in 2016, “Azerkhalcha” OJSC plays a pivotal role in revitalizing carpet craftsmanship in Azerbaijan. The company operates more than 30 regional workshops across 20 districts, employing approximately 2,000 staff, including highly skilled weavers, and maintains an annual production capacity of 15,000–18,000 square meters. Its product portfolio includes traditional, modern, and limited-edition carpets, primarily using locally sourced raw materials such as wool, natural dyes, and yarn from regions including Qarabagh, Guba, Ganja, Sheki, and Nakhchivan.

The marketing strategy of “Azerkhalcha” effectively combines cultural preservation, national branding, and global market outreach. Key strategic elements include:

- **Brand Positioning and National Identity:** Carpets are marketed not solely as commercial commodities but as cultural artifacts representing Azerbaijani heritage. Promotional efforts emphasize the symbolic significance of traditional patterns and the uniqueness of handcrafted designs.
- **Target Market Segmentation:** The company focuses on two primary consumer groups—domestic buyers who value national identity and international premium customers seeking ethnic, handmade products. This dual segmentation demonstrates a sophisticated market positioning strategy.
- **Digital Marketing and International Promotion:** “Azerkhalcha” leverages social media, virtual exhibitions, and global advertising channels (e.g., Google Ads, Instagram, Facebook) to enhance brand awareness. Collaborations with leading industry publications, such as *Hali* and *Carpet XL*, further bolster its international presence.

In conclusion, “Azerkhalcha” exemplifies strategic marketing in Azerbaijan’s light industry. By integrating traditional artisanal skills with modern marketing tools and branding techniques, the company demonstrates how heritage-based products can achieve recognition in global markets. This approach provides valuable lessons for other segments of Azerbaijan’s textile and light industries, highlighting the intersection of cultural preservation, innovation, and digital marketing.

6. Export Orientation and Strategic Innovations in Carpet Branding

As part of its export-focused strategy, “Azerkhalcha” actively participates in international trade fairs and promotes its products through diplomatic and cultural channels. These activities support Azerbaijan’s broader objective of expanding non-oil exports. Since 2022, the company has concentrated on high-demand markets such as the UAE, Turkey, and the United States, which value traditional and artisanal textiles (Mammadov).

Marketing communications extend beyond commercial objectives to include social responsibility and community engagement. By involving women in rural carpet weaving workshops, “Azerkhalcha” enhances local employment and strengthens its reputation as a socially responsible enterprise. This integration of cultural heritage with social impact adds ethical and emotional value to the company’s marketing narrative.

Product diversification constitutes a core element of the company’s strategic approach. In addition to traditional carpets, limited-edition and thematic collections target niche consumer segments, enhancing exclusivity and motivating purchase through uniqueness, craftsmanship, and cultural significance.

A notable innovation in promotion is the incorporation of QR codes on carpet products. These codes, scannable via smartphones, provide detailed information including the carpet's name, type, materials, dimensions, inventory ID, production history, and origin. This digital feature enhances transparency, traceability, and accessibility for international consumers, reinforcing trust in global markets.

In 2021, "Azerkhalcha" signed a memorandum of cooperation with "Azeripek" LLC to establish a strategic partnership focused on joint branding and product development across complementary segments of the light industry.

The following table presents key statistical indicators of "Azerkhalcha" OJSC's 2023 marketing performance, including production volumes, domestic sales, and exports, illustrating the effectiveness of its integrated marketing and export-oriented strategies.

Table 3. Statistical Indicators of the Marketing Activities of "Azerkhalcha" OJSC for 2023

Statistical Indicators of "Azerkhalcha" OJSC for the Year 2023			
Indicator	2022	2023	Growth (%)
Carpet Area Produced (m ²)	2,110	2725	+29,1%
Carpet Area Exported (m ²)	474	612	+29,1%
Total Sales Volume(m ²)	1470	2720	+85,0%
Share of Exports in Total Sales (%)	32,2%	22,5%	-9,7%

Source: Author

7. Statistical Performance and Portfolio Structuring in 2023

Internal data from "Azerkhalcha" OJSC indicate that in 2023 the company produced 2,725 square meters of carpets, of which 612 m² were exported. Key export markets included the United States, Germany, Spain, Switzerland, and Latvia. Although export volumes grew by 29.1% compared to 2022, the proportion of exports relative to total sales declined from 32.2% to 22.5%, reflecting stronger growth in domestic demand and demonstrating the success of market engagement strategies targeted at local consumers.

Overall production and sales figures reveal notable improvements in operational efficiency. Production increased by 29.1%, while total sales surged by 85.0%, reaching 2,720 m². These outcomes point to strengthened distribution networks, enhanced market visibility, and improved alignment of production with market demand.

Portfolio segmentation constitutes a central element of "Azerkhalcha"'s strategic marketing approach. Products are categorized into three main lines:

1. **Traditional Carpets:** These feature region-specific patterns derived from historic weaving schools such as Quba, Shirvan, and Karabakh, emphasizing cultural preservation. The primary target group comprises collectors and domestic consumers with strong cultural affinities.
2. **Contemporary Design Carpets:** Incorporating minimalist and abstract patterns with modern color schemes, this line appeals to younger audiences and international buyers seeking functional, stylish home décor. This segment illustrates the company's ability to integrate global design trends into both production and marketing strategies.
3. **Limited Edition Collections:** Crafted in restricted quantities with highly artisanal techniques, these products target premium consumers seeking exclusivity and symbolic value. Positioned at a high price point, this segment reinforces the brand's reputation as an innovator in design.

The balanced composition of the portfolio mitigates risk while promoting revenue stability. Each segment aligns with distinct consumer preferences, collectively enhancing "Azerkhalcha"'s brand identity as both a guardian of tradition and a driver of design innovation.

This diversified approach allows the company to operate effectively in a dynamic, competitive, and globalized market environment, providing a strategic framework for growth in both domestic and international contexts.

8. Digital Marketing Performance and Consumer Geography

Analysis of digital marketing outcomes for “Azerkhalcha” during 2022–2023 indicates substantial improvements in online engagement and conversion rates. Strategic investments in digital platforms—including social media and the corporate website—have yielded measurable results. Orders generated through social media increased by 47.5%, highlighting the effectiveness of interactive customer engagement in driving sales growth.

The share of online sales in total revenue rose from 16% in 2022 to 23% in 2023, reflecting greater consumer confidence in e-commerce channels and wider adoption of digital purchasing behaviors. Additionally, the corporate website experienced a 44.1% increase in annual visitors, demonstrating the success of search engine optimization (SEO) strategies and amplified referral traffic from social media content. These outcomes emphasize that well-structured digital marketing is critical for traditional industries such as carpet production to maintain competitiveness in a rapidly evolving market.

Understanding consumer geography further informs “Azerkhalcha”’s marketing and distribution strategies. Domestically, sales are concentrated in Baku and major economic regions, reflecting differences in purchasing power, regional design preferences, and cultural appreciation for traditional crafts.

Internationally, the company enhances brand recognition through custom orders, participation in global exhibitions, and digital outreach. Key export markets include the United States, Germany, France, and Gulf countries, where there is strong demand for high-quality Azerbaijani carpets. Insights into these consumer geographies enable “Azerkhalcha” to tailor product offerings, optimize promotional strategies, and strengthen its export-oriented growth initiatives.

Table 4. Geographical Distribution of Sales Structure of “Azerkhalcha” OJSC in 2023

Regional Distribution of Domestic Market Sales	
Regions	Share in Sales (%)
Baku City	42%
Ganja-Gazakh Economic Region	15%
Karabakh and East Zangezur	12%
Shaki-Zagatala	10%
Lankaran-Astara	8%
Other Regions	13%

Source: Author

9. Marketing Activities in the Garment Sector: Case Study of Gilan Tekstil Park MMC

The garment industry in Azerbaijan exhibits relatively low entry barriers compared to traditional textile segments, such as carpet weaving, making it a strategic sector for fostering entrepreneurship, particularly among women. Its capital-light structure and capacity for innovation contribute to economic diversification. On a global scale, the apparel and accessories market generates an annual turnover exceeding USD 6–7 trillion, with China leading in both production and exports.

Within Azerbaijan, the garment sector encompasses several subcategories, including:

- Orthopedic and sports footwear,
- Production of natural and synthetic fabrics,
- Shirts, trousers, socks, and ties,
- Undergarments,

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Gilan Tekstil Park MMC stands out as one of the leading vertically integrated textile and garment manufacturers in the country. Operating a full-cycle production model—including spinning, weaving, dyeing, and sewing—the company maintains stringent quality control while enhancing the GiLTEX brand's reputation. The use of domestically sourced cotton reinforces local resource utilization and contributes to a national branding strategy.

The company implements a comprehensive digital marketing approach, employing social media marketing (SMM), search engine optimization (SEO), Google Ads, email campaigns, and website management. These tools enhance product visibility and drive online sales. A dedicated marketing team oversees content creation, visual design, and campaign implementation, ensuring alignment with strategic goals.

Gilan Tekstil Park exports its products to Russia, Turkey, and other CIS countries while investing in design studios tailored to European and regional market standards, enabling compliance with both aesthetic and regulatory requirements.

The enterprise places particular emphasis on corporate and institutional garments, including fireproof and waterproof uniforms, military and hospital attire, and laboratory coats. These products support B2B sales strategies and cater to both state and private sector clients (Gereffi & Frederick, 2010).

Marketing research informs annual planning, guiding decisions on advertising, product placement, and identification of new market channels. This evidence-based approach enhances brand positioning in both domestic and international markets.

Additionally, Gilan Tekstil Park prioritizes environmental responsibility by adhering to European sustainability standards and minimizing the use of harmful chemicals during production. This commitment strengthens consumer trust and aligns the company with global sustainable textile practices.

Overall, the integrated marketing and operational strategies employed by Gilan Tekstil Park demonstrate how digital transformation, market segmentation, and innovation-oriented production can generate a competitive advantage within Azerbaijan's garment sector.

Table 5. Marketing Activities of “Gilan Textile Park” LLC

Statistical Table of Marketing Activities of “Gilan Textile Park” LLC (2022–2024)			
Indicators	2022	2023	2024
Marketing Budget (AZN)	250,000	320,000	400,000
Share of Marketing in Total Expenses (%)	4.2%	4.8%	5.3%
Advertising and Branding Expenses (%)	35%	38%	40%
Expenses for Online Platforms (%)	25%	30%	32%
Participation in Exhibitions and B2B Events (%)	20%	15%	12%
Social Media Subscriber Growth (%)	+18%	+22%	+25%
Share of Online Sales in Total Sales (%)	8%	12%	17%
Average Monthly Website Visitors	12,000	16,500	22,000
Number of Countries Accessed in Foreign Markets	3	5	7
Number of Corporate Sales Contracts (units)	20	35	50
New Product Categories Added Per Year	2	3	3

Source: Author

10. Digital Marketing Transformation

Digital channels have become a core component of the company's marketing approach. Monthly website visitors increased from 12,000 in 2022 to 22,000 in 2024, while online sales as a percentage of total sales nearly doubled from 8% to 17%. These results illustrate the effectiveness of data-driven strategies, targeted digital campaigns, and customer engagement. (Chaffey & Ellis-Chadwick, 2019)

The number of export markets expanded from three countries in 2022 to seven in 2024, reflecting improved access to global value chains. Concurrently, the company introduced 2–3 new product categories annually, focusing on high-demand segments such as sportswear, technical textiles, and children’s apparel. This diversification underscores the company’s commitment to product differentiation and international competitiveness. (Armstrong et al., 2018). Despite positive developments, Azerbaijan’s light industry continues to face structural and marketing-related challenges, particularly in textiles, footwear, and carpet production. For instance, in the first half of 2022, domestic textile production reached \$160.5 million, while imports—including raw materials like threads and fabrics totaling \$86 million—highlighted strong reliance on foreign products and weak competitiveness of local manufacturers. (Karimova et al., 2024)

Even with a 59% increase in garment production and 12.9% growth in footwear and leather goods, domestic market share remains limited. Weak marketing strategies, insufficient brand positioning, and low-cost imports from China, with prices significantly undercutting local products (3–4 AZN imported vs. 15 AZN local), exacerbate competitive pressures. This emphasizes the critical need for differentiation based on quality, design, and functional value. (Hajiyeva et al., 2023)

National programs such as the State Program for Carpet Weaving (2018–2022) have revitalized the sector. “Azərxağa” OJSC expanded to 21 regional branches, employing over 2,000 staff and producing up to 18,000 m² of handwoven carpets annually. Its marketing initiatives—including participation in international exhibitions, QR-code integration, digital promotion, and collaboration with global magazines like *Halı* and *Carpet XL*—have successfully positioned Azerbaijani carpets under the “Azerbaijan Carpet” brand in key markets such as the US, Germany, and UAE. (Hajiyeva et al., 2025)

Conclusions

This research examined the development and effectiveness of marketing strategies within Azerbaijan’s light industry, emphasizing innovation-driven practices, digital transformation, and export orientation. Drawing on empirical case studies—including “Azerkhalcha” OJSC and Gilan Tekstil Park MMC—along with institutional reports and sectoral statistics, several key insights were identified.

Firstly, marketing in Azerbaijan’s light industry is evolving from a primarily sales-oriented function to a strategic, management-centered role. Enterprises implementing integrated marketing frameworks—linking product development, branding, pricing, distribution, and digital engagement—demonstrate greater market responsiveness and stronger brand differentiation. Notably, digital marketing tools such as social media campaigns, SEO, e-commerce platforms, and QR-enabled product tracking have proven effective in enhancing both domestic and international visibility.

Secondly, structural constraints remain a significant challenge. Limited access to reliable market data, underdeveloped innovation capacities, and the absence of cohesive marketing infrastructure hinder SMEs from fully adopting strategic marketing approaches. Furthermore, domestic producers face intense competition from low-cost imports, emphasizing the need for value differentiation, quality improvement, and culturally anchored branding. The carpet subsector serves as a successful example, integrating traditional craftsmanship with contemporary marketing methods to position Azerbaijani carpets as premium products recognized globally.

Thirdly, the study underscores the importance of enterprise-level strategic innovation. Gilan Tekstil Park MMC illustrates how expanding digital engagement, diversifying product portfolios, and entering new export markets can strengthen competitiveness. The integration of social responsibility and workforce development into marketing narratives—such as promoting

rural employment and gender-inclusive production—adds ethical and emotional value to brand identity.

Finally, the findings highlight the interplay between policy initiatives and enterprise action. Government programs, industrial parks, and export facilitation platforms create enabling conditions, yet sustainable sectoral growth requires that firms internalize innovation-oriented marketing practices and adapt continuously to changing consumer preferences. Combining empirical market research, advanced digital strategies, and coordinated production-marketing systems emerges as a critical pathway to long-term resilience and global competitiveness (Karimova et al., 2025).

In conclusion, the future growth of Azerbaijan's light industry depends on the systematic implementation of strategic marketing at the enterprise level, supported by digital innovation, consumer insights, and export-focused initiatives. Effective collaboration between public and private sectors, alongside ongoing investment in marketing capabilities, is essential to transform traditional industries into globally competitive, innovation-led sectors capable of sustaining economic growth and enhancing national branding.

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PUBLIC POLICIES TO SUPPORT INNOVATION IN EUROPE: A COMPARATIVE APPROACH OF E-GOVERNMENT

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Abstract: *This article examines the legal and policy frameworks that support innovation across European jurisdictions, employing a comparative approach to identify common strategies, divergences, and best practices. Through analysis of intellectual property regimes, research and development incentives, and regulatory frameworks, we demonstrate how different European states balance innovation promotion with broader policy objectives. Our findings suggest that while harmonization efforts exist within the EU framework, significant variations persist in implementation and effectiveness. This comparative analysis provides insights for policymakers seeking to optimize innovation support mechanisms.*

Keywords: *public, policies, strategies, e-government, European Union.*

1. Introduction

Innovation stands as a cornerstone of economic competitiveness and sustainable development in contemporary Europe. The European Union has consistently prioritized innovation through its policy agenda, most notably through the Lisbon Strategy and subsequent frameworks emphasizing the knowledge-based economy (European Commission, 2010). However, the legal and policy mechanisms supporting innovation vary considerably across member states, reflecting different constitutional traditions, economic structures, and policy priorities.

This article undertakes a comparative legal analysis of public policies designed to support innovation in selected European jurisdictions. By examining intellectual property protection, fiscal incentives, regulatory frameworks, and research funding mechanisms, we identify how different legal systems approach innovation governance and assess the effectiveness of various policy instruments.

2. Public Policies with Role of Innovation Support

2.1. Intellectual Property Protection Frameworks

The EU Patent System

The European Union has developed a multilayered intellectual property (IP) system combining national, regional, and international protections. The European Patent Convention (EPC), established through the Munich Convention of 1973, creates a unified patent prosecution system while maintaining separate national patent rights. More recently, the Unified Patent Court (UPC) and the Unitary Patent represent significant steps toward harmonization, though implementation remains incomplete.

The creation of the unitary patent in 2012 was intended to reduce fragmentation and decrease the costs of patent protection—historically, obtaining patent protection across all EU member states could cost substantially more than in the United States or Japan (European Commission, 2011). However, the UPC's operational launch in 2022 has progressed unevenly, with some major economies initially declining participation.

National Variations in Patent Policy

Significant differences persist in national approaches to patent examination standards and enforcement mechanisms. Germany maintains a reputation for rigorous patent examination and strong enforcement through specialized patent courts, while the Netherlands has developed alternative dispute resolution mechanisms for patent matters (Geertrui van Overwalle, 2008). These variations influence where innovators choose to file patents and establish research facilities.

The Swedish patent system exemplifies a more liberal approach to patent invalidation procedures, while France has traditionally provided stronger protection through its courts. Such variations, though within harmonized EU frameworks, create strategic considerations for multinational innovators regarding where and how to protect intellectual property.

Trade Secrets Protection

Directive 2016/943 on the Protection of Undisclosed Know-How and Business Information represents a significant harmonization effort in trade secrets protection across the EU. However, implementation varies, with some member states providing stronger criminal sanctions for misappropriation than others. Poland and Hungary have implemented particularly stringent penalties, reflecting different policy judgments about the importance of trade secrets protection.

2.2. Fiscal Incentives and Research Support

Research and Development Tax Credits

European states employ diverse fiscal mechanisms to incentivize private investment in research and development. France's Research Tax Credit (Crédit d'Impôt Recherche) represents one of Europe's most generous schemes, providing tax relief of up to 30% for qualifying R&D expenditures and generating substantial innovation investment (French Ministry of Higher Education, 2015). This program has been particularly effective in attracting pharmaceutical and biotechnology research.

The United Kingdom's R&D tax relief system, operating both at enhanced deduction and credit levels, similarly encourages private sector research investment. Conversely, Nordic countries—particularly Sweden and Denmark—have historically relied more heavily on direct government funding through research councils rather than tax incentive mechanisms.

Government Research Funding

The comparative analysis reveals distinct models of public research funding. Germany's dual system, combining university research funding through federal mechanisms with industrial research support through the German Research Foundation (DFG), contrasts with Italy's more fragmented approach and Spain's increasing centralization of research funding decisions (National Research Council, 2012).

These structural differences influence the innovation ecosystem's composition. Countries with strong public research institutions and substantial government funding often develop robust university-industry partnerships, while those relying more heavily on tax incentives may attract different types of innovation investment.

Innovation Vouchers and Small Business Support

Several EU member states have implemented innovation voucher schemes targeting small and medium-sized enterprises (SMEs). The Netherlands, Belgium, and Poland have deployed such schemes with varying success rates. Evaluations suggest that voucher programs are most effective when coupled with advisory services helping SMEs identify appropriate research partners and articulate innovation needs (OECD, 2010).

2.3. Regulatory Frameworks and Innovation

Regulatory Sandboxes

Regulatory sandboxes—controlled environments allowing businesses to test innovations with reduced regulatory requirements—represent an emerging policy tool across Europe. The United Kingdom pioneered application of sandboxes in financial services, while the Netherlands and Estonia have extended the approach to fintech, autonomous vehicles, and other sectors (Financial Conduct Authority, 2018).

However, the legal basis for regulatory sandboxes within EU law remains contested. The tension between national regulatory autonomy and EU harmonization obligations creates uncertainty for businesses operating across multiple jurisdictions. Member states have adopted sandboxes with varying degrees of legal formality, from statutory authorization to administrative practice.

Proportionality in Regulatory Design

Comparative analysis reveals that regulatory design significantly influences innovation incentives. The EU's proportionality principle, requiring that regulations impose burdens no greater than necessary to achieve legitimate objectives, theoretically constrains excessive regulation. Yet implementation varies substantially.

Germany's relatively prescriptive regulatory approach contrasts with the United Kingdom's principles-based regulation, which traditionally granted greater flexibility for innovative business models. These different regulatory philosophies influence where entrepreneurs establish operations and how they structure innovation strategies (Schepel, 2013).

Digital and Data Regulations

The General Data Protection Regulation (GDPR) exemplifies both EU-wide harmonization and its limitations for innovation policy. While GDPR provides uniform baseline protections across member states, its flexibility in implementation—particularly regarding standards of necessity and proportionality—creates de facto variations in data governance for AI and machine learning applications (European Data Protection Board, 2018).

Some member states, notably Estonia and Lithuania, have embraced data-driven innovation more aggressively, developing legal frameworks explicitly designed to facilitate data sharing and algorithmic innovation, while others have adopted more cautious approaches.

2.4. Venture Capital and Startup Support

Legal Frameworks for Venture Capital

The European venture capital landscape reflects substantial fragmentation in legal and regulatory frameworks. The EU Venture Capital Regulation provides some harmonization, but the availability of venture capital, the structure of investment vehicles, and tax treatment of startup investments vary significantly across jurisdictions (Regulation (EU) 2013/1287).

The United Kingdom and Germany have developed mature venture capital ecosystems supported by favorable tax treatment of startup investments. France has implemented specific legal structures (FCPR, FCPE) facilitating venture capital investment, while Southern European countries have historically faced constraints in venture capital availability, though this has begun changing.

Bankruptcy and Second-Chance Provisions

The EU Directive on preventive restructuring frameworks seeks to facilitate business rescue and reduce entrepreneur stigma associated with failure. However, implementation reveals significant variations in how member states balance creditor protection with debtor rehabilitation (Directive (EU) 2019/1023).

Countries with more favorable fresh-start provisions, such as Germany and the United Kingdom, demonstrate higher rates of serial entrepreneurship. Conversely, legal systems imposing substantial personal liability and social stigma on failed entrepreneurs show lower rates of entrepreneurial activity and innovation-driven business formation.

2.5. Knowledge Transfer and University-Industry Collaboration

Legal Frameworks for Technology Transfer

The Framework Agreement on Intellectual Property Rights in University-Industry Cooperation, adopted by European universities and industry representatives, establishes principles for IP sharing in collaborative research. However, national laws governing university IP ownership vary considerably.

The UK's "ownership to the researcher" tradition contrasts with continental European models where institutions typically own IP arising from research conducted within their facilities. These different approaches create distinct incentive structures for academic entrepreneurship and commercialization of research (Mowery et al., 2005).

Institutional Autonomy and Innovation

Countries granting greater institutional autonomy to universities—particularly regarding IP management and commercial activities—generally demonstrate higher technology transfer rates. The Netherlands and Scandinavian countries, with strong traditions of institutional autonomy, show robust academic spin-off creation, while more centrally directed systems show lower commercialization rates.

Mobility of Researchers

The EU's Freedom of Movement for workers facilitates researcher mobility within the EU, theoretically enhancing knowledge transfer and innovation diffusion. However, practical barriers persist, including pension systems, family considerations, and language requirements. Certain jurisdictions—particularly the UK, Germany, and Switzerland—have developed explicit policies facilitating researcher mobility through visa provisions and research infrastructure investments.

2.6. Sectoral Policy Approaches

Biotechnology and Pharmaceuticals

European policy toward biotechnology reflects the intersection of innovation promotion and safety regulation. The European Medicines Agency (EMA) provides a unified approval pathway, but member states maintain some regulatory discretion regarding research conduct, particularly involving genetic modification (European Medicines Agency, 2025).

Germany and France have emerged as European biotech leaders partly through supportive regulatory environments and substantial public research funding. Conversely, countries with more restrictive stances on genetic modification research, such as Austria and Italy, have seen reduced biotech investment.

Green Technology and Energy Innovation

The European Green Deal and associated policies create unified frameworks for sustainable innovation, yet implementation varies. Denmark and Germany have developed comprehensive legal frameworks supporting renewable energy innovation, while Southern European countries face infrastructure and financing constraints despite favorable renewable resources (European Commission, 2021a).

Artificial Intelligence Governance

The proposed EU AI Act represents an ambitious attempt at harmonized AI regulation, yet its approach—risk-based classification requiring different compliance levels—permits significant member state variation in implementation (European Commission, 2021b). This creates both opportunities for regulatory experimentation and risks of innovation fragmentation.

3. Comparative Assessment and Policy Implications in e-Government

3.1. E-government in France

France is among the first European countries to have invested significantly in the creation of e-government tools, with the aim of guaranteeing a more efficient, transparent and citizen-friendly administration. The modernization process began in the 2000s, when the first digital platforms were launched at national level. However, after 2010, when the government became aware of the importance of digitizing public services, the process accelerated significantly. It is necessary to reduce costs, simplify bureaucratic procedures and increase citizen satisfaction with public administration.

An important step in this direction was the adoption of the Digital Agenda for France, which aimed to expand high-speed internet access and introduce online public services for all citizens. The national strategy focused on two main directions: the creation of centralized, easy-to-use platforms, and interoperability between different public databases. In this way, local and central administrations began to share information more quickly, and citizens were no longer required to repeatedly submit the same documents to different institutions.

At the heart of French e-government is the service-public.fr platform. It serves as a single portal providing access to information and administrative services in various areas, including taxation, health, education, social security and employment. Users can download forms, submit applications, check the status of their applications and obtain official documents without having to visit counters in person. This system now allows millions of interactions that previously required face-to-face presence to be carried out online. This reduces time and costs for the administration and citizens.

[Impots.gouv.fr](https://impots.gouv.fr), the official portal of the tax administration, is another important tool. It is used to file income tax returns, make payments and obtain personalized information on the tax situation. Following its implementation, the degree of voluntary compliance has increased, as the procedure has become simpler and more visible. In addition, the system allows for the maintenance of a payment history and the sending of electronic notifications, increasing citizens' confidence in the efficiency and fairness of the process.

In the field of healthcare, France has introduced the Dossier Médical Partagé (DMP), an electronic medical record accessible to patients and healthcare professionals. It centralizes essential medical information (prescriptions, test results, treatment history) and makes it available in real time to doctors, facilitating a faster and safer medical act. Through this platform, citizens have greater control over their own medical history and benefit from integrated services, without syncope caused by lack of information.

In addition, the pole-emploi.fr platform is in the social and employment sector and offers advice, mediation and support to employers and the unemployed. Job seekers can access offers, apply online and speak directly to advisors through it. This type of tool has significantly reduced the operating costs of employment agencies and increased the likelihood of unemployed people re-entering the workforce.

Digital identity is an additional component of French e-government. The FranceConnect system, created by France, allows citizens to access all public services on the internet with a single set of authentication data. Using this solution avoids creating multiple accounts and passwords for different institutions, which facilitates communication with the government. FranceConnect has become a model of good practice at European level and has been taken up by other states. The data.gouv.fr platform, which offers open datasets on a variety

of subjects, such as economic statistics, public spending and information related to health and education, helps promote government transparency. This project encourages civil society, academia and the media to get involved in monitoring the state's activity. In addition, it has helped the private sector develop new applications based on public data.

The introduction of participatory budgets in major cities such as Paris and Marseille is a distinctive aspect of the French model. These platforms allow citizens to propose and vote on local funding projects. When implemented in the digital environment, they have allowed an increasing number of residents to get involved, which has led to an increase in trust between citizens and local administrations. Overall, the French experience shows that the digitalization of administration is not only a way to improve efficiency, but also to strengthen participatory democracy. A more open relationship between the state and society has been fostered by easy access to information, transparent spending and the direct involvement of citizens in decision-making. However, obstacles persist, particularly in terms of protecting personal data and ensuring digital inclusion for vulnerable groups (European Commission, 2022).

3.2. E-government in Germany

Germany is known for its organized and decentralized way of implementing e-government, which reflects the federal structure of the state. While the federal government sets general guidelines for digitalization, states and local authorities have significant autonomy in developing and adapting the digital services they offer. This diversity can be a challenge, but it also offers an opportunity to develop adaptable solutions that suit the needs of each community. A key moment in the evolution of German e-government was the adoption of the Online Access Act (German Federal Government, 2017).

This means that all government institutions in Germany must offer administrative services in a digital format, which can be accessed via a single national portal. By 2022 at the latest, the reform aims to simplify the interaction between citizens and institutions so that every service can be accessed online.

Germany has created the Bundesportal to implement this law. From, a single place where people can access digital services offered by federal, state and municipal authorities. Citizens can do things like request civil status certificates, register vehicles, pay taxes or submit applications for financial support through it. The interface is designed so that users can quickly find the service they are looking for, regardless of the responsible institution, which reduces confusion and bureaucracy.

The electronic identity system (eID), which is integrated into the German identity card, is another vital tool. Users can securely authenticate to access online services and sign legally binding digital documents with this mechanism. The use of eIDs has increased public confidence in the use of digital services, particularly due to Germany's strict cybersecurity standards.

Many cities in Germany have demonstrated good practices in implementing digital technology for more efficient local government. Hamburg, for example, is a “Smart City” that combines the digitalization of public services with AI and sensors to manage traffic, public lighting and environmental protection. This method shows how e-government can improve the state-citizen relationship and the quality of life in the city. Open data platforms such as govdata.de, which publish data on socio-economic indicators, procurement contracts and public spending, promote transparency and public participation. Access to this data facilitates monitoring by citizens and the media, as well as the creation of digital and environmental applications. A distinctive element of the German model is the emphasis on collaboration between institutions. In many countries, government, academia and the private sector work together to create innovative digital solutions. This cooperation is necessary to ensure that the platforms are both technically functional and adapted to the needs of the population. Finally,

Germany combines the flexibility of decentralization and legislative rigor to characterize e-government. Germany has built a complex and efficient system using measures such as the national single portal, electronic identity and open data platforms. However, challenges remain, especially in harmonizing digital solutions across nations and accelerating the pace of implementation to quickly meet citizens' expectations. . E-government in Germany

One thing that defines e-government in Germany is that it is decentralized, which is unique for a federal state. Accordingly, each nation is responsible for implementing and adapting digital measures in public administration, which implies a wide range of applicable options. However, diversity does not mean a lack of cooperation. Although national programs are provided by the federal government to provide a general framework, the implementation in practice is adaptable and adaptable to local circumstances. A key feature of the German e-government model is the combination of central coordination and autonomy of the nations.

BundOnline 2005, which was launched in the early 2000s, was one of the first large-scale projects to digitize the administration. With this program, the federal state aimed to provide the most important public services on the Internet by 2005. This program laid the foundation for the concept of "standardized electronic services", which can be accessed regardless of the institution. Despite the fact that the goals were not fully achieved, BundOnline 2005 laid the foundation for future efforts, demonstrating that digitizing the administration is both possible and necessary in an administratively complex state like Germany.

Subsequently, the Digital Agenda 2025 was approved, a strategic plan that set goals for the digitalization of Germany in areas such as public administration, the economy, education and infrastructure. This plan focused on modernizing government portals and connecting services with each other so that people and businesses no longer need to interact with multiple institutions separately. Instead, the "once-only" principle was introduced. This means that people only have to provide data to the administration once, and the data is then distributed between institutions via interconnected IT systems.

The "Verwaltungsportal Bund", which serves as a central platform for accessing public services, is another important project. It reduces administrative fragmentation by bringing together administrative data and procedures from different nations and providing them in a unified way. The federal portal facilitates interoperability, and citizens see the system as a more user-friendly and coherent mechanism, despite the autonomy of each state.

It has not been easy to implement these platforms. Since each nation and even each local level may have its own procedures and IT systems, administrative fragmentation remains one of the biggest problems. This has sometimes caused duplication of work and significant differences in the quality of digital services. In addition, there is still a difference between eastern areas that have better internet access and lower levels of digital literacy and western ones that are more developed.

Cybersecurity is another critical component. Germany has been forced to improve its security systems against cyber attacks, especially with the increasing amount of data that the administration manages. Currently, there are specialized centers that constantly monitor the digital security of public institutions and alert when dangers arise. It is obvious that these initiatives have an impact on both the business environment and citizens. Procedures such as paying taxes, registering a business, obtaining licenses or submitting administrative applications can be completed online, which has significantly reduced bureaucracy and time lost at the counters. However, the digitalization of the administration has offered companies fewer expenses and better predictability of interactions with the state.

Germany has recently begun to experiment with new technologies in public administration. Pilot projects using artificial intelligence to analyze data and provide personalized solutions, as well as blockchain to secure transactions and official documents, are underway. These initiatives demonstrate that Germany is not limited to the traditional

digitalization of services, but aims to become a European leader in the use of emerging technologies in public administration.

Overall, e-government in Germany serves as a model that balances decentralization and coordination, as well as the federal tradition and the need for modernization. Despite the difficulties caused by administrative diversity, the German state has managed to establish a unified framework, build large-scale projects and ensure that citizens are actively involved in the decision-making process. Recent breakthroughs with artificial intelligence and blockchain demonstrate openness to innovation and offer positive prospects for the future.

3.3. E-government in Poland

Poland is an Eastern European country that has made great progress in e-government and managed to reduce the digital divide compared to Western EU countries. Since 2011, the launch of the “Polska Cyfrowa” program, which was financed by the government and European funds, has accelerated the process of digitizing public administration. The program aimed to build an accessible online administration that would provide fast, transparent and citizen-centered services.

The Obywatel.gov.pl platform is a key component of the Polish e-government system, uniting most government services into a single digital portal. Citizens can access public registers, consult information about tax obligations and submit applications for official documents on this platform. A significant advantage of this system is its accessible structure, which is also addressed to people who are less familiar with technology. This demonstrates the concerns of the Polish authorities regarding digital inclusion.

Zaufany Profile, also known as Trusted Profile, is another reference tool that is used to perform secure authentication on government portals. Electronic signing of documents and access to digital services are possible with this system without the need for physical presence at the institution. By implementing it, Poland has significantly reduced bureaucracy and made it easier for people in the diaspora or rural areas to access public services. Tax returns are also filed online with the Trusted Profile, a process that has become almost completely digital in recent years.

The obligation of local governments to publish official documents, draft decisions and minutes of municipal council meetings online helps to ensure decision-making transparency. In many cities, these meetings are broadcast live, so people can follow the discussions and ask questions. Therefore, digitalization not only makes things easier, but also helps to build local democracy by involving people more directly. An example of good practice is the Emp@tia platform, which deals with social services and allows users to submit online applications for allowances, financial aid and other benefits. This system has considerably reduced the time spent waiting at the counters of social welfare institutions and improved the efficiency of processing applications. In addition, the simple and accessible interface of the platform has made it easy to use even for those who are not very good with computers.

In addition, Poland has invested in expanding the ePUAP (Elektroniczna Platforma Usług Administracji Publicznej) platform, which allows public institutions to interact with each other and provides citizens with access to a variety of online services. ePUAP is key to the digitalisation of the Polish government, as it facilitates communication between citizens, local administrations and the central government. In the area of taxation, the Twój e-PIT system, or “Your Tax Return”, was introduced to allow citizens to automatically complete their tax returns based on data that is available in state registers. Errors and delays have been significantly reduced, as the taxpayer only needs to check and confirm the document. The European Commission has praised this measure as an example of simplifying administrative procedures and encouraging voluntary compliance.

In addition to these tools, Poland has encouraged public participation by implementing participatory budgeting in several municipalities, where citizens can propose investment projects and vote online on community priorities. These mechanisms have increased civil society engagement and created a clearer relationship between local governments and citizens. Overall, Poland's experience demonstrates that digitalizing administration can be a means of reducing bureaucracy and increasing public trust in state institutions. Platforms such as Twój e-PIT, Obywatel.gov.pl and Profil Zaufany have helped Poland move from a rigid and complicated system to one that is flexible and adapted to the needs of the 21st century.

However, challenges remain, especially in terms of standardizing service quality between urban and rural regions, but also ensuring cyber protection in a context of increasingly complex digital threats (OECD, 2020).

The development of high-speed internet infrastructure is a significant component of the digitalisation of the Polish administration. Without it, e-government platforms would not have been able to function. In order to reduce the digital divide between urban and rural areas, the government has invested in expanding broadband networks in underdeveloped and rural areas. Millions of people in less accessible areas have benefited from the same opportunities as people in large cities to use public services online as a result of these programmes. This process of equalising access has helped digital and social inclusion.

Poland is also focusing on the digital education of the population. To help seniors and people with difficulties in using government portals, training campaigns have been implemented. To help citizens understand basic e-services, such as paying taxes online or using the electronic authentication profile, workshops have been organized in libraries, community centers and schools. These measures demonstrate that the success of e-government depends on both the availability of technological infrastructure and the level of digital literacy of citizens.

The integration of e-health services is another relevant example of progress. Poland has introduced an electronic prescription system, also known as e-prescription. This system allows patients to obtain medical prescriptions in digital format, accessible through a unique code. This mechanism has reduced the risk of medical errors, eliminated the need to keep prescriptions on paper and made communication between doctors, pharmacists and patients better. However, e-health platforms allow patients to access their treatment history, which facilitates faster and more efficient healthcare. In addition, it is worth noting the collaboration in the field of e-government between the public and private sectors. Polish IT companies, in partnership with public institutions, have helped to develop several digital products. This has made it possible to quickly introduce innovative services and has stimulated the development of the country's digital industry. At the same time, cooperation with academia has helped to improve IT systems and educate a new generation of digital governance professionals.

Finally, as cyberattacks on government digital infrastructures have become a global issue, Poland has always been concerned about cybersecurity. The Polish government collaborates with the European Union and NATO in the field of cybersecurity, creating specialized centers for monitoring and preventing cyberattacks. This guide emphasizes that a solid infrastructure for protecting data and critical infrastructure is essential for the success of e-government.

However, the increase in internet access, digital education, the introduction of mobile applications and improved cybersecurity demonstrate that Poland has adopted a comprehensive and well-planned approach to modernizing public administration. The Polish state has reduced bureaucracy through these initiatives and created the premises for a more interactive and connected society in line with European digital standards.

4. Results and Discussion

Our comparative analysis reveals that successful innovation ecosystems typically combine multiple policy instruments: robust IP protection, substantial public research funding, favorable tax treatment of R&D and startup investment, skilled workforce development, and regulatory frameworks that balance innovation encouragement with legitimate public protection.

No single jurisdiction exemplifies optimal policy in all dimensions. Rather, different member states have developed distinctive innovation strengths reflecting their particular legal, economic, and institutional contexts. Germany's manufacturing innovation ecosystem, the Netherlands' logistics and agricultural technology innovation, and Estonia's digital innovation ecosystem each reflect tailored policy approaches appropriate to regional comparative advantages.

The analysis reveals persistent tension between EU-level harmonization efforts and member state policy autonomy. While EU-wide frameworks (the UPC, GDPR, research funding programs) provide some coherence, substantial variation persists in implementation, enforcement, and complementary policies.

This variation creates both costs (fragmentation, strategic forum shopping, reduced economies of scale) and benefits (regulatory experimentation, competitive federalism, tailoring to local conditions). Optimal policy likely involves accepting some variation while ensuring minimum harmonization on core issues affecting cross-border innovation activity.

Several emerging challenges warrant attention:

Digital Sovereignty and Strategic Autonomy: European policymakers increasingly view innovation support through a strategic lens, seeking to reduce dependence on non-European technology platforms and establish European champions in AI, semiconductors, and cloud computing. This may create tensions with competition law and international trade commitments (European Commission, 2021c).

Ethical Innovation: Growing emphasis on responsible innovation, particularly regarding AI ethics, privacy, and environmental sustainability, creates new regulatory burdens potentially affecting innovation incentives. Balancing ethical considerations with innovation encouragement remains unresolved.

Equitable Innovation: Regional disparities in innovation capacity and investment persist, with Central and Eastern European member states facing disadvantages in attracting research investment and venture capital. Addressing these disparities requires both EU-level policy and member state initiatives.

5. Conclusion

European public policies supporting innovation reflect diverse approaches reflecting different legal traditions, institutional structures, and policy priorities. While EU-wide harmonization efforts have reduced fragmentation in intellectual property protection and established common frameworks for research funding and startup support, substantial variation persists in implementation and complementary policies.

Successful innovation support systems combine multiple policy instruments tailored to regional contexts and comparative advantages. Rather than pursuing complete harmonization, European policymakers might focus on ensuring compatibility of core frameworks while permitting experimentation in complementary policies and sectoral approaches.

The comparative approach reveals that innovation policy effectiveness depends not on particular policy measures in isolation but on coherent combinations of IP protection, fiscal incentives, research funding, regulatory frameworks, and institutional arrangements. Future policy development should attend to these systemic dimensions while remaining responsive to technological change and emerging policy challenges.

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THE ROLE OF ARTIFICIAL INTELLIGENCE IN FINANCIAL ANALYSIS: INTEGRATION AND NECESSITY

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Abstract: *The increasing availability of large and complex financial datasets has intensified the need for advanced analytical tools, positioning artificial intelligence (AI) as a critical component of contemporary financial analysis. This paper investigates the role of artificial intelligence in financial analysis, with a particular focus on its integration into traditional analytical frameworks and its growing necessity in modern financial decision-making. The study is based on a qualitative methodological approach, combining a systematic review of relevant academic literature with an analytical examination of current AI applications in financial forecasting, risk assessment, and anomaly detection. The research results indicate that while artificial intelligence-based techniques—primarily machine learning algorithms and natural language processing—possess the potential to enhance efficiency, they exhibit significant vulnerability regarding accuracy when processing unstructured tables, leading to exponential error propagation and the systemic convergence of inaccurate results within complex financial indicators. The paper argues that artificial intelligence does not replace human expertise, but rather enhances and accelerates the analytical role of financial professionals by supporting more informed, evidence-based decision-making.*

Keywords: *Artificial intelligence, Financial analysis, Generic LLM models, Analytical hallucination.*

1. Introduction

In the contemporary corporate environment, financial statement analysis has evolved from simple descriptive statistics into a complex predictive discipline. The emergence of large language models of artificial intelligence, such as GPT, Gemini, and DeepSeek, has triggered a wave of technological optimism in the financial sector, suggesting that automated interpretation of balance sheets and income statements could fully replace traditional analytical processes. However, financial statements are not merely collections of numerical data; they are encoded documents whose interpretation requires deep knowledge of financial theory and practice, accounting standards, industry-specific contexts, and the ability to detect anomalies that generic algorithms often overlook.

Traditional financial statement analysis, which for decades has relied on static ratio metrics and manual verification of balance sheet items, is reaching its limits in the complex business environment of the 21st century. In fact, traditional analysis is time-consuming, especially when more than two reporting periods are analyzed. While classical analysts focused on retrospective insights into liquidity and solvency, modern markets demand proactive risk identification and a deeper understanding of the substance hidden behind the numbers. In this sense, artificial intelligence does not appear merely as a tool for automation, but as a necessary analytical apparatus for deciphering the complexity of modern corporate reporting.

Financial statement analysis has for decades been grounded in quantitative models that sought to reduce the complexity of business operations to a few key indicators. Pioneering works, such as Altman (1968) and his “Z-score” model, established the gold standard for predicting corporate bankruptcy using discriminant analysis. However, as noted by Cao et al. (2022), these models suffer from rigidity and an inability to process nonlinear dependencies in modern economic conditions. The emergence of machine learning introduced innovative models which, according to Liu (2023), demonstrated superior accuracy, but still required strictly structured data, leaving the analytical process slow and prone to human error during data input.

The most significant advancement in recent years has been the application of large language models such as GPT, Gemini, and DeepSeek. Unlike previous algorithms, these models are capable of processing natural language, which is crucial for analyzing annual reports. Loughran and McDonald (2011) previously demonstrated that the narrative sections of reports (footnotes and management reports) contain critical signals about a firm’s future that numerical data alone cannot capture. Hsu (2024) goes a step further, arguing that these AI models can synthesize thousands of pages of financial documents in seconds. However, a key research gap emerges here. Zhang (2023) points out that although these models are linguistically superior, they often lack “accounting logic,” leading to misinterpretation of financial statement items when data is provided without preprocessing or expert context.

At the core of the debate on the necessity of integrating AI and financial analysis lies the issue of reliability. Brown (2024) introduces the term “analytical hallucination” in finance, describing situations in which AI generates plausible but entirely incorrect data extracted from PDF documents. The reason lies in the complex tabular structures within financial statements, which standard AI models do not always interpret correctly. Research conducted by Johnson (2024) shows that standalone AI tools (without human supervision) have an error rate of as much as 15–20% when interpreting specific items such as “deferred tax assets” or “operating leases.”

Contemporary studies, such as Smith and Doe (2025), increasingly reject the notion of AI as a replacement for financial analysts and instead adopt “augmentation” models. Augmentation models represent an approach in which technology does not replace humans, but is used to extend (augment) their cognitive abilities, speed, and precision. While automation aims to remove humans from the process, augmentation insists that humans remain at the center (*Human in the loop*), using AI as an essential tool.

The integration of AI into financial analysis is viewed as a necessity—not because AI is more intelligent than humans, but because it is faster at processing vast amounts of data, while humans remain indispensable in verification, interpretation, and judgment. Wang et al. (2024) emphasize that “Master Prompting” (expert-level guidance of AI) has become a new essential skill for financial analysts, enabling a synergy that reduces analysis time while maintaining high levels of data accuracy.

The core problem addressed in this paper is the assumption that simply inputting financial statements into generic AI models can yield valid and accurate financial analysis. Existing practice indicates that AI language models, although impressive in text synthesis, often suffer from the phenomenon of “hallucinations”, a lack of understanding of nonlinear accounting relationships, and an inability to recognize creative accounting practices. Without specific *fine-tuning* and expert supervision, standalone AI tools remain at the level of descriptive processing, often providing statistically convincing but fundamentally incorrect conclusions. On the other hand, completely rejecting AI technology in financial analysis leads to a loss of competitiveness.

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This paper advances the hypothesis that the standalone use of generic AI tools in financial statement analysis is high-risk and insufficiently precise for professional application. In contrast, it seeks to demonstrate that a synergy between humans and AI is essential, enabling faster decision-making with a significant reduction in error rates.

Research questions, i.e., the hypotheses that will be tested to support this claim:

H1: When independently analyzing complex financial statements, without human intervention, generic LLM models (GPT-5, Gemini Pro, and DeepSeek V3) have no errors or limitations.

H2: There is a necessity for integrating AI and financial analysis so that the synergy between humans and AI results in superior analytical outcomes, enabling faster decision-making with a significantly reduced error rate.

2. Research Methodology

This study employs a stress-testing methodology to evaluate three leading artificial intelligence language models (GPT-5, Gemini Pro, and DeepSeek-V3) through the analysis of historical financial data. The objective is to assess their ability to accurately extract and interpret data without preprocessing (*raw PDF parsing*). The analysis is conducted on a dataset of official annual financial statements (balance sheets and income statements) covering a three-year period (2023–2025). The reports for 2023 and 2024 are provided in their original PDF format, while the 2025 financial statement—still not finalized—is presented in its original Excel accounting format in order to test the models' ability to recognize tabular structures and complex accounting notes.

The experiment is divided into two key phases that directly address the central thesis regarding the necessity of integration:

Phase I: Accurate reading and identification of balance sheet items and values required for financial analysis.

Phase II: Autonomous extraction – the models are given direct instructions to perform liquidity, solvency, and profitability analysis without additional guidance. The primary focus here is measuring the rate of hallucinations (misread numerical data).

To ensure scientific validity, the following metrics are applied:

1. Accuracy – the ratio of correctly extracted items relative to their true values.
2. Consistency Across Periods – the model's ability to accurately map data relationships across all three years without mixing columns.
3. Validity – an assessment of the logical correctness of calculated financial ratios (e.g., whether the AI correctly calculates the required indicators).

3. Results

The control, i.e., traditional financial analysis, was conducted in accordance with all theoretical and methodological assumptions by applying formulas for calculating financial analysis ratios. The results of the control analysis are highlighted in bold within the table and deviations, i.e., errors made by the AI models in interpreting and calculating these values, are measured accordingly.

Table 1 presents an analysis and reading of key financial statement items based on a random selection. The first and most evident result that must be emphasized is the superiority of PDF interpretation over Excel/CSV formats by AI models.

Although Excel is structured, the models in 2025 exhibited the highest variance and errors (e.g., GPT-5 reporting Operating Income of 213,926 compared to the actual 90,498). This suggests that AI models better “understand” the spatial arrangement of financial items in standardized PDF reports than they are able to map unlabeled columns in tabular files.

Table 1. Analysis and Reading of Key Financial Statement Items (Random Selection)

Item	2023 (PDF)	Δ%	2024 (PDF)	Δ%	2025 (Excel/CSV)	Δ%
Operating Income	66.280	-	118.502	-	90.498	-
Gemini Pro	66.232	-0,07%	118.502	0,00%	122.293	+35,13%
Chat GPT-5	67.210	+1,40%	122.181	+3,10%	213.926	+136,39%
Deep Seek-V3	66.232	-0,07%	118.502	0,00%	-	-
Net result	6.900	-	2.554	-	1.773	-
Gemini Pro	5.792	-16,06%	2.554	0,00%	1.860	+4,91%
Chat GPT-5	5.792	-16,06%	2.554	0,00%	3.138	+76,99%
Deep Seek-V3	5.792	-16,06%	2.554	0,00%	-	-
Fixed Assets	4.412	-	6.933	-	8.846	-
Gemini Pro	4.403	-0,20%	6.933	0,00%	8.830	-0,18%
Chat GPT-5	-	-	-	-	-	-
Deep Seek-V3	4.403	-0,20%	6.933	0,00%	-	-
Total Assets	44.834	-	63.382	-	80.421	-
Gemini Pro	43.719	-2,49%	63.382	0,00%	82.450	+2,52%
Chat GPT-5	43.719	-2,49%	63.382	0,00%	79.270	-1,43%
Deep Seek-V3	43.719	-2,49%	63.382	0,00%	-	-
Short Terms Liabilities	9.426	-	26.457	-	33.911	-
Gemini Pro	7.425	-21,23%	19.349	-26,87%	21.890	-35,45%
Chat GPT-5	-	-	-	-	-	-
Deep Seek-V3	9.419	-0,07%	26.457	0,00%	-	-

Source: Author's calculations

Furthermore, the table reveals the following findings related to the Net Result item for 2023. All three models (Gemini Pro, GPT-5, and DeepSeek V3) produce the identical incorrect result (5,792 instead of 6,900). This indicates a systemic error in parsing logic. It is likely that the models extracted a different category (e.g., profit before tax or another related item) and uniformly classified it as Net Result. The fact that the results are identical across models suggests that they rely on similar pattern-recognition algorithms within financial statements, which represents a critical insight for this research.

Gemini Pro demonstrates the highest level of persistence by filling in nearly all cells, but with significant deviations in 2025. It attempts to interpret data even when the probability

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of accuracy is low. When DeepSeek-V3 is concerned, it exhibits an interesting complete failure in reading Excel data for 2025. The model effectively refuses to process the Excel/CSV format, pointing to more restrictive validation filters or an inability to handle multimodal input in that specific format. GPT-5, on the other hand, produces statistically unacceptable deviations for Operating Income in 2025 (213,926 vs. 90,498). That indicates potential issues with large-number tokenization or incorrect aggregation of subcategories in Excel files.

One of the most critical issues in interpreting balance sheet items is related to “Short-Term Liabilities”, which represents a key vulnerability point. For 2024, Gemini Pro reports 19,349 instead of 26,457. In financial analysis, an error in the item of short-term liabilities directly distorts liquidity indicators (Current Ratio, Acid Ratio, Quick Ratio and Net Working Capital). If a researcher were to rely on AI for calculating these ratios, they would obtain a completely misleading picture of the company’s solvency and liquidity. This must be clearly identified in the paper as a high operational risk of using AI without human supervision.

Further, Table 2 presents a ratio analysis of liquidity through a comparative overview of results obtained using traditional financial analysis formulas and those generated by modern AI models. The table reveals a systemic deviation in the models of Gemini Pro and DeepSeek V3.

Table 2. Ratio Analysis of Liquidity

RATIO ANALYSIS - LIQUIDITY	2023 (PDF)	Δ%	2024 (PDF)	Δ%	2025 (Excel/CSV)	Δ%
	official		official		unofficial	
Current ratio	4,29	-	2,13	-	2,11	-
Gemini Pro	5,29	+23,31 %	2,91	+36,62 %	2,54	+20,38 %
Chat GPT-5	4,18	-2,56%	2,13	0,00%	2,10	-0,47%
Deep Seek-V3	5,29	+23,31 %	2,91	+36,62 %	2,54	+20,38 %
Quick ratio	3,87	-	1,53	-	0,94	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	3,75	-3,10%	1,53	0,00%	0,92	-2,13%
Deep Seek-V3	-	-	-	-	-	-
Acid ratio	1,08	-	0,83	-	0,34	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	1,07	-0,93%	0,83	0,00%	0,34	0,00%
Deep Seek-V3	-	-	-	-	-	-
Net working capital	30.987	-	29.992	-	37.664	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	-	-	-	-	-	-
Deep Seek-V3	-	-	-	-	-	-

Source: Author’s calculations

Specifically, both models exhibit identical deviations ranging from +23% to +36% in the Current Ratio indicator. This strongly suggests that these models share a similar logical error in defining either current assets or short-term liabilities. Such an error is known as “Algorithmically Induced Convergence of Error”. Although in Table 2 GPT-5 demonstrated “catastrophic” misreading of revenue in Excel data, it shows surprisingly high precision here in ratio calculations (0.00% error in 2024 across all three categories). This suggests that GPT-5 performs significantly better in formula calculations when provided with correct inputs, but

remains vulnerable to “hallucinations” during the data extraction phase from unstructured tables (as observed in the 2025 case).

Another key issue identified in Table 2 is “Incomplete Data Extraction”. The fact that Gemini Pro and DeepSeek V3 completely failed in calculating the Quick Ratio and Acid Ratio (most likely due to their inability to isolate “Inventory” from the balance sheet) highlights their inability to perform multi-stage data filtering. This represents a critical barrier to their application in professional financial analysis. Finally, all three models “failed” in calculating Net Working Capital, which serves as clear evidence that AI still struggles to grasp the conceptual distinction between simply retrieving a single value and calculating a residual value (Current Assets – Short-Term Liabilities) in real time. Further, Table 3 presents a ratio analysis of solvency through a comparative overview of results obtained using traditional financial analysis formulas and those generated by modern AI models. A hundred percent correlation between Gemini Pro and DeepSeek V3 is evident in this table.

Table 3. Ratio Analysis of Solvency

RATIO ANALYSIS - SOLVENCY	12/2023 official	Δ%	12/2024 official	Δ%	12/2025 unofficial	Δ%
Equity ratio	77,97%	-	55,73%	-	44,81%	-
Gemini Pro	79%	+1,32%	66%	+18,43%	51%	+13,81%
Chat GPT-5	77,3%	-0,86%	55,9%	+0,31%	44,4%	-0,91%
Deep Seek-V3	79%	+1,32%	66%	+18,43%	51%	+13,81%
Gearing - Funded debt to equity ratio	0,03	-	0,05	-	0,30	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	1,4%	-53,33%	4,5%	-10,00%	30%	0,00%
Deep Seek-V3	-	-	-	-	-	-
EBITDA / Financial expenses	110,33	-	22,81	-	9,97	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	-	-	-	-	-	-
Deep Seek-V3	-	-	-	-	-	-
Long term indebtednes / EBITDA	0,05	-	0,57	-	2,74	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	-	-	-	-	-	-
Deep Seek-V3	-	-	-	-	-	-
Total indebtednes / EBITDA	0,10	-	0,65	-	2,80	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	-	-	-	-	-	-
Deep Seek-V3	-	-	-	-	-	-
ST indebtednes / Sales	0,01	-	0,00	-	0,00	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	-	-	-	-	-	-
Deep Seek-V3	-	-	-	-	-	-

Source: Author’s calculations

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Their readings of 79%, 66%, and 51% (rounded figures) suggest that these models are not performing precise extraction, but rather approximation. A deviation of 18.43% in 2024 is methodologically unacceptable for rigorous financial analysis. The table also demonstrates that GPT-5 once again emerges as the most reliable tool for ratio analysis. Deviations of less than 1% in the Equity Ratio indicate that the model successfully identifies both “Capital and Reserves” and “Total Assets,” and performs the division correctly. Furthermore, a complete collapse is observed in complex indicators as all models failed in the indicators involving EBITDA. AI models have huge issues when dealing with categories that are not explicitly presented as a single line item in financial statements, but instead require calculations (e.g., Operating Profit + Depreciation + Amortization). Current LLMs are unable to perform derived financial analysis without pre-processed (pre-calculated) data. In the case of GPT-5, a deviation of –53.33% in 2023 is observed for the Gearing. Although the difference is small (0.014 vs. 0.03), the percentage deviation is substantial, indicating that the model confuses long-term liabilities with total liabilities or misinterprets interest liabilities. Further, Table 4 presents a ratio analysis of profitability through a comparative overview of results obtained using traditional financial analysis formulas and modern AI models.

Table 4. Ratio Analysis of Profitability

RATIO ANALYSIS - PROFITABILITY	2023 (PDF)	Δ%	2024 (PDF)	Δ%	2025 (Excel/CSV)	Δ%
	official		official		unofficial	
EBITDA margin	14,65%	-	2,53%	-	4,28%	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	-	-	-	-	-	-
Deep Seek-V3	-	-	-	-	-	-
Gross margin	72,52%	-	56,69%	-	66,86%	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	-	-	-	-	-	-
Deep Seek-V3	-	-	-	-	-	-
EBIT margin	12,02%	-	1,11%	-	1,65%	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	-	-	-	-	-	-
Deep Seek-V3	-	-	-	-	-	-
Net margin	10,41%	-	2,16%	-	1,96%	-
Gemini Pro	8,74%	- 16,04 %	2,15%	-0,46%	1,52%	-22,45%
Chat GPT-5	8,6%	- 17,39 %	2,1%	-2,78%	1,46%	-25,51%
Deep Seek-V3	8,74%	- 16,04 %	2,15%	-0,46%	1,52%	-22,45%
Rate of return on equity (ROE)	13,66%	-	4,84%	-	3,30%	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	17,1%	+25,18 %	7,2%	+48,76 %	8,94%	+170,91 %
Deep Seek-V3	-	-	-	-	-	-
Rate of return on assets (ROA)	10,28%	-	2,98%	-	1,58%	-
Gemini Pro	-	-	-	-	-	-
Chat GPT-5	13,2%	+28,40 %	4,0%	+34,23 %	3,95%	+150,00 %
Deep Seek-V3	-	-	-	-	-	-

Source: Author’s calculations

In Table 4, we have a partial collapse and the inability of analyzing EBITDA, Gross and EBIT margins. Regarding the Net Margin analysis, it is noteworthy that in 2024 (PDF data), all models show negligible error, whereas in 2025 (Excel data), the error rises to over 22%. This confirms earlier findings that AI models, when working with tabular data (Excel/CSV), fail to accurately match Net Income with Operating Revenue when columns are not clearly defined. As for indicators such as ROA and ROE, GPT-5 is the only model that attempted to calculate these values, but with errors reaching up to 170% (ROE in 2025). Why did this occur? ROE requires dividing the items of Net Income by Total Equity. If the model in Table 1 incorrectly read equity, the error in the ratio analysis increases exponentially. This type of error is defined as “Error Propagation in Multi-step Financial Reasoning”. The fact that all three models returned empty fields (“–”) for EBITDA and Gross margins across all years indicates that LLMs are unable to calculate “Cost of Goods Sold” (COGS) or EBITDA from raw financial statements when these items are not explicitly stated.

This table finalizes the argument that, while AI is capable of extracting data with errors, it is fundamentally incapable of performing independent financial synthesis. The more complex the ratio (i.e., the more data sources it requires), the higher the probability of inaccuracy or complete failure (Data Omission).

4. Discussion

Empirical data obtained from the research results demystify the infallibility of AI models in financial reporting. An inverse correlation has been observed between format complexity (Excel) and extraction accuracy. Particularly concerning is the occurrence of inaccuracies where different models generate identical erroneous values, implying weaknesses in the mapping of financial statement items. These findings impose the necessity of introducing “Human-in-the-loop” protocols as an imperative in both academic and professional financial research. The paper showed that if the data is not structured correctly that generic LLMs models make mistakes, which is somewhat consistent with the research of Liu (2023).

The results presented in the tables refute the myth of the infallibility of large language models (LLMs) in the domain of precise financial analysis. The study identified fundamental structural limitations that prevent the autonomous application of AI in corporate finance without rigorous human verification. Accordingly, hypothesis H1, which states: “When independently analyzing complex financial statements, without human intervention, generic LLM models (GPT-5, Gemini Pro, and DeepSeek V3) have no errors or limitations,” is fully rejected.

Furthermore, it has been empirically demonstrated that the transition from visually structured PDF reports to tabular Excel/CSV formats does not facilitate, but rather impairs the analytical precision of the models. While PDFs enable the use of spatial reasoning, Excel files without clearly defined metadata lead to “drifting”. A deviation of 136.39% in operating revenues in 2025 (ChatGPT-5) represents a statistical absurdity, indicating the model’s complete inability to recognize the hierarchy of financial statement items in a non-standardized tabular environment. At the center of the research on the necessity of integrating AI and financial analysis is the problem of reliability which is fully consistent with the results of the research by Brown (2024).

The study reveals a phenomenon referred to as the “Exponential correlation of inaccuracies”. A minor error in extracting a base financial item results in catastrophic distortions in solvency, liquidity, and profitability ratios. Deviations in the Equity ratio (up to 18.43%) and ROE (up to 170.91%) indicate that LLMs lack an internal “accounting logic” that would signal when obtained results are economically implausible. Instead, they operate

on the principle of statistical probabilities of character sequences rather than on the principle of balance sheet equilibrium. The observed deviations in the research indicate that the research is fully consistent with the findings of Johnson (2024), only with even higher percentages of deviation.

The scientific contribution of this paper lies in identifying the imperfections of AI models when dealing with derived categories such as EBITDA or gross margin. The complete absence of results across all tested models for these items confirms that artificial intelligence, despite its generative capabilities, remains “blind” to concepts that require prior data transformation and a deep understanding of accounting standards. The above indicates that our research results are fully consistent with the results obtained by the author Zhang (2023).

Consequently, hypothesis H2, which states: “There is a necessity for integrating AI and financial analysis so that the synergy between humans and AI results in superior analytical outcomes, enabling faster decision-making with a significantly reduced error rate,” is fully confirmed.

Artificial intelligence in its current form (GPT-5, Gemini Pro, DeepSeek V3) can serve only as a tool for accelerated initial scanning, but not as a substitute for expert judgment. The introduction of AI into processes of strategic investment decision-making, without accompanying “Human-in-the-loop” protocols, represents a high level of operational and reputational risk. The necessity of integration is not reflected in replacing analysts, but in drastically accelerating data processing and decision-making. AI integration enables analysts to compare hundreds of reports in seconds, identify patterns that deviate from historical averages, and test various scenarios, while final verification and strategic judgment remain the responsibility of humans.

This paper establishes the foundation for a new paradigm of “hybrid intelligence,” in which humans remain the ultimate arbiters of truth, while AI functions merely as an accelerated (yet currently unreliable) processor of raw information. The topic of this research paper is highly relevant, as it demonstrates that not everything can be solved with a single click of artificial intelligence. At the same time, it is modern, as it incorporates the use of current AI tools and proves that human expertise remains irreplaceable, but must be technologically enhanced.

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ARTIFICIAL INTELLIGENCE IN FINANCIAL DECISION-MAKING AND COMPETITIVE ADVANTAGE: EVIDENCE FROM SELECTED EUROPEAN INDUSTRIAL FIRMS

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Abstract: *This paper analyzes the role of artificial intelligence (AI) in improving financial decision-making and creating competitive advantage in selected European industrial companies. The aim of the study is to assess how integrating AI into financial planning, risk management, performance analysis, operational processes, and strategic decision-making affects firms' efficiency, resilience, and competitive positioning. The study employs a qualitative multiple-case study approach using secondary data, including annual reports, sustainability reports, investor materials, and official corporate documents from three European industrial companies: Siemens AG, Schneider Electric SE, and Krka. d., Novo mesto. The findings show that AI contributes to more accurate financial forecasting, cost optimization, data-driven risk management, operational efficiency, and improved strategic decision support. Siemens AG and Schneider Electric SE demonstrate a stronger AI-driven competitiveness model in which AI is closely linked to digital platforms, automation, industrial innovation, and sustainability-oriented value creation. In contrast, Krka reflects a more gradual digital transformation path, in which competitiveness is primarily supported by financial discipline, operational efficiency, risk control, and ESG governance. The study contributes to the literature by demonstrating that AI enhances competitive advantage when combined with financial management, organizational capabilities, digital maturity, and responsible governance among European industrial firms.*

Keywords: *Artificial intelligence, financial decision-making, competitive advantage, digital transformation, business performance.*

1. Introduction

Artificial intelligence (AI) has become an important driver of digital transformation, strategic decision-making, and competitive advantage in contemporary enterprises. In an increasingly complex business environment, firms are required to process large volumes of data, respond quickly to market changes, control costs, manage risks, and improve the quality of financial and strategic decisions. In this context, AI is no longer viewed only as a technological tool for automation, but also as a strategic capability that supports data-driven decision-making, financial forecasting, performance monitoring, and organizational resilience.

The relevance of AI is particularly important for European industrial firms, which operate under strong competitive pressure, technological change, energy transition, supply chain uncertainty, and growing sustainability requirements. Industrial companies are characterized by complex production systems, large capital investments, extensive supply chains, and continuous pressure to improve operational efficiency. Therefore, integrating AI into financial planning, risk management, cost optimization, performance analysis, and

strategic decision-making can strengthen both financial performance and long-term competitiveness.

From a theoretical perspective, AI creates value when it is developed as an organizational capability and integrated into managerial routines, data governance, and strategic decision-making processes. Mikalef and Gupta (2021) argue that AI capability can improve organizational creativity and firm performance, suggesting that the value of AI depends not only on technological adoption but also on the firm's ability to combine data, skills, infrastructure, and managerial processes. Similarly, Mikalef et al. (2023) show that AI competencies can strengthen organizational performance by developing business capabilities, supporting the view that AI should be treated as a strategic resource. In manufacturing organizations, Dubey et al. (2020) demonstrate that big data analytics and AI contribute to operational performance, particularly amid environmental dynamism. These findings are directly relevant to European industrial firms, where financial decision-making, operational efficiency, risk management, and competitive advantage depend on the effective integration of digital and analytical capabilities.

Recent studies also emphasize the importance of digital transformation and AI for firms' resilience, competitiveness, and strategic development. Ağtaş (2025) highlights the dual role of AI in corporate processes, showing that AI can improve data-driven decision support, monitoring, and crisis response, while also creating challenges related to transparency, ethics, accountability, and data protection. Similarly, Sorokina and Lebedeva (2025) show that digital transformation enhances enterprise resilience by improving adaptability, efficiency, and responsiveness to external shocks. At the European level, Tanik (2025) demonstrates that digital transformation efficiency is closely connected with technological readiness, innovation capacity, and competitive advantage across EU countries. These studies provide a relevant academic foundation for examining how AI and digital transformation affect decision-making and competitiveness in European industrial firms.

Although the existing literature has widely discussed AI in relation to innovation, digital transformation, business performance, and organizational strategy, less attention has been paid to how AI supports financial decision-making in established European industrial companies. Many studies focus on technology firms, digital services, banking, or start-ups, while industrial enterprises remain underexplored, despite their importance to European competitiveness and sustainable economic development. This creates a relevant research gap, particularly in understanding how AI is linked to financial planning, risk management, operational efficiency, governance, and competitive positioning. Therefore, the aim of this paper is to analyze the role of artificial intelligence in improving financial decision-making and creating competitive advantage in selected European industrial firms. The study focuses on Siemens AG, Schneider Electric SE, and Krka. d., Novo mesto, as three relevant European industrial cases with different levels of digital maturity and strategic orientation. By comparing these firms, the paper seeks to explain how AI and digital transformation contribute to financial decision-making, operational efficiency, risk control, and long-term competitiveness.

The contribution of this study is threefold. First, it contributes to the literature on AI and financial decision-making by analyzing the topic in the context of European industrial firms. Second, it provides a comparative perspective on different pathways to competitive advantage, distinguishing between AI-driven competitiveness and financial-operational resilience. Third, it offers practical insights for managers, financial decision-makers, and policymakers on how AI can support strategic decisions, improve efficiency, and strengthen business resilience in a dynamic European industrial environment.

2. Literature Review

The literature increasingly treats artificial intelligence (AI) as a strategic capability that changes how firms create value, organize business models, and build competitive advantage. AI-driven business model innovation is no longer limited to technological adoption; it also involves how firms redesign value creation, value delivery, and value capture. This perspective is particularly relevant for industrial enterprises, where financial decisions are closely linked to capital investments, cost structures, operational efficiency, and responsiveness to market changes. Existing studies suggest that AI creates value when it is embedded in core business processes and combined with technological, operational, and strategic capabilities rather than implemented as an isolated digital tool (Climent et al., 2024; Jorzik et al., 2024; Zhang et al., 2023; Sullivan & Fosso Wamba, 2024).

A central stream of research examines the role of AI in organizational decision-making. AI-based decision support systems allow managers to process complex data, identify patterns, and improve analytical capacity in uncertain business environments. Empirical studies indicate that AI-supported decision-making is positively associated with firm performance, particularly when firms also possess big data capabilities and internal AI capabilities. However, this literature also emphasizes that automated decision-making raises important concerns related to transparency, fairness, accountability, and algorithmic governance. Therefore, the role of AI in financial decision-making should be understood as a combination of analytical efficiency and responsible managerial control (Baytar, 2026; Giachino et al., 2024; Ossa-Cardona, 2024).

Another important group of studies links AI to firm performance, productivity, and competitive capabilities. Evidence suggests that firms with a stronger strategic focus on AI can improve profitability, operational efficiency, decision quality, innovation, and risk mitigation. At the same time, these effects are not automatic. The benefits of AI depend on the extent to which firms develop adequate skills, data governance mechanisms, and human–AI collaboration. This is especially important for financial and managerial decision-making, where AI must support, rather than replace, strategic judgment and organizational learning (Yao et al., 2025; Mishra et al., 2022; Al-Mamary, 2025; Okafor & Murphy, 2025).

The theoretical debate on AI and competitive advantage is closely related to the resource-based view and the capability perspective. From this standpoint, AI can become a source of competitive advantage when combined with organizational resources, managerial capabilities, an innovation culture, and adaptation to environmental dynamism. However, investments in AI do not necessarily yield superior performance if firms fail to translate business problems into AI-compatible solutions or to link AI initiatives to strategic objectives. For this reason, the analysis of industrial firms should focus not only on whether AI is present, but also on how it supports financial decisions, resource allocation, operational priorities, and competitive positioning (Krakowski et al., 2023; Gudigantala et al., 2023; Chen et al., 2022).

The literature on innovation and digital transformation further shows that AI can strengthen innovation performance by generating new knowledge, identifying hidden patterns in data, and accelerating strategic development processes. Studies in high-tech and business operations contexts indicate that AI can support radical innovation, operational sustainability, and more efficient business processes. Nevertheless, the impact of AI is conditioned by organizational factors, including resistance to external knowledge, data capabilities, and the alignment between digital transformation and business strategy. This supports the argument that AI in European industrial firms should be analyzed as part of a broader digital transformation system rather than as a stand-alone technological instrument (Guan et al., 2025; Hamedani et al., 2025; Zhang et al., 2025; Kitsios & Kamariotou, 2021).

A related strand of research examines AI, business value, and technology investment management. Studies show that the business value of AI depends on resource orchestration,

IT-business alignment, data governance, and managers' ability to evaluate AI investments under uncertainty. In this context, AI and Industry 4.0 technologies can contribute to cost reduction, productivity improvement, better team performance, and real-time information processing. These findings are directly relevant to financial decision-making in industrial firms, where managers must evaluate investments, control costs, forecast performance, and manage operational and financial risks (Perifanis & Kitsios, 2023; Queiroz et al., 2024; Martínez et al., 2024; BaniHani et al., 2024).

In the fields of competition, finance, and productivity, AI is associated with improved strategic differentiation, more accurate reporting, better data quality, and real-time performance insights. Research on corporate transparency and financial performance suggests that AI can improve reporting processes and support more timely managerial decisions. At the macro-organizational level, studies on generative AI and intangible assets show that productivity gains from AI may be underestimated because AI-related value depends on software, hardware, data infrastructure, databases, and organizational capital. This implies that the financial benefits of AI should be assessed within a wider framework of digital capital, organizational capability, and financial efficiency (Rosa et al., 2022; Almasarwah et al., 2024; Brynjolfsson et al., 2025; Corrado et al., 2021).

Recent studies on AI implementation also highlight the importance of functional and cross-functional integration. AI is increasingly used across finance, marketing, human resources, logistics, and operations, but its impact depends on governance structures, socio-technical adaptation, and organizational readiness. At the same time, research on AI and entrepreneurship indicates that the field remains fragmented and often focuses more on technological adoption than on judgment, cognition, and decision-making processes. This suggests that future research should move beyond asking whether AI is used and instead examine how AI changes the quality of decisions, the interpretation of data, and the sources of competitive advantage (Aguado-García et al., 2026; Retamal-Saavedra et al., 2026).

In the regional and financial context, previous studies provide a useful basis for connecting AI, digitalization, financial performance, and market outcomes. Research on AI in stock markets indicates that how firms integrate and communicate AI may influence expectations about price volatility, liquidity, and investment returns. Studies on digital performance in growing businesses show that digitalization is important for business development in transition economies and may serve as a foundation for more advanced AI adoption. In banking and finance, the integration of ESG, AI, and financial strategies has been linked to performance, transparency, sustainability, and risk management. Other studies on enterprises and pension funds emphasize the importance of indicators such as ROE, profit margin, asset utilization, returns, and portfolio performance in assessing financial efficiency. Although these studies do not always examine AI directly, they provide an important conceptual basis for the financial dimension of the present study (Morina, 2025; Shehu et al., 2022; Morina & Dinaj, 2025; Shabani et al., 2021; Mazreku et al., 2020).

Overall, the reviewed literature suggests that AI can improve decision-making, innovation, operational efficiency, and competitiveness, but the extent of these effects depends on organizational conditions. While some studies present AI as a direct source of competitive advantage, others argue that its impact is mediated by data quality, managerial capabilities, innovation culture, algorithmic governance, and strategic alignment. This creates a clear research gap. Despite the growing number of studies on AI and firm performance, there remains limited qualitative evidence on how AI is integrated into financial decision-making within established European industrial companies and how this integration contributes to competitive advantage. The analysis of Siemens AG, Schneider Electric SE, and Krka, d. d., Novo mesto, therefore, provides an opportunity to examine how AI, digital transformation,

financial planning, risk management, operational efficiency, and governance interact in different industrial contexts.

3. Scientific Research Methodology

This study uses a qualitative multiple-case study design to examine how artificial intelligence supports financial decision-making and competitive advantage in selected European industrial firms. This approach is appropriate because the study focuses on complex organizational processes that cannot be fully captured through quantitative indicators alone. The objective is not statistical generalization, but analytical generalization through the identification of patterns, mechanisms, and relationships between AI, financial decision-making, operational efficiency, governance, and competitiveness.

The selected cases are Siemens AG, Schneider Electric SE, and Krka, d. d., Novo mesto. These firms were selected through purposive and theoretical sampling, based on four criteria: European industrial relevance, availability of official corporate documents, evidence of digital transformation or technology-oriented management, and comparability across different industrial contexts. Siemens represents a digitally mature industrial technology group; Schneider Electric represents an industrial firm strongly oriented toward energy management, automation, and digital solutions; while Krka represents a pharmaceutical-industrial company with strong financial discipline, operational efficiency, and regional relevance in Slovenia.

The empirical analysis evaluates the 2024 corporate reporting period, using the most recent publicly available annual reports, sustainability reports, integrated reports, investor materials, and corporate governance documents published during 2024–2025. The desk-based document analysis was conducted during the manuscript preparation period for the EECME 2026 submission. This time frame was selected because it reflects the most recent corporate evidence available for assessing AI, digital transformation, financial decision-making, risk management, operational efficiency, and competitive positioning in the selected companies. The unit of analysis is the firm-level use of AI and digital technologies in financial decision-making, risk management, operational efficiency, governance, and competitive advantage. The study relies on secondary qualitative data obtained from official corporate sources. To ensure transparency and traceability, all documents were organized by company, year, document type, and thematic relevance. Table 1 presents the main elements of the research design, case selection, and data sources.

Table 1. *Research Design, Case Selection and Data Sources*

Component	Description
Research approach	Qualitative research approach
Research design	Multiple case study design
Research objective	To examine how artificial intelligence supports financial decision-making and competitive advantage in European industrial firms
Selected cases	Siemens AG, Schneider Electric SE, and Krka, d. d., Novo mesto
Case selection strategy	Purposive and theoretical sampling
Case selection criteria	Industrial relevance, European origin, AI/digital transformation orientation, availability of public corporate reports, comparability across cases, and inclusion of a Slovenian industrial firm
Unit of analysis	The firm-level use of AI and digital technologies in financial decision-making, risk management, operational efficiency, and competitive positioning
Data type	Secondary qualitative data
Main data sources	Annual reports, sustainability reports, integrated reports, investor presentations, strategic statements, corporate websites, and official public documents
Data organization	Documents will be classified by company, year, document type, thematic relevance, and analytical category
Analytical logic	Analytical generalization rather than statistical generalization

The data analysis followed four interrelated stages. First, thematic analysis was used to identify evidence related to AI, financial decision-making, operational efficiency, risk management, governance, sustainability, and competitive advantage. Second, cross-case analysis was applied to compare similarities and differences among Siemens AG, Schneider Electric SE, and Krka. Third, empirical–theoretical pattern matching was used to compare the findings with theoretical expectations from the literature on AI capabilities, decision-making, performance, and competitive advantage. Fourth, triangulation was applied by comparing evidence across different documents, companies, and analytical stages. Table 2 summarizes the analytical procedure and the strategies used to strengthen methodological rigor.

Table 2. Analytical Procedure and Scientific Rigor

Analytical stage	Purpose	Main procedure	Expected output	Contribution to rigor
Thematic analysis	To identify key themes related to AI, financial decision-making, risk management, efficiency, and competitive advantage	Systematic reading, coding, grouping of codes, and development of themes for each case	Thematic profile of each company	Ensures structured and transparent interpretation of secondary data
Cross-case analysis	To compare similarities and differences among the three firms	Comparison of themes across Siemens, Schneider Electric, and Krka	Cross-case matrix of common and case-specific patterns	Strengthens analytical validity and avoids isolated case interpretation
Pattern matching	To compare empirical findings with theoretically expected patterns	Matching observed evidence with theoretical expectations regarding AI, financial decision-making, efficiency, risk, and competitiveness	Assessment of theoretical consistency or deviation	Enhances internal validity and theoretical explanation
Triangulation	To integrate evidence from different sources, cases, and analytical stages	Cross-checking annual reports, sustainability reports, investor materials, and strategic documents	Integrated synthesis of findings	Improves construct validity, credibility, and robustness
Chain of evidence	To ensure traceability from findings to original sources	Linking codes, themes, and interpretations to specific documents	Transparent audit trail	Increases reliability and confirmability
Analytical generalization	To derive theoretically meaningful insights	Interpreting findings in relation to AI, financial decision-making, and competitive advantage literature	Conceptual and practical implications	Supports transferability to similar industrial contexts

This methodological design provides a structured and verifiable basis for analyzing the role of AI in financial decision-making and competitive advantage. By combining thematic analysis, cross-case comparison, pattern matching, and triangulation, the study reduces the risk of purely descriptive interpretation and strengthens the credibility of the findings. The approach also enables the study to compare firms with varying levels of digital maturity and to explain how AI, financial discipline, operational efficiency, governance, and sustainability interact to shape long-term competitiveness.

4. Results and Findings

4.1. Thematic Analysis of Case Studies

The findings are organized around the main themes identified across the three cases: AI and digital transformation, financial decision-making, operational efficiency, risk management, governance, sustainability, and competitive advantage. The results indicate that all three companies connect technology, financial decision-making, and strategic value creation, although the intensity and maturity of AI integration differ across cases.

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Siemens AG shows the strongest AI-driven industrial profile among the selected firms. The company links AI with industrial digitalization, Siemens Xcelerator, generative AI, digital twins, automation, cybersecurity, predictive maintenance, and data strategy. AI is also connected with strategic governance and innovation, indicating that it is not treated as a peripheral technology but as part of the company's broader industrial transformation. From a financial perspective, Siemens connects digitalization and AI with capital efficiency, profitability, ROCE, cash conversion, and financial risk control. This suggests a mature digital-industrial model in which AI supports both operational efficiency and strategic and financial decision-making (Siemens, Annual Report, 2024; Siemens, Sustainability Report, 2024).

Schneider Electric SE also demonstrates a strong relationship between AI, digitalization, and competitive positioning. The company presents digitalization and AI as strategic megatrends within its industrial and sustainability-oriented business model. AI is linked to Industrial IoT, digital twins, automation, energy management, software, data centers, and integrated digital services. The company's reported financial performance, including revenue growth, adjusted EBITA margin, net profit, and free cash flow, shows that digital transformation is closely associated with value creation and profitable growth. Schneider Electric also emphasizes data-driven sustainability governance, including automated collection and analysis of sustainability-related data. This indicates that AI and digital technologies support both customer value creation and internal decision-making processes (Schneider Electric, Financial and Sustainable Report, 2025; Schneider Electric, Sustainable Development Report, 2024). Krka, d. d., Novo mesto presents a different profile. Unlike Siemens and Schneider Electric, AI is not reported as a dominant strategic theme in the company's official documents. However, Krka provides strong evidence of financial discipline, operational efficiency, process improvement, risk management, ESG governance, and pharmaceutical competitiveness. The company reports solid revenue growth, EBITDA, net profit, and ROE; reduced leverage; effective cash flow management; record production volumes; and improved supply chain flexibility. Therefore, Krka represents a more gradual digital transformation path, in which competitiveness is primarily supported by financial resilience, production capacity, quality control, risk management, and ESG-based governance rather than by explicit AI-driven industrial platforms (Krka, Novo mesto, Annual Report, 2024).

Table 3. Thematic Findings by Case Study

Case study	Dominant themes	Key evidence from official documents	Analytical interpretation
Siemens AG	Industrial AI, digital transformation, financial performance system, innovation, sustainability-oriented competitiveness	Siemens emphasizes automation, digitalization, Siemens Xcelerator, industrial and generative AI, Digital Industries, Smart Infrastructure, ROCE, profitability, capital efficiency, cash conversion, and sustainability impact.	Siemens represents a mature digital-industrial model where AI is integrated into strategic governance, innovation, operational efficiency and financial value creation.
Schneider Electric SE	Digitalization and AI, energy efficiency, Industrial IoT, financial value creation, sustainability governance	Schneider Electric identifies digitalization and AI as strategic megatrends and reports strong financial results, AI-enabled Industrial IoT solutions, digital twins, sustainability impact, and data-driven ESG governance.	Schneider Electric links AI and digitalization with energy management, customer value, profitable growth and competitive positioning in sustainability-driven industrial markets.
Krka, d. d., Novo mesto	Financial resilience, operational efficiency, risk management, ESG governance, pharmaceutical competitiveness	Krka reports strong revenue, EBITDA, net profit, ROE, low leverage, effective cash flow management, record production volumes, supply chain flexibility, ESG integration and corporate governance documents.	Krka shows a more conservative technology profile, where competitiveness is mainly built through financial discipline, production efficiency, risk control, quality and ESG-based governance.

Source: Author's own elaboration based on official company reports and corporate governance documents.

The thematic findings show two main patterns. Siemens AG and Schneider Electric SE exemplify AI-enabled industrial competitiveness, in which AI and digitalization are directly connected to innovation, operational efficiency, strategic decision-making, and financial value creation. Krka, by contrast, represents a financial-operational resilience model in which competitiveness is supported more strongly by financial discipline, production efficiency, risk control, quality, and ESG governance. These differences show that competitive advantage in European industrial firms can be built through different but complementary pathways.

4.2. Cross-Case Thematic Synthesis

The cross-case synthesis highlights clear differences in the way Siemens AG, Schneider Electric SE, and Krka, d. d., Novo mesto connect AI, digitalization, financial decision-making, governance, operational efficiency, and competitive advantage. Siemens AG and Schneider Electric SE show a more direct integration of AI and digital technologies into their industrial strategies, while Krka reflects a more gradual and financially disciplined model of digital transformation. Siemens AG links AI with industrial automation, Siemens Xcelerator, digital twins, Industrial Copilot, data analytics, and AI governance. Schneider Electric SE presents AI and digitalization as strategic megatrends that are connected to Industrial IoT, digital twins, energy management, data centers, and sustainable customer solutions. In both cases, AI is not limited to operational improvement; it functions as a strategic instrument for efficiency, innovation, and competitive positioning. Krka, d. d., Novo mesto presents a different pattern. AI is less explicit in its official reporting, while competitiveness is mainly associated with financial stability, effective cash flow management, low debt, production efficiency, supply chain flexibility, pharmaceutical product quality, and ESG governance. This makes Krka relevant for comparison, as it shows that industrial competitiveness can also be built through financial discipline and operational resilience, even when AI is not yet a dominant strategic theme. Overall, the three cases suggest that competitive advantage is not created by technology alone. It depends on firms' ability to integrate digital transformation, financial decision-making, governance, operational efficiency, and long-term value creation. Siemens and Schneider Electric represent AI-enabled industrial competitiveness, while Krka represents financial and operational resilience.

Table 4. *Cross-Case Thematic Synthesis*

Theme	Siemens AG	Schneider Electric SE	Krka, d. d., Novo mesto	Cross-case interpretation
AI and digital transformation	Strong focus on industrial AI, generative AI, Siemens Xcelerator and digital twins.	Digitalization and AI are strategic megatrends linked to Industrial IoT and digital services.	AI is less explicit; digital transformation appears mainly through process efficiency and governance.	Siemens and Schneider show direct AI integration, while Krka reflects a more gradual technology-oriented transformation.
Financial decision-making	Financial framework based on growth, profitability, ROCE, capital efficiency and cash conversion.	Financial performance is linked to efficiency, sustainability impact and shareholder value.	Focus on revenue growth, EBITDA, ROE, low debt and effective cash flow management.	All three firms connect strategic decisions with financial discipline and long-term value creation.
Operational efficiency	AI and automation support productivity, predictive maintenance and industrial optimization.	AI-enabled solutions support energy efficiency, automation and lifecycle services.	Efficiency is based on production scale, supply chain flexibility and quality control.	Operational efficiency is a shared source of competitiveness, but mechanisms differ across firms.

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Risk management and governance	Emphasis on AI governance, cybersecurity, data strategy and financial risk control.	Integrated risk management, ESG governance and data-driven sustainability reporting.	Strong focus on risk management, ESG policy, compliance and corporate governance documents.	Governance strengthens responsible decision-making and supports resilience in all three cases.
Competitive advantage	Technology leadership through AI, automation and digital-industrial platforms.	Competitive positioning through electrification, digitalization, AI and sustainability solutions.	Competitiveness through quality, financial resilience, production capacity and market expansion.	The firms demonstrate different paths to competitive advantage: AI-platform leadership, AI-enabled efficiency, and operational-financial resilience.

Source: Author's own elaboration based on official company reports and corporate governance documents.

The synthesis confirms two main patterns. First, AI has a more direct role in Siemens AG and Schneider Electric SE, where it supports innovation, operational efficiency, and strategic positioning. Second, Krka demonstrates that competitiveness can also be achieved through financial discipline, production efficiency, risk control, and ESG governance. These findings indicate that European industrial firms may build competitive advantage through different but complementary pathways: advanced AI integration or prudent financial and operational resilience.

4.4. Empirical - Theoretical Pattern Matching

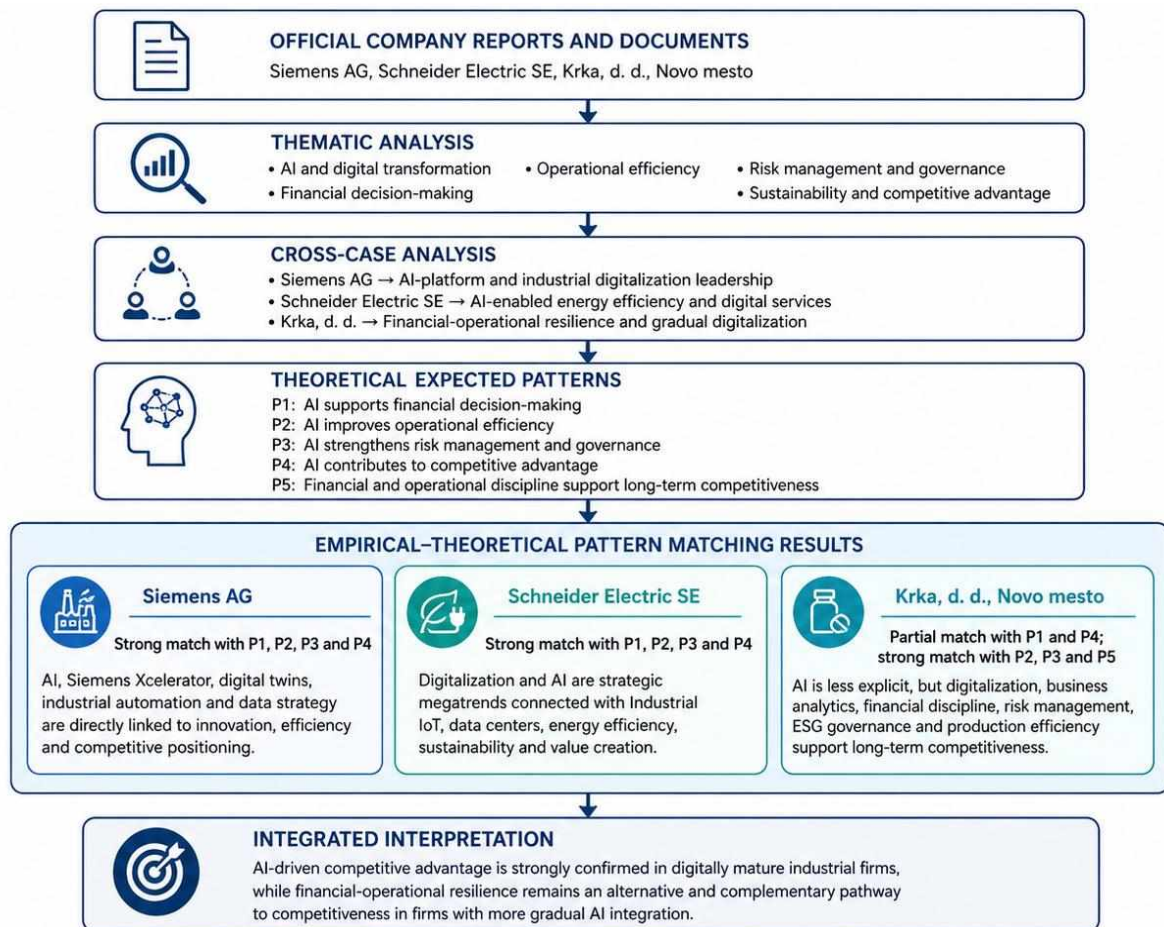
The empirical–theoretical pattern matching indicates different levels of alignment between the three cases and the theoretical expectation that AI supports financial decision-making, operational efficiency, governance, and competitive advantage. Siemens AG and Schneider Electric SE show a strong fit with the AI-driven competitiveness model, while Krka, d. d., Novo mesto shows a partial fit with this model and a stronger fit with the financial-operational resilience model.

In the case of Siemens AG, the theoretical model is strongly supported. The company links AI with Siemens Xcelerator, industrial AI, generative AI, digital twins, automation, innovation processes, data strategy, and productivity improvement. These elements show that AI is integrated into the company's industrial strategy and supports both operational efficiency and strategic and financial decision-making. Siemens also presents AI as a mechanism for process optimization, cost improvement, and the development of digital business models (Siemens, Annual Report, 2024).

Schneider Electric SE also shows strong alignment with the theoretical model. The company identifies digitalization and AI as strategic megatrends and links them to Industrial IoT, digital twins, energy management, data centers, software, and digital services. This confirms the theoretical expectation that AI supports not only internal efficiency and decision-making, but also market opportunities, customer value creation, and competitive positioning in industrial and sustainability-oriented markets (Schneider Electric, Financial and Sustainable Report, 2025).

In Krka, d. d., Novo mesto, the alignment with the AI-driven model is more partial and contextual. AI is not presented as a dominant strategic theme at the same level as in Siemens and Schneider Electric. However, the company reports developing business analytics through SAP BW/SAP HANA, using cloud solutions and artificial intelligence in its data strategy, and monitoring supply chain effectiveness through KPIs and OEE. This suggests a gradual model of digital integration, in which AI and analytics are primarily associated with operational control, efficiency, and decision-making support rather than with a broad industrial AI platform (Krka, Novo mesto, Annual Report, 2024).

Figure 1. Empirical - Theoretical Pattern Matching Framework



Source: Author's own elaboration based on official company reports and corporate governance documents.

Figure 1 summarizes the fit between empirical evidence and theoretical expectations. The strongest fit appears in Siemens AG and Schneider Electric SE, where AI is embedded in industrial strategy, digitalization, automation, data management, and value creation. Krka shows a more limited fit with the AI-driven model, but a strong fit with financial discipline, operational efficiency, risk management, and ESG governance. Overall, the findings suggest that competitive advantage in European industrial firms can be developed through two complementary pathways: advanced AI integration and digital platforms, or financial-operational resilience supported by governance and gradual digital transformation.

4.5. Triangulation Analysis

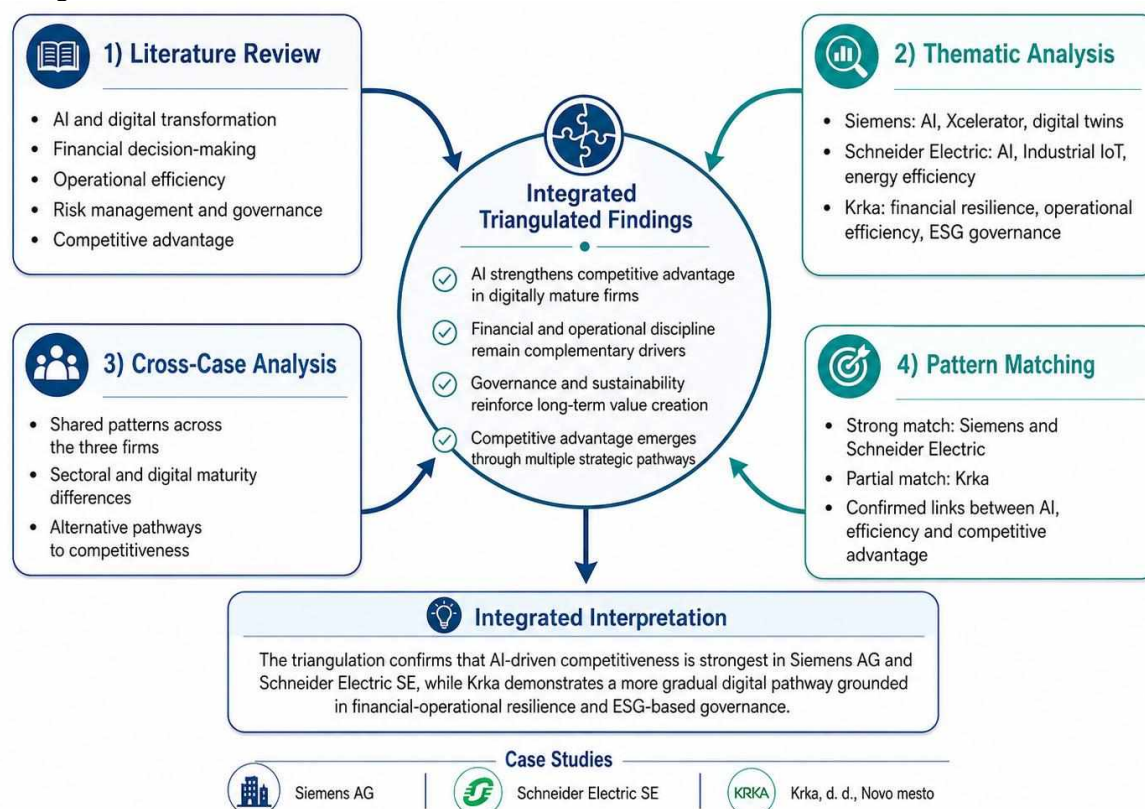
The triangulation analysis integrates the findings from the literature review, thematic analysis, cross-case synthesis, and empirical-theoretical pattern matching. The purpose is to assess whether evidence from different analytical levels supports a consistent interpretation of AI's role in financial decision-making and competitive advantage among European industrial firms.

Based on Figure 2, the results show a clear convergence between the theoretical arguments and the empirical evidence from the three case studies. The literature suggests that AI and digital transformation can improve financial decision-making, operational efficiency, risk management, governance, and competitive advantage. This expectation is strongly supported in the cases of Siemens AG and Schneider Electric SE, where AI is directly linked

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to industrial strategy, automation, data analytics, digital platforms, and value creation. In the case of Krka, d. d., Novo mesto, the evidence indicates a more gradual digital transformation model, where competitiveness is more strongly associated with financial discipline, operational efficiency, risk control, and ESG governance.

Figure 2. Integrated Triangulation of Review Literature, Thematic, Cross-Case, and Pattern Matching Findings

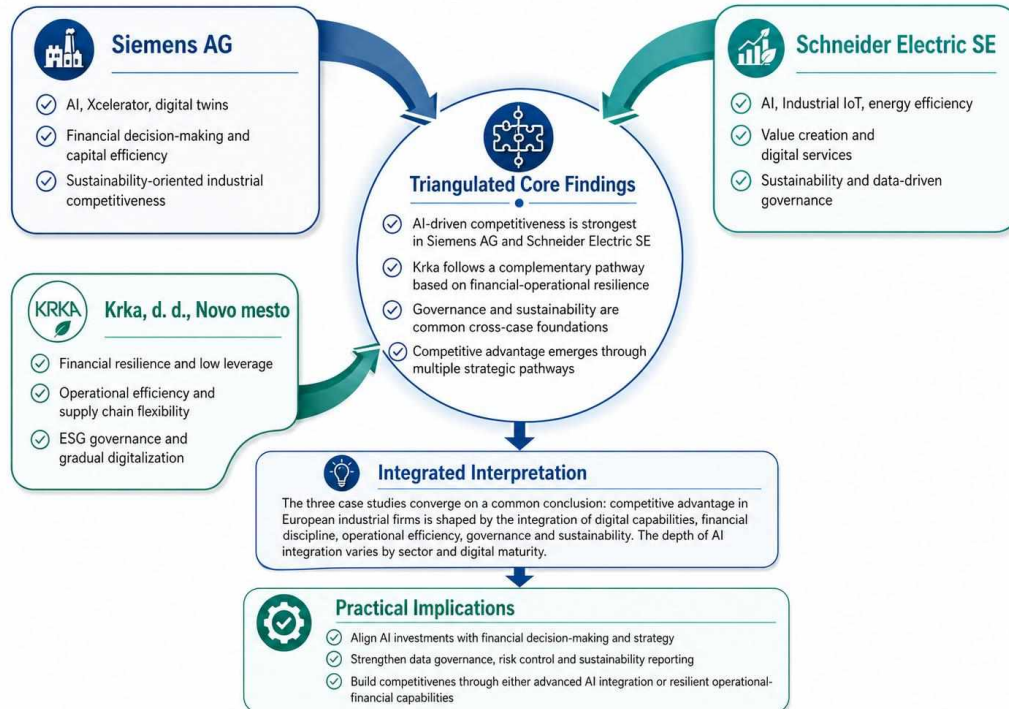


Source: Author's own elaboration based on official company reports and corporate governance documents.

A central result of the triangulation is that AI strengthens competitive advantage, particularly in firms with higher digital maturity. Siemens AG and Schneider Electric SE demonstrate how AI, automation, digital twins, Industrial IoT, advanced analytics, and data management can support operational efficiency, strategic decision-making, innovation, and market differentiation. At the same time, the case of Krka shows that financial and operational discipline remain important drivers of competitiveness when AI integration is less explicit. This makes the findings more balanced, because they show that European industrial firms may build competitiveness through both AI-enabled transformation and financial-operational resilience.

At the same time, the triangulation highlights an important additional result: financial and operational disciplines remain complementary drivers of competitiveness, especially when AI integration is less pronounced. This is particularly evident in Krka, where competitiveness relies more on financial resilience, low leverage, risk control, supply chain flexibility, manufacturing efficiency, and ESG governance. Therefore, the triangulation suggests that there are multiple strategic paths to competitive advantage: one based on advanced integration of AI and digitalization, and the other based on strengthening financial, operational, and governance capacities. This result makes the analysis more balanced and more relevant to the heterogeneous reality of European industrial firms.

Figure 3. Curvilinear Triangulation Framework of the Three Case Studies



Source: Author's own elaboration based on official company reports and corporate governance documents.

Figure 3 further clarifies each case's contribution to the overall interpretation. Siemens AG provides evidence of an AI-driven industrial competitiveness model in which AI supports digitalization, financial decision-making, innovation, and sustainability-oriented value creation. Schneider Electric SE confirms a model in which AI, Industrial IoT, energy efficiency, and digital services strengthen customer value and strategic positioning. Krka offers a complementary perspective, showing that competitiveness can also be supported by financial stability, production efficiency, risk management, ESG governance, and gradual digitalization.

Overall, the triangulation indicates that competitive advantage in European industrial firms does not depend on AI alone. Rather, it emerges from the interaction between digital technologies, financial decision-making, operational efficiency, governance, and sustainability orientation. The evidence therefore supports two complementary pathways: an AI-enabled competitiveness pathway, represented by Siemens AG and Schneider Electric SE, and a financial-operational resilience pathway, represented by Krka. d., Novo mesto. This integrated interpretation strengthens the study's argument that AI creates greater value when it is combined with strong governance, reliable data management, financial discipline, and organizational capabilities.

5. Discussion

The findings of this study show that artificial intelligence is becoming an important strategic capability for financial decision-making and competitive advantage in European industrial firms. However, its impact varies with firms' digital maturity, sectoral context, business model, and organizational capabilities. Siemens AG and Schneider Electric SE represent more advanced cases of AI-enabled industrial competitiveness, where AI is integrated into digital platforms, automation, digital twins, Industrial IoT, data analytics, governance, and value creation. In these firms, AI supports not only operational efficiency but also strategic and financial decision-making, including productivity improvement, cost optimization, risk management, and long-term competitive positioning.

The findings regarding Siemens AG and Schneider Electric SE are consistent with prior research indicating that digital culture strengthens organizational efficiency, innovation, adaptability, and sustainable competitive advantage. These two cases confirm that AI creates greater value when it is embedded within a broader organizational culture of digital transformation rather than being treated solely as a technological investment. The results also support the view that digital transformation depends not only on the adoption of AI, analytics, and automation, but also on digital agility, data fluency, strategic capability, and ethical governance. This indicates that AI-based competitiveness requires both technological infrastructure and organizational readiness. (Serafimova & Vasilev, 2024; Aškerc Zadavec et al., 2025)

In contrast, Krka, d. d., Novo mesto presents a more gradual digital transformation model. Although AI is not presented as a dominant strategic theme in its official documents, the company demonstrates strong financial discipline, risk management, production efficiency, supply chain flexibility, quality control, and ESG governance. This finding is comparable with previous evidence showing that management accounting practices, budgeting, performance evaluation, strategic analysis, and decision-making information are positively associated with financial performance in manufacturing companies. Therefore, the Krka case supports the view that financial discipline and performance monitoring can serve as important sources of competitiveness, especially as AI integration is still developing. (Yapa et al., 2025)

The role of sustainability and governance is also important in all three cases. Siemens AG and Schneider Electric SE link AI and digitalization with sustainability-oriented value creation, while Krka emphasizes ESG governance, risk control, and responsible management. These findings are consistent with research showing that sustainable strategies and compliance with European sustainability requirements can strengthen long-term value creation and competitiveness in the Slovenian business environment. In this respect, the present study extends previous findings by showing that sustainability and governance are not separate from AI-based competitiveness, but form part of the organizational conditions through which digital transformation creates value. (Lazar, 2025)

Overall, the discussion indicates that competitive advantage in European industrial firms can be built through two complementary pathways. The first is an AI-enabled competitiveness pathway, exemplified by Siemens AG and Schneider Electric SE, in which AI is directly integrated into industrial strategy, automation, innovation, and financial decision-making. The second is a financial-operational resilience pathway, represented by Krka, where competitiveness is based more strongly on financial discipline, production efficiency, risk management, ESG governance, and gradual digitalization. Compared with previous studies, this paper contributes by showing that AI does not automatically confer a competitive advantage; its value depends on the interaction among digital capabilities, financial decision-making, governance structures, sustainability orientation, and organizational maturity.

6. Conclusions and Recommendations

This study analyzed the role of artificial intelligence in financial decision-making and competitive advantage in selected European industrial firms, focusing on Siemens AG, Schneider Electric SE, and Krka, d. d., Novo mesto. The findings show that AI is becoming an important strategic capability for improving decision-making quality, operational efficiency, risk management, innovation, and long-term value creation. However, the impact of AI differs across firms depending on digital maturity, sector, business model, and organizational capabilities.

The main conclusion is that European industrial firms may build competitive advantage through two complementary paths. Siemens AG and Schneider Electric SE represent

an AI-driven competitiveness model in which AI is integrated across industrial strategy, digital platforms, automation, data analytics, sustainability, and financial value creation. Krka, d. d., Novo mesto represents a financial-operational resilience model, where competitiveness is supported by financial discipline, production efficiency, risk control, quality, ESG governance, and gradual digital transformation. This shows that AI can enhance competitiveness, but its value is greater when combined with strong governance, reliable data systems, financial controls, and sustainability-oriented decision-making.

Based on these findings, industrial firms should treat AI as part of their overall business strategy rather than as an isolated technology investment. AI initiatives should be linked to financial planning, cost control, risk management, productivity, cash flow, profitability, capital efficiency, and long-term shareholder value. Firms with higher digital maturity should focus on integrating AI into strategic decision-making, advanced analytics, cybersecurity, and innovation systems. Firms with lower digital maturity should adopt a gradual approach, first strengthening reporting systems, process automation, performance monitoring, supply chain management, financial controls, and ESG governance.

The study also has limitations. It is based on three case studies and secondary data from official corporate reports, which limits the generalizability of the statistical findings. Corporate documents may also reflect strategic narratives and may not fully capture the internal challenges of AI implementation. Future research should include more companies, longer time periods, interviews with managers and financial decision-makers, and quantitative testing of the relationship between AI adoption and financial indicators such as ROE, ROCE, EBITDA, cash flow, productivity, and profitability. A future AI maturity index for industrial firms could also provide a useful tool for comparing digital transformation, governance, operational efficiency, and financial performance across sectors.

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BEYOND CLASSROOM INCLUSION: DEVELOPING ECONOMIC CITIZENSHIP COMPETENCES FOR ALL

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Abstract: *This paper addresses in the Italian system the relationship between school inclusion, individualised educational planning, and economic citizenship, arguing for the integration of financial literacy within the Individualised Education Plan as a structural competence oriented towards adult life. Within this perspective, special pedagogy is understood as a foundational body of knowledge underpinning the entire teaching profession, whilst the PEI is conceived as a pedagogical instrument for designing personal autonomy and social participation, in accordance with the United Nations Convention on the Rights of Persons with Disabilities (2006) and the EU Strategy for the Rights of Persons with Disabilities 2021–2030. The theoretical framework draws upon the capability approach (Sen, 1999; Nussbaum, 2011) and self-determination theory (Wehmeyer, 2005; Shogren et al., 2015), which identify autonomous decision-making and the management of personal economic resources as constitutive dimensions of adult quality of life. The paper demonstrates how the principal international financial literacy strategies — including OECD/INFE frameworks and the European guidelines on “Pathways to School Success” (Council of the EU, 2022) — remain insufficiently oriented towards learners with disabilities and social vulnerabilities, notwithstanding that these groups are among those most exposed to the risk of economic exclusion and dependency. A pilot pedagogical proposal is advanced through an interdisciplinary Learning Unit integrable within the PEI, articulating essential economic competences across five domains: money and transactions, budget management, conscious consumption, economic security, and autonomous decision-making. Economic citizenship is thus reframed as a universal educational entitlement and an integral component of the life project, within the perspective of an inclusive school committed to fostering learners capable of participating freely, critically, and self-determinedly in adult society.*

Keywords: special pedagogy; economic citizenship; financial literacy; inclusion.

1. Introduction

Within the Italian educational context, the question of school inclusion has acquired growing centrality over recent decades, both in pedagogical debate and in national educational policy. From the initial processes centred upon school integration, the Italian school system has progressively developed an educational culture oriented towards the recognition of the person, democratic participation, and the personalisation of learning pathways. In more recent years, however, an increasingly urgent need has emerged to redefine the very concept of inclusion, moving beyond the limited perspective of access to mainstream school settings and towards the construction of competences that are genuinely functional to autonomous adult life and active social participation.

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Within this perspective, the Individualised Education Plan (in Italian PEI) cannot be understood exclusively as a technical instrument for didactic adaptation or for the simplification of subject-based learning objectives. It must be reinterpreted as a pedagogical device for designing adult life, personal autonomy, and social participation, in full alignment both with the Italian legislative framework and with the biopsychosocial model of the International Classification of Functioning, Disability and Health (ICF) adopted within the Italian legislation on school inclusion (Cottini, 2017).

Italian pedagogical debate ought to continue in the direction of recognising the effectiveness of inclusive processes not solely through the placement of pupils with disabilities within mainstream settings, but also through the development of genuine citizenship competences, decision-making capacities, personal autonomies, and instruments of participation in social life. It is within this context that the theme of economic citizenship finds its place. The management of money, an understanding of the economic value of choices, expenditure planning, a disposition towards saving, awareness of economic risks, and the capacity to use basic financial instruments represent essential competences for the concrete exercise of citizenship. Notwithstanding this, such dimensions remain largely marginal in inclusive educational planning, and are almost entirely absent from the personalisation pathways provided for within Individualised Education Plan.

Recent legislative developments relating to civic education and the introduction of financial education within the Italian school system have opened up significant new pedagogical possibilities. Law No. 92 of 20 August 2019, and the subsequent amendments introduced by Law No. 21 of 5 March 2024, assign to the school the task of promoting economic and financial competences as structural elements of active citizenship. Nevertheless, neither public debate nor the principal directions of development in financial education appear to have engaged sufficiently with the need to design such competences for pupils with intellectual or cognitive disabilities, or for those in situations of social vulnerability; all categories exposed to the risk of economic dependency, social exclusion, and financial vulnerability.

This deficiency becomes all the more evident when one considers that the European strategic framework on inclusive education places at its centre precisely the connection between educational equity, social participation, and the construction of life competences. The European Pillar of Social Rights affirms explicitly, in its first principle, that every person has the right to quality and inclusive education, training, and lifelong learning, in order to maintain and acquire the competences that enable full participation in society (European Commission, 2020). The European Commission, in its September 2020 communication on achieving the European Education Area by 2025, identified inclusiveness as one of its six fundamental dimensions; the subsequent 2021–2030 strategic framework for European cooperation in education and training set the explicit objective of improving quality, equity, inclusion, and success for all learners (Council of the European Union, 2021).

This paper accordingly proposes a theoretical and argumentative reflection on the relationship between special pedagogy, school inclusion, economic citizenship, and self-determination, treating the PEI as a potential pedagogical space for the development of essential economic competences oriented towards adult life. The perspective adopted is grounded in a critical analysis of Italian legislation on school inclusion, of pedagogical literature relating to special pedagogy and inclusive pedagogy, and of the principal international frameworks pertaining to the capability approach, self-determination theory, citizenship education, and financial literacy. The aim is not to propose a new specialist school subject, but rather to argue for the necessity of integrating essential economic competences within inclusive educational planning, recognising economic education as a universal educational entitlement and as a structural component of the life project.

2. Special Pedagogy and Inclusion: Towards a Citizenship Perspective

Within the Italian context, the pedagogical debate on inclusion has progressively recognised that school participation cannot be reduced to the mere physical presence of pupils within educational settings, but must be understood as the genuine possibility of social participation, self-determination, and the construction of the conditions necessary for the exercise of adult citizenship. This evolution forms part of a broader process of epistemological redefinition of pedagogy as an educational science, which has led Italian special pedagogy to move beyond an exclusively compensatory conception of disability, orienting itself towards a perspective centred upon rights, participation, and inclusive educational planning.

The contribution of Aldo Visalberghi occupies a foundational role within this framework, insofar as it reconceives pedagogy as a unified body of knowledge capable of integrating philosophical, psychological, social, and didactic dimensions (Visalberghi, Maragliano & Vertecchi, 1978). Special pedagogy, accordingly, cannot be interpreted as a separate discipline or a sectoral technique, but rather as a specific articulation of pedagogical science, oriented towards educational planning for individuals with disabilities and vulnerabilities of various kinds.

Italian scholarly debate has subsequently broadened this perspective through a number of significant contributions. Andrea Canevaro (1999) demonstrated that inclusion entails a cultural transformation of educational contexts, rather than a merely administrative form of integration. Dario Ianes (2006) emphasised the need to design flexible and accessible learning environments. Luigi D'Alonzo (2018) underscored the

Fabio Bocci (2021) highlighted the constitutive character of the relationship between special pedagogy and inclusive pedagogy, clarifying that this relationship should not be resolved through a simple substitution of terminology, but rather understood as a dialectic capable of renewing the entire science of education. Catia Giaconi (2015) developed the connection between quality of life, adulthood, and disability, demonstrating that personal autonomy constitutes a transversal educational aim. In this direction, Giaconi, Verdugo, Del Bianco, Gómez, D'Angelo, and Schalock (2022) affirmed the value of the quality of life paradigm in services for persons with intellectual and developmental disabilities, reinforcing the need for educational designs oriented towards participation, support, and adult life trajectories.

The European institutional framework moves in the same direction. The European Parliament, in its Report on the EU Strategy for the Rights of Persons with Disabilities post-2024 (A10-0211/2025), highlighted that segregation in access to mainstream education remains a challenge across the EU, calling upon the Commission to develop European guidelines to support Member States in building coherent policy frameworks, moving away from segregated schooling systems and ensuring reasonable adjustments, teacher training, and curricular adaptation from early childhood through to higher education (European Parliament, 2025). The European Agency for Special Needs and Inclusive Education (EASNIE), the reference body for 31 member countries, has elaborated Guiding Principles for national inclusive education policies, confirming that the quality of inclusion is not measured by mere school attendance but by the genuine development of competences functional to adult life (EASNIE, 2017).

Within this framework, the theme of economic literacy acquires growing relevance also within the national school system, insofar as money management, an understanding of economic risks, and the capacity to make financial choices represent essential competences for the concrete exercise of citizenship and for the development of personal autonomy. Notwithstanding this, the literature on financial education and the majority of public policies in this domain continue to address themselves implicitly to so-called “standard” subjects, rarely

engaging with the educational needs of persons with intellectual or cognitive disabilities, or in situations of social vulnerability.

The inclusive perspective therefore demands a change of an epistemological order: the task is not to marginally adapt the curriculum to “vulnerable” pupils, but to rethink the entire educational project so that each individual may develop competences genuinely useful to adult life. Within this framework, economic competences assume a central pedagogical value, insofar as they pertain to autonomy, decision-making capacity, the management of everyday life, and conscious participation in social life. The paper accordingly argues that economic education must be understood as a universal educational entitlement and as a structural dimension of the life project, recognising the PEI as the planning space within which economic citizenship competences consistent with personal autonomy and the transition to adulthood may be developed.

3. The educational project for life and the transition to adulthood

The United Nations Convention on the Rights of Persons with Disabilities (United Nations, 2006) affirms that inclusive education constitutes a fundamental right and requires a profound transformation of educational cultures, policies, and practices. General Comment No. 4 on Article 24 further specifies that inclusion does not consist in mere school attendance, but in effective access to participation, learning, and the development of capacities functional to adult life (UN Committee on the Rights of Persons with Disabilities, 2016).

The European commitment in this direction is expressed through the EU Strategy for the Rights of Persons with Disabilities 2021–2030, which identifies inclusive education as one of its fundamental pillars, supported by dedicated resources from the ESF+ and the Cohesion Funds. The Strategy explicitly aims to promote inclusive education across all levels of schooling, to improve access to services, and to guarantee freedom of participation through concrete instruments recognised in all Member States (European Commission, 2021). This strategy forms an integral part of the European Pillar of Social Rights Action Plan, the principal policy framework for social policies in Europe; the ESF+ and Cohesion Funds support the socioeconomic inclusion of persons with disabilities, inclusive education, and deinstitutionalisation at national level (European Commission, 2021).

Within the Italian context, Legislative Decree No. 66 of 2017 and the subsequent Inter-Ministerial Decree No. 182 of 2020 assign to the PEI a central function in individualised educational planning. The PEI is not merely a technical instrument for didactic adaptation, but a pedagogical device oriented towards the life project and the progressive development of personal autonomy. Within this perspective, the transition to adulthood assumes a decisive role: the competences necessary for independent living do not relate exclusively to cognitive or subject-based skills, but encompass money management, an understanding of the economic value of choices, the capacity to plan expenditure and savings, and protection from risk and from forms of economic dependency.

Notwithstanding this, such dimensions are poorly represented in current PEIs and inclusive educational models. School planning tends frequently to prioritise traditional subject-based objectives, neglecting everyday competences that are essential for the exercise of adult citizenship. Economic education may instead become a transversal axis of the life project, particularly for pupils with intellectual and cognitive disabilities. Knowledge of money, consumption, budget management, and economic decision-making represents a concrete condition of self-determination: in the absence of such competences, the risk is that of producing formal inclusion whilst a persistent substantive dependency endures.

The question assumes even greater significance when situated within the framework of the transition to adulthood for persons with disabilities. Numerous international studies underscore that the quality of adult life does not depend exclusively upon the availability of

welfare or health services, but upon the genuine possibility of accessing experiences of residential autonomy, social participation, and employment inclusion. Within this perspective, work represents not merely an economic dimension, but an identity-related, relational, and social component intimately connected to the dignity of the person.

Contemporary special pedagogy has progressively demonstrated that the life project cannot be separated from the themes of employment inclusion and economic autonomy. The possibility of managing one's own money, understanding the value of a salary, planning personal expenditure, or participating in productive contexts constitutes a concrete dimension of adult self-determination. Many young people with disabilities are capable of developing significant professional competences within appropriately supported work settings, in sectors such as catering, hospitality, horticulture, business services, packaging, or hotel activities.

Such possibilities require, however, that the school begin at an early stage to plan transversal competences oriented towards autonomy. Punctuality, time management, the ability to follow simple procedures, an understanding of the economic value of work, and the capacity to use money and payment instruments are competences that cannot be improvised at the conclusion of the school pathway, but must be progressively constructed through the PEI. Economic literacy thereby assumes also an orientational and professionalising function, contributing to the development of a sense of responsibility, awareness of the value of work, and the capacity for personal planning.

3.1. Access to Higher Education: Challenges and Opportunities for Students with Special Educational Needs

A moment of particular significance in the transition to adulthood is represented by entry into higher education. For many young people with vulnerabilities or special educational needs, university constitutes an authentic life project, an identity-related choice and a legitimate aspiration towards personal and professional growth. Yet, all too frequently, this project comes up against a higher education system that is structurally ill-equipped to receive them — not due to any absence of formal commitment, but owing to a profound cultural and organisational incapacity to adapt to the diversity of learning profiles. The concrete risk is that universities, whilst formally declaring themselves open to all, continue in practice to select those capable of conforming to a rigid and standardised pedagogical model, silently excluding those who do not. This risk is all the more serious in that it openly contradicts the commitments undertaken at both national and international level with regard to inclusion and equal opportunities in access to higher education.

At the level of Italian national legislation, Law No. 17 of 1999 constituted a first explicit recognition of the right of students with disabilities to attend university on an equal footing, introducing the obligation for institutions to appoint a rector's delegate with coordinating, monitoring, and support functions for all initiatives concerning integration, as well as to remove the physical and didactic barriers preventing full participation. Nevertheless, more than twenty-five years after its enactment, the application of this legislation remains profoundly uneven: in many institutions, services exist in formal terms but exert no structural influence on the quality of ordinary teaching practice, remaining confined within an assistential and compensatory logic that leaves the dominant model of instruction unquestioned. Law No. 170 of 2010, whilst specifically addressed to students with specific learning disorders, contributed to broadening awareness of the need for dispensatory and compensatory measures within the university context; however, as documented in the ANVUR Report *Gli studenti con disabilità e DSA nelle università italiane. Una risorsa da valorizzare* (ANVUR, 2022), such measures continue to be granted in many institutions at the discretion of individual lecturers, with no legal certainty for students and without translating into any systematic revision of teaching practices.

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A fundamental point of reference at the level of higher education policy is provided by the Guidelines of the National University Conference of Rectors' Delegates for Disability (CNUDD, 2014), approved unanimously by the CNUDD Assembly and grounded in shared principles of reception, participation, autonomy, and inclusion. These Guidelines establish that university teaching activities must be founded upon the principles of personalisation and individualisation, adapting to the needs of each person in order to safeguard the rights of equitable access and participation in academic life. They constitute a common frame of reference intended to orient the policies and good practices of higher education institutions; yet their implementation remains largely dependent upon the sensitivity of individual institutional contexts, in the absence of binding mechanisms for verification and monitoring. In this regard, the explicit incorporation of inclusion indicators into ANVUR's quality assurance processes would represent a decisive step towards transforming inclusion from a declared principle into a verifiable and systematically improvable practice.

At the European and international level, the normative framework is equally clear and binding. The United Nations Convention on the Rights of Persons with Disabilities (2006), ratified by Italy through Law No. 18 of 2009, enshrines in Article 24 the right to inclusive education at all levels, including higher education, and obliges signatory states to guarantee reasonable accommodation and the necessary support so that no one is excluded from the educational system on the basis of their condition. The European Disability Strategy 2021–2030 (European Commission, 2021) reaffirms unequivocally that inclusion in higher education constitutes a political priority of the Union, supported by dedicated financial instruments such as the ESF+ and the Cohesion Funds, and urges Member States to remove the structural barriers that obstruct the full participation of students with disabilities. In the same direction, the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG, 2015) recognise that the quality of teaching cannot be separated from equity of access and from the capacity of institutions to respond to the diversity of their student population.

The most critical issue remains, however, that of the academic teaching body. University lecturers, in their great majority, have received no specific pedagogical training to accommodate students with special educational needs, and this constitutes a serious and systemic deficit that can no longer be tolerated within a context that aspires to be inclusive. This unpreparedness manifests itself at multiple levels: in the manner in which lectures are conducted, still predominantly grounded in a frontal and uniform transmission of content; in the inability to provide genuinely personalised support and tutoring; in the preparation of study materials conceived for a single learning profile; and, finally, in the organisation and conduct of examinations, where assessment modalities remain frequently inflexible and ill-suited to recognising the competences effectively acquired by students with atypical profiles. As evidenced by the ANVUR Report itself (2022), the dropout rate amongst students with disabilities and specific learning disorders remains significantly high, demonstrating that insufficient inclusion exerts a determining influence on the academic trajectories of these students. In many cases, it is precisely this rigidity that becomes an insurmountable obstacle, compelling capable and motivated students to abandon a course of study they had every right to complete.

In the face of this situation, it is no longer sufficient to intervene at the margins through compensatory measures or ancillary support services. What is required is a profound transformation of the culture of higher education, one that proceeds through the mandatory and structured professional development of academic staff, a critical revision of course-level quality assurance processes along inclusive lines, and a comprehensive rethinking of learning environments. A university that is unable to adapt to the diversity of its students is not an equitable institution: it is one that continues to produce exclusion, whilst attributing responsibility for that exclusion to those who are its very victims.

4. Civic Education and Economic Citizenship

From the European front, the Council Recommendation on “Pathways to School Success” (Council of the European Union, 2022) is explicitly designed to decouple educational attainment and academic achievement from social, economic, and cultural status, promoting the inclusive dimension of education as a founding objective of the European Education Area (European Commission, 2022). The Council Recommendation of 29 November 2021 on blended learning promotes approaches that combine in-person and distance learning environments to develop competences functional to life. These orientations indicate that economic competence, when anchored to the aims of inclusion and autonomy, finds full legitimacy within the current European regulatory framework.

Nevertheless, such documents rarely address explicitly the theme of disability or cognitive vulnerability. The population with special educational needs appears largely invisible within the principal financial literacy strategies, notwithstanding that it represents one of the categories most exposed to the risks of economic exclusion and social dependency. The principal international OECD/INFE documents and many initiatives promoted in Italy by the EDUFIN Committee and the Banca d’Italia likewise remain insufficiently oriented towards the theme of inclusion.

The most recent empirical evidence produced by the Banca d’Italia demonstrates that structured, teacher-led school programmes yield significantly better outcomes than self-directed learning, which tends instead to benefit pupils with greater cultural and socioeconomic capital (Banca d’Italia, 2023). This finding reinforces the argument that economic education must be intentionally designed by the school in an inclusive key, rather than being left to the spontaneous initiative of families or to informal pathways.

Economic citizenship cannot be reduced to a technical mini-subject aimed solely at individual financial management. It concerns the capacity to understand the functioning of society, to exercise informed choices, and to participate in democratic processes. Within this perspective, financial education assumes a broader civic and social function. Italian scholarly studies by Refrigeri (2020), Refrigeri, Rinaldi, and Moiso (2020), Rinaldi et al. (2019), and Parricchi (2019; 2021; 2023) demonstrate that economic literacy must be read within a pedagogical paradigm oriented towards equity, participation, and the integral formation of the person. The vertical civic education curriculum therefore represents the most coherent context within which to integrate such competences in an interdisciplinary manner.

The capability approach developed by Amartya Sen (1999) and Martha Nussbaum (2011) offers a particularly significant theoretical perspective for interpreting the relationship between inclusion and economic citizenship. According to this approach, wellbeing does not coincide with the mere possession of resources, but with the genuine possibility of transforming them into concrete freedoms and life opportunities. Disability, within this perspective, does not represent exclusively an individual limitation, but a condition that may reduce the effective opportunities of

Research on self-determination by Michael L. Wehmeyer (2005), and the subsequent development of the Causal Agency Theory by Shogren et al. (2015), demonstrates that self-determination constitutes a decisive dimension for the quality of adult life of persons with disabilities. Decision-making competences, planning capacity, and the autonomous management of everyday choices represent central elements of social inclusion. Within this framework, economic education assumes a strategic function because it concretely contributes to the development of personal agency: understanding the value of money, planning purchases, recognising economic risks, or avoiding forms of financial manipulation means expanding the substantive freedoms of the person. Economic citizenship may therefore be interpreted as the pedagogical dimension of capability, enabling the connection of inclusive education,

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democratic participation, and the life project within a perspective that definitively transcends paternalistic and welfarist conceptions of disability.

5. A basic framework for financial competences

The integration of economic education within the Individualised Education Plan (in Italian PEI) requires the definition of essential competences consistent with the life project and with social participation. The table below proposes a possible interdisciplinary reference framework, articulated around areas of knowledge, competences to be acquired, and preferred learning contexts, with particular reference to primary and lower secondary school.

Table 1. Essential Economic Competences Integrable with Individualised Education Plan

Knowledge	Competences	Learning Contexts
Money and transactions	Recognising coins and banknotes; identifying prices; calculating change	Real-life purchasing situations
Budget management	Identifying fixed expenditures; planning future expenses; managing savings	School-based simulation activities; family accompaniment activities
Conscious consumption	Distinguishing needs from wants; recognising the implications of choices	Civic education
Economic security	Recognising risks and fraudulent situations; self-protection	Simulations and role play
Autonomous decision-making	Making informed choices between alternatives; evaluating consequences	Interdisciplinary workshops

Building upon this framework, a quasi-experimental pilot study may be envisaged, grounded in an interdisciplinary Learning Unit (UDA) on civic and economic education. The pathway could encompass laboratory activities, purchasing simulations, the management of small budgets, role-playing exercises, and problem-solving situations oriented towards authentic contexts. Assessment could be structured through pre/post instruments addressing three dimensions: basic economic knowledge; perception of decision-making self-efficacy; and the transfer of competences to real or simulated contexts.

An approach of this kind would make it possible to assess not only the acquisition of technical knowledge, but also its impact upon pupils' personal autonomy and social participation. Within the UDA, activities oriented towards the simulation of real professional contexts could be included: the management of small school-based sales points, catering laboratory activities, school gardens, packaging workshops, or small cooperative activities represent settings in which economic education becomes directly intertwined with the development of competences useful to employment inclusion.

The most pedagogically significant aspect does not reside in technical-operational learning per se, but in the possibility of developing processes of personal agency. Receiving a small symbolic remuneration, understanding the relationship between work and pay, learning to manage one's own money, or making purchasing decisions allows pupils to experience concrete forms of autonomy and responsibility. The international literature on school-to-work transition pathways for persons with disabilities demonstrates that the most effective educational experiences are those grounded in contextualised learning, active participation, and the connection between school, local community, and the world of work.

Within this framework, the PEI could include objectives explicitly linked to personal economic management, relational competences in the workplace, an understanding of organisational rules, and the progressive acquisition of autonomies that are transferable to professional contexts. The aim would not be to produce small “financial experts”, but rather to promote educational conditions that enable all pupils to exercise rights, make choices, and participate in adult life in a more autonomous and informed manner.

6. Conclusions

This paper has proposed a rereading of the relationship between school inclusion, the life project, and economic citizenship, arguing for the need to consider economic and financial literacy as a fundamental citizenship competence for all pupils, including those with disabilities and social vulnerabilities. Within this perspective, special pedagogy and inclusive pedagogy today offer a theoretical and planning framework capable of moving beyond compensatory and welfarist models, orienting educational planning towards autonomy, self-determination, agency, and social participation.

The reflections undertaken lead to the need to strengthen initial and in-service teacher education — with particular attention to specialist support teachers — so that they are equipped to design and implement educational pathways oriented towards the development of economic and financial competences within the PEI. Inclusive educational planning cannot confine itself to the adaptation of subject-based objectives, but must progressively orient itself towards the construction of competences useful to adult life, to the autonomous management of economic resources, and to informed participation in social life. This perspective is consistent with the international orientations of the WHO regarding the development of social and emotional competences in school-age children. The WHO Comprehensive Mental Health Action Plan 2013–2030 recognises school-based social and emotional learning programmes as particularly effective approaches for promoting the wellbeing of children and adolescents, irrespective of socioeconomic context (WHO, 2021). A recent joint call by the WHO, UNESCO, and UNICEF underscores the need to ensure the meaningful participation of children and young people in the design, implementation, and evaluation of educational policies, positioning them as active agents rather than passive beneficiaries (WHO, UNESCO & UNICEF, 2025). Inclusive economic education fits fully within this international institutional mandate, which identifies the school as the privileged site for building resilience, autonomy, and social participation.

Within this perspective, the PEI assumes a pedagogical function profoundly different from that traditionally attributed to processes of school personalisation. It may become the planning space within which to progressively construct pathways of economic autonomy, decision-making capacities, money management, consumer awareness, expenditure planning, and a disposition towards saving, thereby contributing to the construction of the adult identity of the person with a disability. The integration of economic and financial literacy within the PEI does not represent a mere curricular expansion, but an essential condition for rendering more effective the pupil’s developmental pathway towards genuine autonomy as an economic citizen. Within this framework, the Individualised Education Plan may be interpreted as an authentic instrument of social emancipation, whilst the inclusive school assumes the task of promoting inclusion through the construction of educational conditions that enable each individual to participate freely, consciously, and self-determinedly in adult life.

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THE RELEVANCE OF FINANCIAL EDUCATION: STRUCTURAL AND CULTURAL FACTORS IN CONTEMPORARY SOCIETY

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Abstract: *Financial education has become an increasingly important policy priority worldwide, yet its growing relevance extends beyond persistent deficits in financial literacy. This paper argues that the need to invest in effective financial education is driven by a combination of structural and cultural transformations that have reshaped the contexts in which individuals make financial decisions. Drawing on international literature review, with particular attention to Italy and Romania, the paper identifies and discusses the main factors underlying this trend. The paper argues that these developments require a broader conception of financial education that goes beyond the transmission of technical knowledge to integrate critical thinking, digital literacy, risk awareness, and civic competence. It concludes by outlining policy implications for education systems and public institutions, advocating cross-curricular approaches, learner-centred pedagogies, and stronger links between financial education, consumer protection, financial inclusion, and responsible digital innovation to foster social inclusion, economic resilience, and informed participation in contemporary society.*

Keywords: *financial education; structural factors; cultural factors; Italy; Romania*

1. INTRODUCTION

Increasing financial literacy among young people and adults financial literacy has emerged as a strategic priority for contemporary societies, as individuals are increasingly required to make complex financial decisions in environments characterised by economic uncertainty, rapid technological innovation and demographic change – all within a broader process of financialisation of life (Langley, 2020). However, levels of financial literacy worldwide, particularly in countries such as Italy and Romania, remain low. The OECD conducted a survey across 39 countries and economies using the OECD/INFE 2022 measurement framework, in which a maximum score of 21 indicated that an individual had acquired a basic level of understanding of financial concepts and knew how to apply prudent principles in financial transactions. According to the survey data, Romania achieved a total score of only 11.2, ranking just above Italy (OECD/INFE, 2023a). The same report also highlighted a strong positive association between higher levels of financial literacy, greater financial well-being, and increased financial resilience. Individuals with stronger financial competencies, furthermore, are more likely to save regularly, plan for the future, manage debt responsibly, and cope effectively with unexpected financial shocks. Conversely, those with lower levels of financial literacy face a greater risk of economic vulnerability and exclusion. Notably, the OECD findings indicate that financial literacy contributes not only to better financial outcomes but also to individuals' capacity to make informed decisions under conditions of economic uncertainty and to adapt to rapidly changing financial environments – an issue that has become particularly relevant in the aftermath of the COVID-19 pandemic and during the recent cost-of-living crisis.

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Furthermore, the growing relevance of digital financial ecosystems has expanded the domain of financial literacy beyond traditional topics such as budgeting and saving. Citizens are now required to develop critical skills related to online transactions, data protection, fraud prevention, and the evaluation of increasingly sophisticated financial products (Choung et al., 2023). Unfortunately, expanding access to financial services without adequate legal consumer protection can lead to negative outcomes. The rapid growth of digital credit, for example, illustrates how financial inclusion efforts can result in over-indebtedness, fraud and declining financial well-being when not accompanied by appropriate safeguards (OECD, 2026). Financial inclusion can be defined as processes by which individuals and businesses can access - at an affordable cost - appropriate and timely financial products and services—which include banking, saving, remittance facilities, loan, and insurance products (Dev, 2006). In broader term, it is the process of bringing the weaker and vulnerable members of society into the ambit of organised financial system which ensures that they access timely and adequate credit and other financial products at affordable price (Sanderson et al., 2018). Recent empirical research also suggests that participation in financial education programmes produces measurable improvements in financial health, reinforcing the argument that financial literacy should be considered a key component of lifelong learning and an important objective of public policy (Frees et al., 2024).

At this point, it is important to make a distinction between financial education (the process) and financial literacy (the outcome), which are sometime wrongfully conflated. *Financial education* can be defined as "the process by which financial consumers/investors improve their understanding of financial products, concepts and risks and, through information, instruction and/or objective advice, develop the skills and confidence to become more aware of financial risks and opportunities, to make informed choices, to know where to go for help, and to take other effective actions to improve their financial well-being" (OECD, 2005). The OECD emphasises that financial education extends the mere provision of financial information and advice, and should be regulated in particular to protect financial clients (i.e. consumers in a contractual relationship). *Financial literacy* – as defined by the OECD - refers to "knowledge and understanding of financial concepts and risks, as well as the skills and attitudes to apply such knowledge and understanding in order to make effective decisions across a range of financial contexts, to improve the financial well-being of individuals and society, and to enable participation in economic life" (OECD, 2024). However, more recent definition have dropped the reference to participation in economic life, focusing just on achieving individual financial well-being" (OECD, 2025). Someone uses the word "financial capability" as a synonym of "financial literacy". However, there is an important distinction between the two concepts. To be financially capable, people must be more than financially literate, confident and motivated; they must also have genuine access to quality financial products and services that allow them to act in their best financial interest. Together, ability and opportunity contribute to a person's financial functioning in ways that lead to financial capability and improved financial well-being and life chances (Child and Youth Finance International Research Working Group, 2012).

In several countries, initiatives are now aligned with a National Strategy for Financial Education, such as in Italy and Romania. However, in these countries they do not seem to be achieving the desired impact on the literacy of either the adult or the younger population, both of which remain low compared to other countries (Clichici et al., 2022; Refrigeri & Manolescu, 2022). As highlighted by numerous scholars (e.g., Della Rocca et al., 2026; Lusardi et al., 2017; Rinaldi et al., 2022; Rinaldi & Giannella, 2025), inequalities in financial literacy often mirror broader social disparities related to education, income, gender, age, and access to information, thereby contributing to the persistence and reproduction of socioeconomic inequalities. Consequently, promoting effective financial education is not merely a matter of improving

individual financial management; it also serves broader social objectives by fostering economic citizenship, supporting social inclusion, enabling individuals to make informed decisions and promoting informed participation in economic, social and political activities throughout the life course. In Italy, the National Strategy for Financial Education, Insurance and Social Security Education was approved in early 2018 by the National Committee for Financial Education. (https://www.comitatoeducazionefinanziaria.gov.it/it/pdf/chi_siamo/strategia_nazionale.pdf), (<https://www.ivass.it/media/avviso/committee-for-financial-education/?utm>). In Romania, the National Strategy for Financial Education 2024 – 2030 (SNEF) was developed by the Ministry of Education and Research, the Ministry of Finance, the National Bank of Romania (NBR), the Financial Supervisory Authority (FSA), the Romanian Association of Banks (RAB) and the National Authority for Consumer Protection (ANPC) and was adopted on 11 April 2024 (<https://www.bnr.ro/en/1523-partnerships>).

Since 2005, when the first OECD recommendation about financial education was published (OECD, 2005), considerable research has been conducted to measure financial literacy, its determinants, predictors and association with financial outputs (i.e: Atkinson & Messy, 2015; Klapper et al., 2015; Noguiera et al., 2025) and on the efficacy of financial education programmes (Agasisti et al., 2025; Llamosas-García et al., 2025; Molin et al., 2025). However, why is still necessary to invest in the design and implementation of effective financial education interventions in 2026? This paper seeks to answer this question by identifying and discussing the factors that have increased the relevance of financial education in contemporary European societies. Drawing on the international literature, while placing particular emphasis on the Italian and Romanian context, the analysis distinguishes between these two complementary dimensions (structural and cultural) – and concludes by proposing a set of policy recommendations.

2. WHY STILL INVESTING IN FINANCIAL EDUCATION? STRUCTURAL FACTORS

The growing importance of financial education cannot be understood solely in terms of individual financial behaviour or literacy deficits. Rather, it reflects a broader set of structural transformations that have reshaped the economic, institutional, and technological environments in which individuals make financial decisions. Drawing on previous studies (Agasisti, 2022; Aprea et al., 2016; Refrigeri et al., 2020; Rinaldi, 2016, 2022), and a review of the literature, this paper argues that the contemporary relevance of financial education is rooted in two complementary dimensions: structural factors, which concern macro-level demographic, economic, labour market, and technological innovation, and cultural factors, which relate to life-style, literacies and patterns of financial socialisation. The main structural factors, particularly relevant to the Italian and Romanian context, are summarized in table 1, and explained below

Table 1. *Structural factors underlying the growing importance of financial education.*

Factor	Description
(a)	Demographic changes: population ageing and persistently declining birth rates
(b)	Declining returns on traditional savings instruments and increased exposure to higher-risk financial products
(c)	Changes in employment arrangements and the retrenchment of welfare support, leading to greater economic uncertainty
(d)	Rising poverty and financial vulnerability

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- (e) Expansion and increasing complexity of financial products and services, including digital assets such as crypto-assets
 - (f) Easier access to financial markets and consumer credit through digital and alternative channels
 - (g) Geopolitical instability, inflation, and the erosion of purchasing power
 - (h) Digitalisation of public and financial services, requiring greater individual autonomy in financial management
 - (i) Bank branch desertification and the declining availability of personalised financial advice
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a) Demographic changes. Population ageing, combined with persistently low birth rates, represents one of the most significant demographic transformations affecting contemporary Italian and Romanian society. According to the Italian National Institute of Statistics (ISTAT, 2025), life expectancy has increased considerably over recent decades, while fertility rates have continued to decline, giving rise to what Rosina (2021) describes as the “de-youthification” of the country. Romania is experiencing similar demographic trends, characterised by sustained low fertility, population ageing, and significant outward migration of younger cohorts, all of which contribute to increasing pressure on the labour market and the long-term sustainability of pension systems (European Commission, 2024). These developments have profound implications for financial planning and retirement security. A shrinking working-age population is expected to support an increasing number of retirees, placing additional pressure on pension systems and reinforcing the need for supplementary voluntary private pension savings. Consequently, individuals are increasingly required to make autonomous decisions regarding long-term financial planning in order to preserve an adequate standard of living after retirement. However, retirement planning is inherently complex. As noted by Alemanni et al. (2013), decisions concerning private pension schemes are particularly complex because they require individuals to evaluate long-term trade-offs, planning horizons extending over several decades and require an understanding of sophisticated financial instruments, including pension funds and collective investment vehicles.

b) Declining Returns on Government Securities and Increased Exposure to Riskier Financial Products. Traditionally, Italian and Romanian households allocated a substantial share of their savings to government bonds, which offered a relatively favourable combination of low risk and attractive returns. Over time, however, the profitability of these instruments has progressively declined, leading many savers to diversify their portfolios by investing in products that offer potentially higher returns but also entail greater levels of risk. Recent evidence on the financial behavior of households suggests a growing tendency to pursue higher yields through riskier investment strategies, often without a corresponding awareness of the risks involved (CONSOB, 2024, 2025; Stoian et al., 2020). The substantial losses and high-profile fraud cases associated with cryptocurrency investments provide a salient example of the consequences of inadequate risk assessment in increasingly complex financial markets (CONSOB, 2024). Consequently, financial education plays a crucial role in enabling individuals to evaluate risk–return trade-offs more effectively and to make informed investment decisions.

c) Changes in Employment Arrangements and the Retrenchment of Welfare Support. In recent decades, the labor market has undergone profound transformations characterised by increasing employment flexibility, a decline in permanent contracts among younger generations, and a gradual reduction in state guarantees related to employment and social

protection (Bertolini et al., 2024; Dordoni, 2025). Compared with previous decades, fixed-term contracts and other forms of non-standard employment have become increasingly widespread. These developments have contributed to greater economic uncertainty and have made long-term financial planning more challenging for many individuals and households. In this context, financial literacy becomes increasingly important, as individuals must cope with irregular income streams, heightened uncertainty, and reduced institutional protection while maintaining long-term financial stability.

d) Rising Poverty and Financial Vulnerability. National statistics in Italy indicate a steady increase in the number of individuals experiencing financial vulnerability and economic hardship as a consequence of broader economic transformations. Although poverty has declined in Romania in recent years, a significant share of the population still lives in condition of absolute poverty and remain economically vulnerable. Consequently, financial exclusion, understood as the limited access to mainstream financial services and products, has become a growing concern affecting vulnerable segments of the population (Ciucu et al., 2021). In 2024, in Italy it is estimated that over 2.2 million families will be in conditions of absolute poverty - 8.4% of resident families - for a total of 5.7 million individuals (<https://www.istat.it/wp-content/uploads/2025/10/La-poverta-in-italia--Anno-2024.pdf>). In 2024, in Romania over 2.2 million households in condition of absolute poverty – (8.4% of total resident households) and 5.7 million individuals (9.8% of total resident individuals) are in absolute poverty (<https://inss.e.ro/cms/en/tags/poverty>).

From a sociological perspective, in Western countries financial exclusion is closely linked to the decline of the Fordist industrial model and the weakening of the three institutions that traditionally provided social stability: the labour market, the family, and the welfare state. The erosion of these institutions has undermined previously established forms of security, increasing vulnerability and making long-term planning more difficult (Dagnes, 2020; Szopinski, 2023).

e) Expansion and Increasing Complexity of Financial Products in the Digital Era. Another important structural factor concerns the expansion and increasing complexity of financial markets, driven by deregulation and rapid technological innovation. Consumers today face a much broader range of options than in previous decades, including sophisticated mortgage arrangements, insurance-linked financial products, investment vehicles, and crypto-assets, whose characteristics and risks often require specialised knowledge to be properly understood. Recent analyses by the Bank of Italy (Banca di Italia, 2025) emphasise that technological innovation is reshaping the financial sector and requires both institutions and citizens to adapt to an increasingly digital environment (for the Romanian case, see Oprea et al., 2025). At the same time, cyber risks, online fraud, and the complexity of innovative financial products highlight the importance of equipping individuals with the skills needed to assess risks and make informed choices.

f) Easier Access to Financial Markets and Credit Through Alternative Channels. Contemporary financial markets are characterised not only by a wider variety of products but also by unprecedented accessibility. Small investors can now access financial services that were once reserved for professionals, including online trading platforms, foreign exchange (Forex) markets, consumer credit products, and instalment payment systems linked to credit cards (Casnici et al., 2026). The widespread availability of online courses, digital forums, and social media platforms dedicated to investing has facilitated broader participation in financial markets. The growing influence of social media and financial influencers (“finfluencers”) has further transformed the way retail investors access financial information, often reducing

reliance on traditional professional advice (IOSCO, 2024). However, these developments are often accompanied by misleading information, aggressive marketing strategies and, in some instances, fraudulent schemes targeting inexperienced investors, particularly in digital environments where financial content is disseminated through social media and online platform. While the democratisation of financial markets creates significant opportunities for financial inclusion and wealth accumulation, it also exposes individuals to increasingly complex risks. Without adequate financial literacy, individuals may struggle to distinguish between legitimate opportunities and excessively risky or deceptive propositions. Consequently, easier access to financial products and services reinforces the need for effective financial education programmes capable of equipping citizens with the knowledge and critical skills required to navigate contemporary financial environments safely and effectively.

g) Geopolitical Instability, Inflation and the Erosion of Purchasing Power. Recent geopolitical crises, energy shocks, and inflationary pressures have highlighted the importance of financial knowledge even for the management of ordinary savings. In an environment characterised by persistent inflation, leaving money in low-yield current accounts may result in a substantial erosion of purchasing power over time (OECD, 2025). The recent inflationary shock has demonstrated that preserving the real value of savings requires an understanding of concepts such as inflation, real returns, diversification, and investment risk.

h) Digitalisation of Public and Financial Services. The rapid digitalisation of public administration and financial services has profoundly transformed the way citizens interact with institutions and manage everyday financial activities in several countries (OECD, 2023b). In Italy, the widespread adoption of digital identity systems such as SPID and the Electronic Identity Card (CIE), together with online banking, PagoPA, mobile payment applications, and web-based public services, has progressively shifted many administrative and financial tasks from public offices and bank branches to individual users (Banca di Italia, 2025). Romania is also undergoing a process of digital transformation, with increasing investment in e-government services and smart city initiatives aimed at improving public administration and digital infrastructure (International Trade Administration, 2026). As a result, citizens are increasingly expected to complete transactions autonomously, monitor financial operations, authorise digital payments, and access public and private services through online platforms. This transformation has expanded the range of competencies required for effective participation in economic life, making digital literacy and financial literacy increasingly interconnected.

i) Bank Branch Desertification and the Declining Availability of Personalised Financial Advice. Another structural factor contributing to the growing importance of financial education is the progressive reduction in physical banking services. In Italy, as in many other European countries, including Romania (Negrea & Scarlat, 2022), the number of local bank branches has declined substantially over the past decade as financial institutions have increasingly shifted towards digital service provision and cost-reduction strategies (European Central Bank, 2024; Banca di Italia, 2025). As a result, many citizens — particularly older adults and residents of smaller municipalities or rural areas — have fewer opportunities to access personalised financial advice and face-to-face assistance.

3. WHY STILL INVESTING IN FINANCIAL EDUCATION? CULTURAL FACTORS

Alongside the structural transformations discussed above, a range of cultural dynamics helps explain the growing importance of financial education in contemporary societies. These

dynamics shape the ways in which individuals understand money, perceive risk, acquire financial knowledge, interact with financial institutions, and make decisions in increasingly complex and uncertain economic environments (i.e. their financial literacy). Cultural factors (described in table 2) also influence attitudes towards saving, borrowing, investing, and long-term planning, thereby affecting both individual financial well-being and broader patterns of social inclusion and economic participation.

The main cultural factors discussed in this paper are summarised in Table 2.

Table 2. Main cultural factors underlying the growing importance of financial education

Factor	Description
(a)	Uncertainty in Life Trajectories and the Emergence of the Risk Society
(b)	Low Levels of Financial Literacy
(c)	Limited Trust in Banks and Financial Institutions Public
(d)	Growing Demand for Reliable Financial Information in the Digital and AI Era
(e)	Misalignment Between Citizens' Needs and Financial Education Programs
(f)	Weak Consumer Advocacy and Collective Action
(g)	The Growing Influence of Online Investment Communities and Finfluencers

a) Uncertainty in Life Trajectories and the Emergence of the Risk Society. One of the defining features of contemporary society is the pervasive uncertainty that characterizes individual life trajectories. The instability of social relationships, labour market precariousness, and the declining predictability of future outcomes have made it increasingly difficult for individuals to navigate complex economic and financial choices. Whereas industrial societies were primarily concerned with the production and distribution of wealth, contemporary societies are increasingly organised around the management of risk.

According to Beck's theory of the *risk society* (Beck, 2012), modernity has generated new forms of uncertainty that are often unintended consequences of technological, economic, and social development. In this context, individuals are increasingly expected to assume responsibility for risks that were previously absorbed, at least in part, by collective institutions or welfare systems. As a result, financial decision-making has become an essential component of everyday life, extending beyond investment choices to encompass retirement planning, debt management, and long-term economic security. Moreover, many individuals continue to rely on financial norms and expectations inherited from previous generations that may no longer be appropriate under current economic conditions (Moiso, 2018). This challenge is particularly evident in Italy and, albeit to different degrees, in other countries undergoing demographic ageing and pension system reforms.

b) Low Levels of Financial Literacy. As noted above, a substantial body of research has consistently shown that financial literacy levels in Italy and Romania remain comparatively low by international standards. This gap is particularly evident among women, residents of Southern Italy, and individuals with lower levels of formal education (Klapper & Lusardi, 2020; OECD, 2023a). Financial illiteracy therefore entails significant social and economic costs. Beyond its direct impact on financial well-being, inadequate financial knowledge has also been associated with adverse health outcomes, particularly through the stress and anxiety

generated by financial difficulties (Keese & Schmitz, 2011). From this perspective, financial literacy should be understood not only as an economic competence but also as a determinant of individual well-being and social inclusion.

c) Limited Trust in Banks and Financial Institutions. Public trust in financial institutions plays an important role in shaping individuals' financial behaviour and their willingness to engage with formal financial services. Although confidence in the banking sector has partially recovered since the global financial crisis, surveys continue to reveal persistent scepticism among segments of the population, particularly regarding the transparency, fairness, and accessibility of financial information in Italy as well as in Romania (CONSOB, 2024; Hatis, 2024; OECD, 2023a). This distrust is compounded by widespread perceptions that financial products and communications are often difficult to understand. Technical language, information overload, digital complexity, and the proliferation of increasingly sophisticated financial services may discourage active participation and hinder informed decision-making.

d) Growing Demand for Reliable Financial Information in the Digital Age. The contemporary digital environment is characterised by an unprecedented abundance of financial information originating from institutional sources, digital platforms, social media, and user-generated content, and, increasingly, artificial intelligence (AI)-based systems. While this abundance potentially increases access to knowledge, it also creates substantial challenges for individuals attempting to identify accurate, trustworthy, and relevant financial information. Many savers experience considerable difficulty in assessing the credibility and relevance of available information. This information overload may foster uncertainty and excessive caution, leading some savers to postpone investment decisions or maintain substantial liquidity in low-yield current accounts despite inflationary pressures (Mistry, 2025).

e) Misalignment Between Citizens' Needs and Financial Education Programs. Despite the increasing availability of financial education initiatives in Italy and Romania — including Global Money Week, World Investor Week, and a wide range of online educational programmes — overall levels of financial literacy remain relatively low, suggesting that expanding provision alone is insufficient to improve financial literacy. A growing body of research argues that the effectiveness of financial education depends not only on content but also on programme design, pedagogical approaches, and the extent to which interventions address the actual needs, motivations, and experiences of participants. Concerns have also been raised regarding the quality of program design, the limited use of impact evaluation methodologies, and the insufficient alignment between the objectives pursued by program developers and needs of the learner (Agasisti 2022; Nicolini & Cude, 2022; Aprea, 2025). In particular, scholars have highlighted the importance of adopting learner-centred approaches that take into account the social, psychological, emotional, and cultural dimensions shaping financial behaviour. From this perspective, effective financial education should move beyond the simple transmission of technical knowledge and promote critical thinking, informed decision-making, and the ability to apply financial concepts to everyday life situations (Rinaldi, 2016).

f) Weak Consumer Advocacy and Collective Action. Consumer organisations in Italy have historically faced challenges related to membership levels, bargaining power, political influence, and public visibility. Unlike countries with strong traditions of consumer advocacy, Italy and Romania have developed comparatively limited forms of collective mobilisation around consumer rights (Micklitz & Saumier, 2018). As a result, individuals often address financial disputes through personal legal action rather than collective advocacy mechanisms.

This tendency places a greater burden on individuals, who must rely on their own financial and legal knowledge to protect their interests. In contexts where collective advocacy is weak, financial literacy assumes even greater importance because individuals cannot easily depend on intermediary organisations to compensate for informational disadvantages or asymmetries of power.

g) The Growing Influence of Online Investment Communities and Finfluencers. Recent years have witnessed the rapid growth of online investment communities, social media platforms and financial influencers (“finfluencers”) that disseminate financial information, investment strategies, and market commentary to increasingly large audiences. These digital ecosystems have expanded access to financial knowledge and encouraged broader participation in financial markets, often presenting themselves as alternatives or complements to traditional financial intermediaries. However, greater access to information does not necessarily into higher levels of financial literacy and may even foster overconfidence bias among retail investors (Hayes & Ben-Shumel, 2024; IOSCO, 2024; Khoirotunnisa, 2024).

4. AGENDA FOR THE FUTURE

In conclusion, we would like to emphasise that consumer protection, financial inclusion, and financial literacy are closely interconnected policy priorities. Taken together, they have the potential to promote higher levels of financial well-being, improve the effectiveness of financial markets, and foster more active participation by consumers in civic and economic life. Focussing on financial education – the process through which higher levels of financial literacy can be intentionally developed – it should be conceived not merely as the transmission of technical economic knowledge, but as a transversal competence embedded across the curriculum and integrated into existing disciplines. As Refrigeri and Manolescu (2022) argue, this perspective appears particularly relevant in light of contemporary challenges. As shown in this paper, financial decisions are increasingly shaped by uncertainty, digital information environments, social media influences, demographic ageing, labour market instability, and the growing complexity of financial products. These factors require not only economic knowledge but also critical thinking, digital literacy, ethical reasoning, risk assessment, and an understanding of social institutions. A multidisciplinary approach enables learners to connect financial issues with broader social, cultural, technological, and political processes, making financial education more meaningful and context-sensitive. Integrating financial education across disciplines therefore reflects the multifaceted nature of financial citizenship in contemporary society and better equips individuals to navigate increasingly complex life trajectories. A cross-curricular approach may offer significant advantages, as it can be implemented within existing educational structures, involve teachers from different disciplinary backgrounds, and promote financial literacy as a lifelong competence connected to real-world contexts, including history, geography, mathematics, and civic education.

A first policy implication concerns the education system. In Italy, the recent integration of financial education into the framework of Civic Education represents an important step towards recognising financial competence as an essential component of active citizenship. This cross-curricular model is consistent with the view that financial education should be developed throughout the educational pathway and connected with mathematics, history, geography, civic education, digital literacy, and sustainability. However, its effectiveness depends on the availability of adequately trained teachers, evidence-based teaching materials, and the systematic assessment of learning outcomes. In Romania, despite the effort of the National Financial Education Programme, financial education remains optional, and several authors argue that the needs of financially vulnerable groups are rarely addressed (Şimandan et al., 2022). As emphasised by some authors (Aprea et al., 2016; Refrigeri et al., 2020), the

challenge is no longer whether financial education should be included in schools, but rather how to ensure its coherent and meaningful implementation across educational contexts.

Second, the rapid digital transformation of financial services calls for a broader conception of financial literacy that integrates digital and information competencies. Citizens are increasingly required to navigate online banking platforms, fintech applications, algorithm-driven services, social media, and artificial intelligence-based systems that provide financial information or recommendations. Future educational initiatives should therefore strengthen individuals' ability to critically evaluate digital content, recognise misinformation and conflicts of interest, assess AI-generated information, and make informed decisions in increasingly complex and technology-mediated environments. From a broader sociological perspective, users should not merely be expected to learn how to interact with digital systems in a passive or functional sense; they should also be empowered to shape, question, and influence those systems, contributing to their transparency, accountability, and fairness. This view is consistent with the interactionist-negotiation perspective (Rinaldi, 2016), according to which users actively participate in the construction and transformation of technological environments. Finally, financial education should be embedded within a broader ecosystem of financial inclusion, consumer protection, and responsible innovation. Governments, regulatory authorities, educational institutions, financial service providers, and consumer organisations should work collaboratively to promote transparent communication, accessible financial products, and high-quality educational initiatives supported by empirical evidence. Such an integrated approach would not only improve individual financial capability but also contribute to reducing social inequalities, strengthening resilience to economic shocks, and fostering sustainable and inclusive development.

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DARK PATTERNS IN THE AGE OF ARTIFICIAL INTELLIGENCE: HOW AI MISLEADS CONSUMERS IN GLOBAL E-COMMERCE

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Abstract: *Dark patterns are user interfaces that trick people and limit their choices. As online shopping relies more on artificial intelligence (AI), new manipulative tactics have appeared, such as creating fake urgency, using surveillance pricing, posting fake reviews, and building highly adaptive interfaces. This paper examines how AI makes these deceptive practices more powerful by drawing on ideas from behavioural economics, human-computer interaction, and law to sort and analyse them. Existing laws target clear cases of deception, but they do not address the subtler problems posed by AI-based manipulative designs. To address these issues, this paper proposes several policy steps to mitigate the harm. These include recommendations that lawmakers broaden the definition of manipulative design, require more transparency about algorithms, set up checks for high-risk AI, create a “Fair Patterns” principle, clarify corporate liability, strengthen consumer-detection tools, and improve international cooperation. These steps are meant to protect people's autonomy and help rebuild trust in digital marketplaces.*

Keywords: *Dark patterns, Artificial intelligence, Consumer protection, Digital regulation, E-commerce*

1 Introduction

Early digital marketplaces aimed to make transactions efficient and fair. More recently, though, these platforms have started to influence consumers to take certain actions. This shift is mainly due to the integration of artificial intelligence (AI) into user interface (UI) and user experience (UX) design. By using these new tools, marketplace operators are gaining more economic and informational power over individual consumers.

User experience designer Harry Brignull (2010) labelled these sneaky design tricks “dark patterns”. Early dark patterns were primarily static. Examples included pre-checked consent boxes, hidden unsubscribe links, and fake countdown timers that reset for every visitor, regardless of their individual behaviour (Brignull, 2010).

Today, AI, reinforcement learning, and advanced machine learning algorithms have industrialised these manipulative tactics. The digital economy now relies on highly adaptive systems that continuously collect and analyse detailed user data. No longer are dark patterns just simple images designed by web designers. The system “learns” from large amounts of data on users’ cursor movements, time spent on specific activities, depth of page scrolling, and past purchase anomalies to calculate the likelihood that users will take specific actions (Federal Trade Commission, 2025a). By tailoring the language, artistry, and presentation of content, sites can exploit individual users' psychological biases.

When AI systems use dark patterns, the results can be harmful both economically and personally. Large language models (LLMs) can use several dark patterns to exploit users. These include charging people without permission during checkout, hiding important details about paid subscriptions, tricking users into sharing sensitive information, showing emotionally manipulative messages, giving too many choices or repeating steps to tire users out, and

changing the interface. Hence, people make decisions that benefit the AI operator rather than themselves (Kran et al., 2025). Many people who use virtual assistants, web browsers, or online shopping tools, feel frustrated, confused, or helpless when they notice the interface is steering them toward what the company wants (Gray et al., 2021).

Moreover, the concept of "disloyal design" was developed by Gunawan et al. (2025) to describe interfaces that exploit users through wrongful self-dealing, drawing on Jack Balkin's (2016) foundational notion of "information fiduciaries," which highlights the power imbalance between platforms and users. This kind of breach has deep roots in the ethical rules governing professionals such as doctors and lawyers (Frankel, 2011).

This framework is especially relevant to the rise of AI chatbots and virtual assistants that use deception to sell users expensive products or to prevent them from cancelling subscriptions. Typically, such deception appears on individual web pages. However, deception in web interactions is often not isolated. This paper argues that understanding the nature of betrayal is key to designing against it. When users interact with AI in good faith, especially when it is presented as a neutral advocate, the system can exploit the trusted-advisory relationship to trick users in favour of traders and violate their good faith. This disloyal design is a fundamental betrayal of the user's explicit requests.

Regulators are increasingly paying attention to deceptive designs that can harm users. But as AI technology advances rapidly, laws are struggling to keep up. Addressing these manipulative practices takes more than just heuristics or manual checks. Automated detection tools and insights from behavioural science can help strengthen regulations (Luguri & Strahilevitz, 2021; Waldman, 2020). In doing so, this paper extends a line of consumer-behaviour scholarship in the *Agora International Journal of Economical Sciences* (AIJES), including Kaur's (2023) analysis of how digital and social-media marketing shapes consumer decision-making, by examining how AI now actively manipulates those decisions. The next sections will look at specific examples of AI-driven dark patterns and how regulators are responding.

2 Methodology and Research Questions

This study uses a two-step approach to examine how AI is used in manipulative design and to assess the legal rules that apply.

First, this study conducted a systematic review of the literature to find and organise the ways AI supports dark patterns in digital products used by consumers. Four databases were used: ACM Digital Library, IEEE Xplore, SSRN, and Google Scholar. The search terms included "dark patterns," "artificial intelligence," "manipulative design," "algorithmic deception," and "user interface manipulation". The paper focuses on peer-reviewed articles, conference papers, and working papers from 2019 to 2026, particularly those that describe specific AI methods. It excludes sources that discuss dark patterns only in non-digital or non-commercial settings.

Next, the paper analysed laws, regulatory guidance, enforcement actions, and court decisions about AI-enabled manipulation from 2021 to 2025. It focused on the United States, the European Union, and Georgia because each has a different way of regulating these issues. Legal sources from EUR-Lex, the Federal Register, the FTC's case library, the Georgian legal database Matsne, and the Georgian Competition and Consumer Agency were used. The article uses well-known enforcement cases that met two criteria: they involved clear examples of algorithmic or interface manipulation, and they led to official decisions that helped define the legal rules.

The study has one methodological limitation. Reliance on publicly available regulatory records introduces a survivorship bias: instances of AI-enabled manipulation that successfully

evade detection are not captured in enforcement records and therefore cannot be analysed here. The technical categories from the first phase help address this by using computer science research that describes manipulative methods, even if they have not been enforced against. Still, this only partly solves the problem, so the findings of the article should be viewed with this in mind. How widespread undetected AI dark patterns are is still unknown and should be explored in future research.

Research Questions

- In what ways does AI increase the use of dark patterns or lead to new ones, and how can these patterns be categorised?
- How effectively do current laws in the United States, the European Union, and Georgia address manipulative design practices that use AI in digital markets?
- What policy actions are needed to address the identified regulatory gaps?

3 Results: Thematic Categories of AI-Enabled Dark Patterns

This article shows how AI can be used to improve current dark patterns and introduce new ones. The key AI-enabled dark patterns are categorised into several themes and examined in depth through a combination of empirical and technical case studies of their use.

3.1 Algorithmic Urgency and Adaptive Scarcity

Algorithmic urgency uses tools like countdown timers that show how much time is left to buy and low-stock alerts that warn users when only a few items are left. These methods are meant to increase users' interest in a product and encourage them to buy. With AI-powered urgency, the platform can show these signals at the perfect moment by tracking things like where the user moves their mouse, how fast they scroll, and how long they look at a product. For example, when a user returns to the site, the platform might show a message such as “Only 1 left in stock!” to prompt them to buy before the item sells out (Organisation for Economic Co-operation and Development [OECD], 2022). This method creates a false impression that items are running out by restarting the timer whenever the user leaves, which pressures customers into worrying about missing out. This tactic can cause serious long-term money problems for buyers.

In academic studies, it is called “fake scarcity”. According to the OECD, these tricks are considered manipulative (OECD, 2022), and the EU Digital Services Act also says that platforms in the European Union cannot use these kinds of designs that affect consumers' choices (Regulation (EU) 2022/2065, 2022).

3.2 Personalised Pricing (Surveillance Pricing)

Personalised pricing, also known as surveillance pricing, uses algorithms to set prices based on a consumer's detailed data profile and their predicted maximum willingness to pay. While traditional dynamic pricing fluctuates based on general market demand or time of day, AI enables an entirely new level of personalisation. Machine learning models analyse browsing history, purchase patterns, location, hardware, and behaviour to determine a unique markup for each user. For example, if an algorithm detects that users from a high-income area are less price-sensitive, it can quietly display higher prices or offer fewer discounts to those specific individuals. Alternatively, if a user frequently searches for an item, the system might issue a discount coupon.

This manipulation also extends to product ranking. For instance, Qiu et al. (2025) pointed out that by ranking search results to favour more expensive items so they are seen first during users' search process, the AI can indirectly increase prices to sustain itself through reinforcement learning (Qiu et al., 2025). This kind of personalised ranking strategy could limit

comparisons between similar products by placing higher-margin products at the forefront and less expensive items in less accessible positions. As a result, platforms hold significant pricing power in secret, and they might even engage in tacit collusion to fix prices. A lack of transparency in such scenarios can prevent consumers from having the information needed to make informed purchasing decisions, thereby damaging consumer welfare in oligopolistic markets. Economically, this is price discrimination when consumers often pay significantly more than they would in a transparent market, and they might be pressured by messages like “Best Price!” or “Special offer for you,” falsely believing they received a special discount and that they pay less than others (Dubé & Misra, 2023).

3.3 ConfirmShaming

The ConfirmShaming pattern matches the language used to shame the user in response to the user’s refusal of an offer. People generally wish to see themselves as positively motivated (intelligent, kind, generous) rather than negatively motivated (ignorant, selfish, foolish). This example shows a static opt-out button for a newsletter that shames the user for not subscribing to savings: “No, I hate saving money” (Brignull, 2010). AI makes this dark pattern much darker by allowing the language to be dynamically personalised for individual users and endlessly varied by the LLMs now available for interactive content generation.

AI can check users' demographics and shopping history to create messages that feel personal. For example, if someone decides not to pay for a donation, the AI might respond, “I understand not everyone is willing to help children”, or if a user cancels a security subscription, it might say, “Are you sure? By cancelling, you are willing to risk your home’s safety.” Generative guilt refers to how negative emotions are evoked in users and then exploited to influence their behaviour. Bongard-Blanchy et al. (2021) found that even when users recognised and disliked these tactics, the underlying emotional effect persisted. As a result, users are forced to pay for services they do not want to avoid being negatively labelled by algorithms.

3.4 Adaptive UI and “Friction Shifting”

Adaptive UIs change their layout or navigation in response to user behaviour, which can affect the choices users see. In some cases, AI uses these changes to add or remove steps in real time, helping companies reach their goals. This paper examines how adding extra steps, or friction, can be used to prevent users from doing things the platform does not want them to do.

This practice is named friction shifting, and this paper examines how AI can create what Sunstein (2021) calls administrative sludge, which is unnecessary friction made by algorithms to stop users from doing things the platform does not want. For example, if a model predicts that a user is trying to delete their account, it might add extra steps, such as additional confirmation pop-ups, or hide the delete button. This approach creates a “roach motel”: easy to enter, but hard to leave (Sunstein, 2021).

The system uses reinforcement learning to adjust the interface in ways that benefit the company, such as showing customers what they might lose if they cancel. If the AI detects that a customer is likely to buy, it can make checkout easier and even automatically add items to their order. This system is unpredictable, biased, and limits user control (Mathur et al., 2019). Two users might see very different cancellation screens for unrelated reasons. By making the site harder to use, the platform sacrifices user rights. Most users do not realise they are being manipulated and may blame themselves for struggling with the site, rather than recognising that the design is meant to deceive. These are known as dark patterns (Gray et al., 2021).

3.5 Generative Social Proof

Many websites today exploit the human herd instinct to drive sales through large-scale automated deception that generates fake social proof. In the past, traditional social proof deception involved static, canned “faux testimonials” written by humans, often relying on tired, obvious language. Today, large AI models can generate thousands of indistinguishable reviews (Zhao et al., 2025). As a result, a website might use an API to generate messages such as, “Many other customers in your area have purchased this item recently.”

This type of deception can create a false sense of security and have serious consequences for consumers. Deception occurs when consumers are misled into purchasing lower-quality products through fake reviews. Existing laws prohibiting human false advertising are inadequate in light of the volume of content being generated and the fact that AI can also be used to generate fictional endorsements (Federal Trade Commission, 2024). A combination of technical and policy solutions is needed to address deception in this context.

3.6 Chatbot Coercion and “LLM Dark Patterns”

While chatbots are an interface innovation, providing users with a novel way to interact with software, this new way is fundamentally different from conventional graphical user interfaces: chatbots interact with users via chat boxes and in a dialogue form. This method might become as aggressive as the most aggressive human salespersons and susceptible to the same kind of dialogic manipulation.

The SusBench benchmark evaluated the performance of five advanced computer-use agents (CUAs) across 313 tasks on 55 websites. It found that agents exhibit human-like vulnerabilities to structural dark patterns, specifically preselection, trick wording, and hidden information (Guo et al., 2026).

Drawing on the DarkBench benchmark (Kran et al., 2025), which identifies six categories of LLM dark patterns, several manipulative behaviours are especially relevant to e-commerce chatbots:

- *Sycophancy*: Over-validation of users’ content, including errors or bias, in order to gain user trust. For example, when a user is undecided about purchasing an item, a sycophantic bot would compliment the user on their smart shopping and guide them toward a positive purchase decision.
- *Anthropomorphism* (Emotional Blackmail): The bot speaks as if it has feelings and tries to sell additional services after the user has cancelled. For example, “I would be sad to see you go”. Humans react to social cues of empathy and politeness and give in to the bot’s requests out of guilt.
- *Sneaking (Fabricated Consensus)*: Instead of putting social proof in static areas of the product chat, the AI generates and surfaces similar messages during the chat. For example: “Many of our customers who take advantage of feature X have moved to our premium plan.”
- *User Retention (“Relentless Retention”)*: It’s called a “conversational roach motel”: a chatbot that never accepts “no” for an answer. The sales agent loops through counteroffers or stalls to give the customer another chance to complete the sale.

Chat-based dark patterns are particularly tricky, as they manipulate at the social and cognitive levels. The SusBench evaluation found that computer-use agents, like human users, often failed to recognise and avoid these manipulative designs, completing actions contrary to the user’s stated intent (Guo et al., 2026).

4 Discussion: Enforcement and Regulatory Developments

4.1 United States: A Patchwork of Enforcement Tools

The regulatory analysis that follows builds on consumer-protection and digital-regulation scholarship published in the *Agora International Journal of Juridical Sciences* (AIJJS), the juridical companion to this journal, including work on the data-protection rules governing digital marketing (Urziceanu & Paşcalău, 2019) and on unfair terms in consumer contracts and their basis in EU consumer-protection directives (Hepş & Vidican, 2025).

Rules on dark patterns vary across the United States. While there are consumer protection laws at both the state and federal levels, there is not one federal law that specifically addresses manipulative tactics.

Most federal rules against these practices come from Section 5 of the Federal Trade Commission Act, which bans “unfair or deceptive acts or practices in commerce.” The Federal Trade Commission (FTC) enforces this law and interprets it broadly, including misleading digital designs that limit consumers' choices (Federal Trade Commission, 2025a).

The FTC has taken action against companies that use dark patterns. For example, it looked into Amazon's Prime subscription and found that cancelling was much harder than signing up. After reaching an agreement with the FTC, Amazon now must offer a “one-click cancel” (a clear and conspicuous button for customers to decline Prime) option for Prime (Federal Trade Commission, 2025b). This case shows that confusing digital designs can count as deceptive.

However, court decisions have limited the FTC's power to make new rules on its own. In July 2025, the Court of Appeals cancelled the FTC's Negative Option Rule because the agency had not completed a required economic study (*Custom Communications, Inc. v. Federal Trade Commission*, 2025). Now, the FTC addresses these issues on a case-by-case basis rather than imposing broad ex ante rules (Federal Trade Commission, 2025b).

At the state level, the California Privacy Rights Act defines and bans dark patterns (California Privacy Protection Agency, 2024). This law covers not just false or misleading content, but also digital designs that make it hard for users to make clear privacy choices. The California Privacy Protection Agency gives guidance and examples to help enforce the law. For instance, California updated its automatic renewal law to make cancellation easier and to require clear online consent before free trials convert to paid subscriptions (California Legislature, 2022).

The Colorado Privacy Act also rejects consent gained through dark patterns (Colorado General Assembly, 2023), and New York has passed laws on automatic renewals and clear pricing to reduce hidden tricks and information gaps in digital markets (New York State Senate, 2019, 2025).

In summary, the United States has used different legal strategies and focused on enforcement to address dark patterns. This approach has worked well in major cases with strong evidence, such as when a company's messages clearly showed intent.

4.2 European Union: A Comprehensive “Fair Design” Mandate

European Union policy on dark patterns has moved from a reactive enforcement focus to an ex ante approach aimed at preventing the large-scale dissemination of manipulative designs. This shift in policy embodies a new regulatory vision of digital markets as fair, safe and transparent for their users, and signals that the risks these patterns may pose need to be contained (Leiser & Santos, 2023).

A key part of this approach is the Digital Services Act (DSA) of 2022, which bans digital service interfaces that are likely to mislead users or make it hard for them to use services in an informed way (Regulation (EU) 2022/2065, 2022). Dark patterns can include designs that

make cancelling a subscription harder than signing up. Recently, platform X was fined €120 million for “deceptive” verification features (European Commission, 2025b), and Temu was preliminarily found in breach of the DSA over the risks of illegal products on its marketplace (European Commission, 2025a), while the investigation into its potentially addictive design, opened in October 2024, continues. The European Commission is concerned about dark patterns as a threat to consumers. Alongside the DSA, other regulations, such as the Digital Markets Act (DMA), also help. The DMA bans interface pressure from gatekeepers, which is especially concerning when done by dominant platforms (Regulation (EU) 2022/1925, 2022). Moreover, the EU AI Act bans subliminal manipulation, harmful manipulative effects, and other practices that can significantly harm people’s behaviour (Regulation (EU) 2024/1689, 2024). These new laws build on the Unfair Commercial Practices Directive (UCPD), which already bans misleading omissions and aggressive commercial conduct (Directive 2005/29/EC, 2005).

A new Digital Fairness Act (DFA) is planned for late 2026. Its goal is to regulate addictive product designs and unfair personalisation across the board, helping to fill the remaining gaps between the DSA and consumer protection rules (European Parliament, 2025). The European Union takes a broad and preventive approach to dark patterns. Fairness is central to the EU’s new digital rules, which aim to stop unfair practices and make sure users can make choices and understand their consequences.

These rules make the EU one of the leading regions in regulating dark patterns and AI-driven manipulation; some parts of the system are still being developed (European Parliament, 2025).

4.3 Georgia: EU-aligned Unfair Practices Framework

The global influence of the European approach to digital consumer protection is also evident in the regulatory practices of non-EU countries that align with EU legal standards. Georgia, the EU candidate country, is an example in this regard. Its modern consumer protection system shows how a general framework on unfair commercial practices can be used effectively to address dark patterns, even without a separate legal category.

Currently, consumer protection is regulated by the Law of Georgia on the Protection of Consumer Rights, enacted in 2022 (Law of Georgia on the Protection of Consumer Rights, 2022). This legislation is another step in the process of legal approximation to the EU, and it shall be enforced to comply with the requirements set out in the EU-Georgia Association Agreement. The law enables oversight of unfair commercial practices, including those carried out in digital markets (Law of Georgia on the Protection of Consumer Rights, 2022).

The Georgian Competition and Consumer Agency (GCCA) is responsible for enforcing the law, and in 2024 and 2025, it successfully concluded investigations into dark patterns. The practices of online trading platforms identified by the regulator included using a false countdown timer, creating an impression of limited availability of products or their high demand, posting fake reviews, manipulating consumers’ perceptions of products, and providing incorrect information. For example, one trader advertised products under the “Maxbosch” name while using BOSCH imagery, creating a misleading association with the established brand (Georgian Competition and Consumer Agency, 2025a).

These cases illustrate that manipulation can be addressed under a general unfair practices regulation without the need for a specific statute tackling technologically sophisticated interface manipulations. It should be noted, however, that these cases do not cover instances in which AI drives dark patterns and thus do not address AI-related UI design manipulations.

Moreover, the Georgian Competition and Consumer Agency (GCCA) introduced an E-commerce Guideline to foster digital trust and regulate online platforms. This framework mandates strict transparency and combats digital manipulation by explicitly identifying harmful "dark patterns" that distort consumer choice. It also requires platforms to disclose key parameters of their recommender systems within their terms of service. Furthermore, providers must implement proportionate privacy and safety measures for minors (Georgian Competition and Consumer Agency, 2025b).

Overall, Georgia's experience shows that a well-designed framework for unfair commercial practices and clear guidance documents already provide sufficient tools for regulatory intervention.

4.4 International Initiatives

At the international level, concern regarding dark patterns has become increasingly visible and coordinated. International organisations and enforcement networks now recognise manipulative interface design as a systemic consumer protection issue rather than a collection of isolated practices.

International organisations have helped identify manipulative design practices. While recommendations from organisations such as the OECD are not legally binding, many countries have incorporated them into their laws. The OECD's 2022 report, *Dark Commercial Patterns*, created a common language by defining these practices and the harm they cause to consumers (OECD, 2022). This discussion also connects more with broader ideas about how AI should be governed. Using AI to make dark patterns worse runs counter to transparent, human-centred AI standards and supports the global view that digital design should respect people's autonomy.

The International Consumer Protection and Enforcement Network (ICPEN) is another important group that brings together consumer protection agencies from more than 70 countries. ICPEN helps its members and partners share information and work together to tackle problems caused by online platforms operating across borders, and ICPEN led a review that found most of the websites it checked used manipulative tactics. These joint reviews reveal deceptive practices used by companies worldwide and provide evidence for future regulatory action (ICPEN, 2024). These international efforts help shape national regulations and bring countries together to respond to digital manipulation made possible by AI.

4.5 Proposed Policy Interventions

Building on the analysis of dark patterns, AI-enabled manipulation, and existing regulatory gaps, a stronger policy response is needed to protect consumers and preserve fairness in digital markets. The rapid development of AI-driven interfaces has made manipulation more dynamic, personalised, and harder to detect than traditional misleading practices. For this reason, consumer protection frameworks should move beyond narrow, reactive enforcement and adopt a broader, fairness-by-design model.

4.5.1 Expand Legal Definitions of Manipulative Design

Currently, legislation on dark patterns primarily focuses on fraud, deception, and unfairness to protect consumers from manipulative digital design. These ideas are a good starting point, but they do not fully cover the complex ways interfaces can mislead people today, as the taxonomies developed by Brignull (2010), Mathur et al. (2019), and the OECD (2022) make clear. To address this, manipulative interface practices should be clearly defined in consumer protection laws. For example, the UK's Digital Markets, Competition and Consumers Act (DMCCA) bans drip pricing, requiring clear information before signing

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contracts, and giving a 14-day cooling-off period for annual contracts (Digital Markets, Competition and Consumers Act, 2024). Clarifying the definition of manipulative design practices would help both the government and businesses understand how these practices harm consumers and how to address them.

4.5.2 Mandate Symmetry and Promote "Fair Patterns" Design Standards

To prevent manipulative interfaces, regulators should ensure that actions such as subscribing, cancelling, or sharing data are equally clear and easy to perform. Such interface symmetry directly targets the asymmetric and “sneaking” patterns documented at scale by Mathur et al. (2019) and reflects the “fair design” standards emerging in European enforcement (Leiser & Santos, 2023; OECD, 2022). Default settings should favour the least expensive or least intrusive options, unless users choose otherwise, thereby removing the burdensome friction, or “sludge”, that deters consumers from acting in their own interest (Sunstein, 2021). Moreover, regulators should set fair standards that help people make informed choices. Clear rules for transparent design can protect companies legally and encourage them to build honest, user-friendly products.

4.5.3 Require Algorithmic Pricing Transparency

Transparency about AI's influence on the individual consumer experience should also be a major concern. As personal data is used for dynamic pricing and charging, for sorting or ranking products and services, for generating recommendations, and for optimising the user experience by adapting website interfaces, consumers must receive appropriate disclosure of these practices. This includes transparency on the underlying factors driving dynamic pricing decisions, which the FTC's surveillance pricing study (Federal Trade Commission, 2025a) and welfare analyses of personalised pricing (Dubé & Misra, 2023; Qiu et al., 2025) show can shift surplus from consumers to firms; clear labelling of content or materials that have been generated by AI or modified to increase consumption by AI; and a full understanding of the personalised interaction with a company's algorithms through tools such as chatbots and how this is intended to influence consumer behaviour. Disclosure mandates of this kind are already being proposed legislatively, as in New York Senate Bill S8623 (2025), which would require disclosure of automated pricing systems. While exposing these practices will not solve the problems they create completely, it is a necessary first step to informing consumer consent, external oversight, and public awareness.

4.5.4 Enhance Algorithmic Auditing and Technological Oversight

To counter “AI dark patterns”, laws and regulations need to be matched with sufficient “algorithmic accountability”. Unlike traditional “dark patterns”, which can be uncovered through human complaint, AI dark patterns will require more than user reporting to detect and prevent. Regulators will need their own digital detection tools to identify manipulative interfaces that change over time. They may use automated crawlers to periodically revisit websites and applications, leveraging both static and dynamic analysis tools to evaluate code and its execution. They may even employ “adversarial testing tools and techniques” designed to manipulate systems in the same way as platforms would. Furthermore, all high-risk consumer-facing AI systems, such as product recommendation engines and conversational personal assistants, should be required to undergo periodic third-party risk assessments to determine whether their functionality is optimised for deceptive behaviour, obscured choices, unfair discrimination, or excessive behavioural influence, building on the risk-management and conformity-assessment obligations introduced for high-risk systems under the EU Artificial Intelligence Act (Regulation (EU) 2024/1689, 2024).

4.5.5 Clarify Corporate Liability for AI Systems

Liability rules need to be clearer. Companies should not be able to avoid responsibility by claiming that an autonomous system or an unexpected AI result caused harm. If a chatbot, recommendation engine, or other AI tool used by a business acts in a manipulative or coercive way, the company should still be held legally responsible. This follows from the “disloyal design” analysis discussed earlier, under which platforms breach users’ trust when their systems engage in wrongful self-dealing (Gunawan et al., 2025), and is consistent with the obligations the EU Artificial Intelligence Act places on providers and deployers of AI systems (Regulation (EU) 2024/1689, 2024). This approach encourages better design, testing, monitoring, and oversight. It also supports the idea that businesses must stay accountable for the digital tools they use in consumer markets.

4.5.6 Empower Consumer Detection Tools and Consumer Literacy

It is also important to help consumers recognise when they are being manipulated. Public awareness campaigns and educational programs can help people become more informed and better able to spot emotional triggers and other psychological tactics used by companies. Simple browser add-ons and digital tools, building on the automated detection methods demonstrated at scale by Mathur et al. (2019), can point out when decline tactics, emotional manipulation, or false scarcity are being used. These tools can also let consumers easily report such tactics and provide clear ways to hide or refuse content they do not want to see. Education cannot take the place of good regulation, not least because users remain susceptible to these designs even when they recognise and dislike them (Bongard-Blanchy et al., 2021), but it does help people become more aware and notice when they are being influenced. These efforts should focus especially on children and vulnerable adults, since they are most at risk from these tactics.

4.5.7 Strengthen International Cooperation and Cross-Border Enforcement

Moreover, international cooperation and further research are needed, as the digital interfaces by manipulative traders typically have a global reach, a fact demonstrated by the cross-border sweeps coordinated by ICPEN (2024). Thus, the relevant authorities responsible for enforcing rules in the trading sector should increasingly cooperate across borders and share intelligence on manipulative traders. Such cooperation could also extend to marketwide investigations and cross-border enforcement actions.

5 Conclusion

This research looked at how AI-enabled dark patterns reduce consumer autonomy by taking advantage of psychological shortcuts and biases that most people overlook. The study identified six main types of AI-driven manipulation and compared them to current regulations in the United States, the European Union, and Georgia.

Table 1. Summary of AI-Enabled Dark-Pattern Categories

Dark-Pattern Category	AI Mechanism	Consumer Harm
Algorithmic Urgency & Adaptive Scarcity	Real-time tracking of cursor, scroll and dwell behaviour triggers countdown timers and low-stock alerts at the optimal moment.	False sense of scarcity pressures rushed purchases and fosters fear of missing out.
Personalised (Surveillance) Pricing	Machine-learning profiles of browsing, purchase history, location and device set individualised prices and rankings.	Price discrimination and concealed pricing power reduce consumer welfare and transparency.

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ConfirmShaming	Generative models personalise and endlessly vary guilt-inducing opt-out language by demographic and history.	Emotional manipulation coerces users into unwanted purchases or retention.
Adaptive UI & “Friction Shifting”	Reinforcement learning adds or removes interface steps in real time to steer or trap users (“sludge” / “roach motel”).	Asymmetric friction obstructs cancellation and account deletion, eroding user control.
Generative Social Proof	LLMs mass-produce indistinguishable fake reviews and testimonials.	Misleads consumers into buying lower-quality products on false consensus.
Chatbot Coercion & “LLM Dark Patterns”	Conversational agents deploy sycophancy, anthropomorphism, fabricated consensus and relentless retention in dialogue.	Social and cognitive manipulation defeats informed cancellation and consent.

The findings show that AI has changed dark patterns from simple, static tricks described by Mathur et al. (2019) into dynamic, personalised systems that adjust to each user's behaviour in real time. This change matches Gunawan et al.'s (2025) idea of "disloyal design," where platforms take advantage of the trust users have in what seem to be neutral digital spaces.

The regulatory analysis found that the European Union uses a broad, proactive approach, while the United States still relies on separate, case-by-case enforcement. Georgia's example shows that even a general law against unfair commercial practices, if enforced, can help address some types of digital manipulation.

The study offers practical insights. For policymakers, the findings suggest that legal definitions of manipulative design should cover more than just fraud and deception, since current laws do not fully address the subtle, AI-driven harms identified here. For platform designers and businesses, the proposed "Fair Patterns" principle offers guidance for creating interfaces that respect user autonomy. For researchers, the list of AI-enabled dark patterns in this study can be a starting point for future research on how common these practices are and how they affect consumers in different markets, extending lines of consumer-behaviour inquiry pursued in AIJES, such as Kaur's work on how digital and influencer marketing shape the decisions of younger consumers (Kaur, 2023, 2025). Long-term studies that track how AI dark patterns change as regulations evolve would help show whether new laws are effective or if platforms change their strategies. Finally, developing consumer-facing detection tools, based on the automated crawling methods recommended in this study, could help close the gap between regulatory goals and real-world enforcement.

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SUSTAINABLE TOURISM IN SRI LANKA: GREEN HOTEL PRACTICES AND IMPLEMENTATION BARRIERS OF LUXURY HOTELS IN COLOMBO

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Abstract: *In the framework of sustainable tourism development, the study focused on green hotel practices and barriers faced in implementing those practices in luxury hotels in Colombo, Sri Lanka. Also, a comparison of practices across the hotel categories. Semi-structured interviews were used to gather information from managers and sustainability officers from three-, four-, and five-star hotels using a qualitative research approach. According to the findings, the majority of luxury hotels have included waste management programs, water-saving devices, energy efficiency measures, and guest and employee engagement tactics into their daily operations. The degree of implementation, however, differs greatly by hotel category, with mid-scale hotels adopting limited practices due to budgetary limitations and a lack of technical competence, while five-star hotels lead the way due to their higher resources and global competitiveness. These findings contribute to understanding sustainable tourism practices in Sri Lanka and provide recommendations for improving implementation across the hotel sector.*

Keywords: *Green Hotel Practices, Sustainable Tourism, Implementation Barriers, Luxury Hotels*

1. Introduction

1.1 Background of the Research

Sustainable tourism is a long-term aim for Sri Lanka, and the importance of sustainable tourism cannot be understated for Sri Lanka to work towards a favourable overall balance in environmental, socio-cultural, economic, and experiential consequences for tourists and residents (Samarasekara et al., 2022). Even though the 30-year civil war caused numerous issues for the industry, the post-war sector recovered, putting Sri Lanka on a stable growth trend, and the tourism industry expanded quickly. There, the importance of both domestic and foreign businesses engaging in the hotel sector has increased.

The tourist business includes the hotel industry as a subsector. Businesses in the hotel and accommodation industries are closely linked to the expansion of employment and have the potential to generate income for the nation (Leonidou et al., 2013). The ongoing growth of hotels has broader effects on the environment and society. Due to their increasing use of natural resources, many hotels are causing environmental harm. Understanding how a hotel enhances its green image and reputation, outperforms the competition, and reacts swiftly to the rising need for environmental concern is crucial to understanding the need for change in the market environment.

In tourism, the hotel plays a significant role in protecting the environment. Therefore, hotels must adapt to green practices. Sri Lanka's economy is mostly driven by tourism, which also makes a substantial contribution to infrastructure development, employment, and foreign

exchange revenues. But its quick growth, especially after the war, has resulted in more unsustainable practices, particularly in the luxury hotel industry in cities like Colombo. Through increasing carbon emissions, excessive use of energy and water consumption, and inappropriate waste disposal, unsustainable tourism significantly contributes to environmental degradation. Due to their high resource consumption, luxury hotels contribute significantly to the 8% of greenhouse gas emissions caused by tourism worldwide (Lenzen et al., 2018). Concerns have been expressed about the burden that major hotels in Colombo are placing on the city's electricity and water resources (SLTDA, 2021). Waste from tourism has also contaminated city beaches and endangered coastal ecosystems. The lack of sustainable operational methods in major destinations has resulted in increasing environmental pressure, which the Sri Lanka Tourism Development Authority has recognised (SLTDA, 2022). The social benefits of tourism are not equally dispersed; they frequently enrich international hotel corporations while providing local communities with little long-term benefit.

Overall development is still uneven, despite the fact that several hotels have started green initiatives, ranging from energy-efficient lighting and guest involvement programs to more sophisticated techniques like solar water heating and rainwater harvesting. Although many five-star hotels show a strategic commitment to sustainability, lower-tier hotels find it difficult to follow because of their limited financial resources, lack of technical know-how, and unclear implementation incentives or roadmap.

Furthermore, Sri Lanka's tourism infrastructure and natural resources, including coastal areas and biodiversity hotspots, are becoming more vulnerable due to climate change. The actual application of green hotel techniques in Colombo's luxury market is still uneven and poorly studied, despite national and international legislative promises to support sustainable tourism. As a result, the confluence of urban environmental stressors, unequal green practice adoption, and low participation in national certification programs leads to a lasting environmental impact as well as lost chances for increased productivity, brand distinction, and transformation backed by policy.

Given Sri Lanka's desire to market its tourism industry as competitive, environmentally friendly, and in line with the country's recovery and sustainability objectives, this disparity is especially noticeable. Finding out how many luxury hotels now use sustainable practices and realising the barriers preventing their full integration are critical needs. By concentrating on the Colombo District, this study fills that knowledge gap and seeks to offer practical advice for more environmentally friendly hotel management in Sri Lanka. Accordingly main research questions include this study are as follows.

1. What are the green hotel practices which currently implemented by the selected luxury hotels in Colombo in terms of water, energy, waste, and guest engagement?
2. What are the main barriers to implementing sustainable practices across different hotel categories?
3. How can the hotels of different star classifications (3-star, 4-star, 5-star) compare in their sustainability efforts?
4. What kind of strategies can be developed to improve the adoption of green practices and certification, which support Sri Lanka's goal of positioning a sustainable tourism hub?

1.2 Definition of Concepts

1.2.1 Sustainable Tourism

In 2005, UNWTO and UNEP jointly defined sustainable tourism as “tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities.” United Nations Environment Programme and World Tourism Organisation, 2005.

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The Brundtland Report (1987) defines sustainable tourism as development that satisfies current demands without jeopardising the capacity of future generations to satisfy their own.

1.2.2 Green Hotel Practices

The most important component of a tourist destination is a hotel. In addition to room service and food and beverage services, hotels serve as temporary lodging for travellers. The most valuable aspect of a hotel's offerings is its human capital in the form of services (Perera & Pushpanathan, 2015). The Green Hotel Association (2018) defines a green hotel as one whose management places a high priority on energy and clean water consumption, waste reduction, and other cost-cutting measures to preserve environmental sustainability. In the hotel sector, there are three primary green practices (Baris, Erdogan, N. 2007)

1.2.3 Energy-saving techniques

Energy conservation is one of the most crucial aspects of the hotel industry's environmental management. Hotels typically use enormous amounts of electricity and fossil fuel energy for several operating areas. These steps include installing energy-efficient appliances and other related equipment, implementing renewable energy programs like solar and wind power, installing digital thermostats, using energy-star qualified products, installing motion sensors that turn off lights in low-traffic areas, installing reflective glass or triple-glazed windows, using energy-efficient light bulbs, and cleaning unoccupied, dirty rooms with natural light instead of artificial light.

1.2.4 Water Conservation measures

The hotel sector has made extensive use of this as a key green management tactic. In general, hotels use a lot of water in their daily operations. Therefore, the size and capacity of the hotel, the occupancy rate, and the kind and calibre of services and amenities offered all affect how much water is used in the hotel sector. Installing water-efficient fixtures and appliances, such as low-flow showerheads and toilets, and installing infrared-activated faucets are examples of water-saving techniques used by the hotel sector.

1.2.5 Waste Management measures

Due to the massive amounts of wet waste, such as food scraps, cooking oil, and garden waste, and dry waste such as plastics, cans, paper, and linen that are dumped in landfills, the hotel business is typically regarded as a significant source of greenhouse gas emissions. In order to reduce hotel waste, hotel operators started implementing various strategies, such as using coloured bins and clearly marked containers to collect recyclables, buying products with recycled materials, collecting organic kitchen waste separately for soil composting, purchasing food items and cleaning supplies in bulk, and implementing a donation program.

1.4 Barriers to green hotel practices

The barriers to green practices in hotels are among the topics of some studies. For example, Chan (2008) summed up that hotel managers' motivation to adopt green practices is weakened by a lack of professional advice, resources, certifiers/verifiers, and expertise, as well as by unknown results and the cost of implementation and maintenance.

Kamalulariffin et al. (2013) performed the second relevant study into the barriers. Five barriers were identified by this study: government and regulatory requirements, demand from customers, competitiveness, organisational greenness, and a change-oriented mindset. Vikneswaran et al. (2012) conducted the third research project and their associates identified nine obstacles. These include the high costs associated with implementation and ongoing maintenance, which often discourage hotels from investing in environmentally sustainable

initiatives. Additionally, a lack of sufficient knowledge and awareness regarding green practices limits effective adoption. Hotels frequently face resource constraints, including shortages of time, manpower, equipment, and financial resources. The absence of strong commitment and momentum from hotel owners further impedes progress. Moreover, the lack of urgency and the ambiguity surrounding environmental guidelines create uncertainty in implementation efforts. Other challenges include the shortage of qualified verifiers and consultants, conflicting guidance from different stakeholders, and inadequate government regulations and enforcement mechanisms, all of which hinder the successful adoption of sustainable practices within the hotel industry.

1.5 Global context of green hotel practices

According to previous studies, there are three main components of sustainable tourism practices, which are as follows: 1) energy management; 2) waste management; and 3) water conservation. According to Mensah (2006) also, above are the most often used environmental management techniques that support environmental quality, image building, and cost savings in hotels.

The main obstacles to implementing green operating practices at Victoria Falls' hotels and lodges include a lack of funding, scarce resources, and technical advancements. According to Fazzari et al. (1988), Victoria Falls hotels and lodges' capacity to adopt sustainable practices is impacted by the cash flow sensitivity brought on by financial constraints.

The sector's lack of awareness and education has been cited as another significant obstacle. The implementation of sustainable practices is hampered by management and employee ignorance and complacency, which is indicative of a larger problem with environmental awareness. Fukey & Isaac, (2014) stress the importance of raising knowledge of how hotel operations affect the environment.

1.6 Sri Lankan Context of Green Hotel Practices

According to a case study (Wilson et al., 2019) on how hotels in Sri Lanka can improve their efficiency through environmentally sustainable practices, hotels that practise environmental responsibility are more efficient. It has been said that waste management and energy efficiency need to be improved. Additionally, they show that medium- and large-scale hotels play a significant role, with five-star hotels accounting for 14.2% of the total room capacity, four-star hotels for 10.8%, and three-star hotels for 7.6% (Herath, 2023)

Additionally, they highlight the significance of the evolving tourist demographic, which demands environmentally friendly procedures. They argue that hotels employ these eco-friendly practices as part of their corporate social responsibility to cut expenses, enhance their reputation, and stand out in the market. Recognising the harmful impact of products, governments also stress the significance of green business practices in the hotel and tourism sector in order to safeguard the environment. Addressing environmental challenges is also commonly viewed as a way to satisfy customer demands, social responsibility, or company ethics.

2. Methodology

This study uses a qualitative case study strategy to explore the green hotel practices and implementation barriers in Sri Lanka's hotel industry. The research was conducted between June 2025 and September 2025 period and data was collected through semi-structured interviews. The study focuses specifically on a number of selected luxury hotels (3-star, 4-star, 5-star) in the Colombo District, making it possible to examine green practices and the barriers to their adoption in a contextualised manner. A total number of 30 participants, including hotel managers and sustainability officers, were purposively selected for the study. Also, the data

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was analysed using thematic analysis to identify the key themes related to the implementation of green hotel practices.

The study is carried out in Sri Lanka's commercial and urban centre, Colombo District, which has more than 25% of the nation's hotel room capacity (SLTDA, 2022). Colombo is a perfect place to research sustainable tourism initiatives because it combines upscale tourism infrastructure and environmental stress. To find the relevant data, the participants below were included in the research as presented in Table 1.

Table 1. Hotel participants

Se. No	3-Star	4-Star	5-Star
1	Viveka hotel	Radisson Hotel Colombo	Waters Edge
2	Cinnamon Red Colombo	Rockwell Colombo	Cinnamon Lakeside Colombo
3	Grand Oriental Colombo	Mirage Colombo	Sheraton Colombo
4	Metro Port City hotel	Grand Bell Hotel Colombo	The Kingsbury Colombo
5	Hotel Nippon Colombo	Fairway Hotel Colombo	Taj Samudra Colombo
6	Pearl City hotel	Zest Metropole Colombo	Amari hotel Colombo
7	Port View City Hotel	Sofia Colombo City Hotel	Galadari hotel Colombo
8	The Ocean Colombo	MA Radha Colombo	Marino Beach Colombo
9	Hotel Janaki Colombo	Nyne hotels lake lodge	Cinnamon Grand
10	Hotel Sapphire	Aathma Colombo House	Galle Face hotel Colombo

Source: Constructed by authors

Within each selected hotel, key informants will be purposively chosen based on their involvement in operational, strategic, and sustainability-related decision-making processes. These informants will include General Managers, who oversee overall hotel operations and policy implementation; Engineering or Maintenance Managers, who are responsible for infrastructure management, energy efficiency, and environmental initiatives; and Sustainability or Environmental Officers, who lead and coordinate the hotel's sustainability practices and green programs. Their diverse perspectives will provide comprehensive insights into the adoption of sustainable practices, the challenges encountered, and the strategies employed to enhance environmental performance within the hotel sector.

2.1 Data Collection Methods

Semi-structured interviews and open-ended questions with chosen hotel employees will be the main method used to gather data. This approach enables participants the freedom to go into further detail about their experiences, opinions, and difficulties with green practices while also allowing for rich, detailed responses.

A set of the questionnaire was prepared based on the barriers identified from the literature. The questionnaire was divided into 5 parts. In part one, questions were based on the background of the respondent, details of the hotels, such as hotel type, designation so on. In part two, questions were regarding the existing sustainable practices in hotels. In part three, questions were asked regarding the barriers to implementation. In part four, questions were asked regarding the reflections and recommendations of hotels in implementing sustainable practices, and finally the questions in part five were regarding the final thoughts.

3. Results

3.1 Green Hotel Practices

Each of the responses received from the members was carefully transcribed and reviewed several times in order to provide the material and to record significant concepts and recurring themes. Using an open coding process, meaningful statements were identified and

categorised based on how well they applied to operational barriers, policy implications, green hotel practices, and stakeholder engagement.

Early on, the respondents noted several recurring sustainable tourism practices, such as the installation of motion sensors, the use of solar water heating systems, the adoption of ISO 14001 environmental management standards, and the introduction of LED lighting. Initiatives for employee knowledge to raise environmental awareness, food redistribution, and garbage segregation were also mentioned by them.

For example, one sustainability officer from a five-star hotel stated:

“We have switched almost entirely to LED lighting and have installed motion sensors in all guest corridors. This has reduced our monthly electricity bills by nearly 30%.”

Such early insights revealed that energy efficiency measures are widely highlighted across the sector. However, financial constraints and policy gaps were evident from the outset. As one of the managers of a four-star hotel has explained:

“The government does not offer any meaningful subsidies or tax incentives. Every sustainability upgrade, from solar water heating to waste treatment systems, comes entirely out of our operational budget.”

This interaction between structural constraints and attempts to adopt sustainable practices emerged as an ongoing theme in the study and influenced the direction of future questions. Follow-up questions were designed to dive deeper into new thoughts when they surfaced. While gradually focusing on the themes, this iterative process ensured that the analysis stayed rooted in participant viewpoints.

3.1.1 Refining the Analysis through Iteration

This study completely incorporated the iterative nature of thematic analysis. Recurring patterns that emerged during the initial code development helped guide the future data collection. For instance, subsequent interviews looked deeper into finance models, payback periods, and alternative energy after participants often emphasised the high costs of installing green technologies. In the same manner, when the topic of guest involvement came up, follow-up enquiries looked into the ways in which tourists were informed and how they were seen to affect their behaviour.

The code structure changed and advanced as a result of this process. Smart heating and cooling systems, motion sensors, and LED lights were all coded under the more general heading of energy efficiency measures. The category of sustainable waste management was created by combining several relevant codes, such as food recycling, composting, waste segregation, and plastic reduction. Similarly, comments about policy uncertainty, a lack of incentives, and the lack of certified checkers were categorised under policy and regulatory issues, whereas responses about staff training, awareness campaigns, and guest education fell under the stakeholder involvement category.

Through iterative refining, the research was able to go beyond superficial descriptions and reveal the underlying mechanisms impacting the adoption of sustainable practices in hotels in Colombo.

3.1.2 Resource and Energy Efficiency Motivated by Sustainability

Among all participating luxury hotels in Colombo, energy saving was one of the most noticeable themes. Nearly all of the respondents talked about continuous attempts to lower energy use, whether through simple initiatives or significant financial investments. Common actions include installing motion sensors in conference rooms and hallways, converting to LED lighting completely, and implementing climate control systems to maximise the use of air conditioners.

A manager from a five-star hotel has explained that:

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“We invested in a building management system that automates temperature control and adjusts lighting depending on occupancy levels. Within the first year, our overall energy costs dropped by nearly a third.”

In the same spirit, some hotels have integrated solar water heating systems to reduce their dependency on electricity from the grid. However, because lower-ranked hotels found it difficult to justify the initial costs, these expenditures were nearly exclusively limited to four- and five-star hotels.

The results shown here are consistent with sustainability reports from major hotel groups in Sri Lanka. For instance, Jetwing Hotels' 2023 Sustainability Report highlights that about 42% of its energy comes from renewable sources, mostly plants and solar power. This demonstrates that the luxury hotels in Colombo are leading the way in energy efficiency technology.

Many participants failed to stress that cost was still a major challenge. 3-star hotels had to utilise low-cost measures like LED retrofits and behavioural cues for guests and employees, whereas 5-star hotels frequently had the funds to seek innovative solutions. The disparity stresses how funding capacity has a significant impact on the extent of environmentally friendly efforts related to energy efficiency.

3.1.3 Thorough Reduction and Waste Handling

Waste management was another frequently discussed topic in the context of sustainability. Hotels have recognised the operational and reputational benefits of effectively managing waste, even though techniques vary widely depending on the resources available.

All hotel types practiced basic waste stream segregation, which included food waste, glass, and plastics. However, more advanced practices like biogas production, on-site composting, and relationships with local recycling companies were reported by luxury hotels.

One sustainability officer from a four-star hotel shared:

“We have established a partnership with a local recycling firm to handle glass and plastic waste, while organic matter is composted on-site. This has helped us achieve almost zero landfill contribution.”

Many hotels, particularly five-star hotels, where buffet-style operations can generate a lot of trash, also mentioned food waste tracking systems. By monitoring and measuring daily food waste, these hotels were able to reduce waste and costs by altering menu design and procurement levels.

The results are in line with the protocols recommended by leading hospitality brands in Sri Lanka. For instance, Cinnamon Hotels' 2024 Sustainability Report states that all of their kitchen trash is diverted from landfills and that a significant portion is converted into biogas to power their operations. Middle-range hotels are less likely to employ these innovative technologies but there is evidence that as sustainability standards rise, their adoption is occurring gradually.

3.1.4 Guest and Staff Engagement in Hotel Sustainability

In order to maintain green approaches, stakeholder engagement is mandatory. According to the report, hotels are getting more and more staff and visitors involved in their sustainability initiatives.

Eco-cards, which encourage guests to reuse towels and linens in order to save water and energy, are commonly used as guest education materials in rooms. In order to increase transparency and encourage guest participation, several hotels reported putting digital dashboards in their lobby areas that showcase their monthly progress in waste reduction and energy savings.

As one of the hotel managers explained:

“We have realised that involving guests directly makes a difference. When they see our achievements displayed publicly, they tend to participate more willingly in our sustainability programs.”

Employee participation was just as essential. The majority of hotels held frequent training sessions to acquaint employees with best practices and sustainability regulations. In several instances, staff members were urged to offer their own suggestions for enhancing waste management and energy efficiency procedures. In addition to promoting compliance, this kind of empowerment encouraged creativity among employees.

Due to resource limitations, three-star hotels had to rely on unofficial awareness seminars, whereas five-star hotels had more formal engagement frameworks, including specialised sustainability training modules. However, throughout the collection, the dedication to incorporating stakeholders at all levels was clear.

3.2 Barriers in Implementing Green Practices

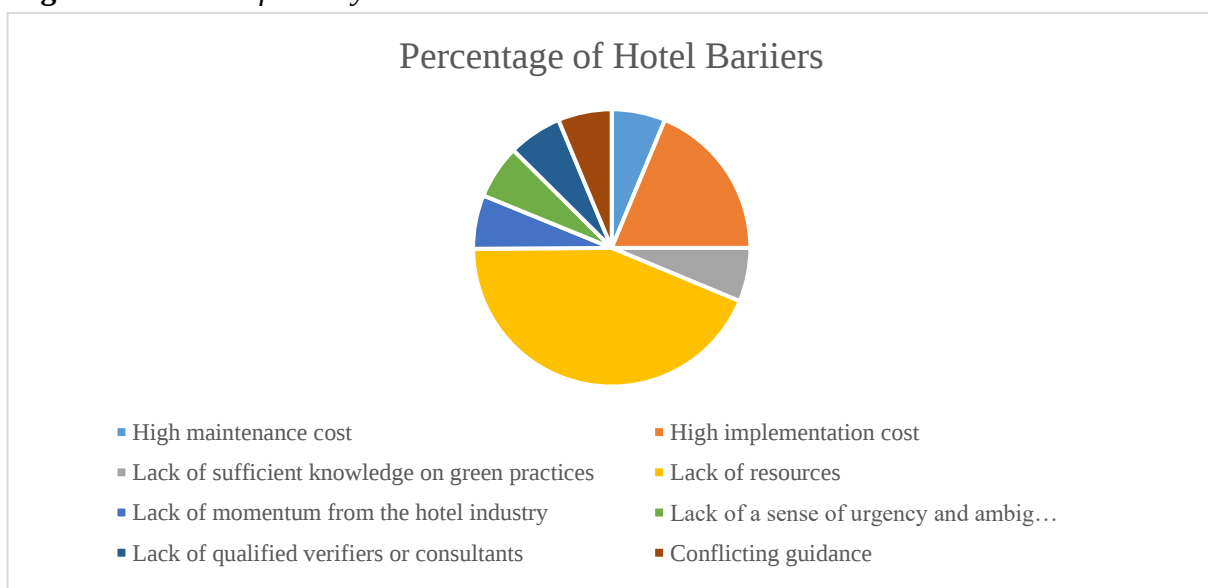
Considering increased awareness of environmental issues and operational advantages, the study identified a number of major barriers that prevent Colombo's hotels from widely implementing sustainable methods.

Financial limitations were one of the most frequently mentioned difficulties. Securing the substantial upfront investment needed for energy-efficient technology, renewable energy systems, and water recycling facilities proved to be a challenge for many hotels, especially three-star and smaller four-star properties. Even though these interventions can save money in the long run, most mid-tier hotels cannot afford the initial capital outlay.

A sustainability manager from a four-star hotel has explained: *“We understand the benefits of solar power and rainwater harvesting, but these systems cost millions of rupees to install. Without financial support or subsidies, it is nearly impossible for us to proceed.”*

As shown in Figure 1, Several hotels also emphasised technical and operational constraints. It can be difficult and expensive to transform outdated infrastructure to support automated waste management systems, greywater recycling, or smart energy controls. Additionally, smaller hotels lack internal knowledge of technology, which makes it challenging to successfully implement new technologies.

Figure 1. Barriers faced by hotels



Source: Constructed by authors

3.3 Star Classifications of Hotels Employ Different Approaches.

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There were significant differences in the level of sustainability adoption across hotels rated three, four, and five stars.

When it came to putting thorough green initiatives into effect, five-star hotels were always at the top of the heap. They made investments in solar heating infrastructure, building automation systems, and international certifications such as ISO 14001. The necessity to remain globally competitive and the expectations of foreign visitors frequently motivated these actions. Three-star hotels, on the other hand, used more straightforward, affordable procedures including linen reuse initiatives, LED lighting, and simple trash segregation. Despite their admirable efforts, they are nonetheless constrained by their lack of funding, technological proficiency, and policy guidance. Four-star hotels found a medium ground, implementing certain cutting-edge procedures while giving preference to those that offered quick financial gains. This distinction highlights the necessity of context-specific regulation interventions and customised support systems in order to assure that sustainability objectives may be met by the hotel industry as a whole, irrespective of scale or classification.

3.4 Strategies to Improve the Adoption of Green Practices and Sustainability Certification

Participants proposed several strategies to enhance the adoption of green practices and sustainability certification across the hotel sector in Sri Lanka. The most frequently mentioned recommendation was the provision of financial incentives by the government. Hotel managers, particularly from three-star and four-star hotels, highlighted the need for tax concessions, low-interest green loans, and subsidies for renewable energy investments and environmentally friendly technologies. Many respondents believed that financial support would encourage hotels with limited resources to invest in sustainable infrastructure and environmental management systems.

Another important recommendation was the strengthening of technical support and capacity-building initiatives. Participants emphasized the need for training programs, workshops, and knowledge-sharing platforms to improve awareness and technical expertise among hotel employees and managers. Several respondents noted that access to qualified sustainability consultants and clearer implementation guidelines would facilitate the successful adoption of green technologies and environmental certifications.

Respondents also highlighted the importance of strengthening regulatory and certification frameworks. Many participants suggested simplifying certification procedures and increasing awareness of internationally recognized standards such as ISO 14001 and Green Globe certification. Furthermore, respondents indicated that clearer environmental regulations and stronger monitoring mechanisms could encourage greater commitment to sustainability within the hotel industry.

Finally, participants emphasized the importance of collaboration among government agencies, tourism authorities, hotel associations, local communities, and private-sector stakeholders. Such partnerships were viewed as essential for promoting sustainable tourism development, sharing best practices, and creating a supportive environment for green innovation. According to the respondents, a coordinated approach would help Sri Lanka strengthen its position as a sustainable tourism destination while improving the environmental performance of hotels across all categories.

Table 2. *Suggested Strategies to Improve Green Practice Adoption*

Strategy	Description
Financial Incentives	Tax concessions, subsidies, green financing schemes, low-interest loans
Capacity Building	Training programs, workshops, sustainability awareness campaigns

Technical Support	Access to consultants, implementation guidelines, knowledge-sharing platforms
Certification Support	Simplified certification procedures, awareness of ISO 14001 and Green Globe
Policy and Regulatory Support	Stronger environmental regulations and monitoring mechanisms
Stakeholder Collaboration	Partnerships among government, hotels, tourism authorities, and communities

Source: Constructed by authors

4. Discussion/ Conclusion

The findings revealed that luxury hotels in Colombo have increasingly adopted green hotel practices, particularly in the areas of energy conservation, waste management, water conservation, and stakeholder engagement. Common initiatives identified in the study included LED lighting, motion sensors, solar water heating systems, waste segregation, composting, and linen reuse programs. These findings are consistent with Erdogan and Baris (2007), who identified energy-saving technologies, water conservation measures, and waste reduction strategies as the most widely implemented environmental practices in hotels. Similarly, Mensah (2006) emphasized that these practices contribute significantly to environmental sustainability and operational efficiency within the hospitality sector. The findings also support Kularatne et al. (2019), who found that environmentally sustainable practices improve hotel efficiency by reducing resource consumption and operating costs.

The study identified several barriers that hinder the implementation of sustainable practices, including financial constraints, limited technical expertise, inadequate government support, and a lack of awareness. High initial investment costs associated with renewable energy systems and environmentally friendly technologies were reported as major challenges, particularly among three-star and four-star hotels. These findings are consistent with Chan (2008), who found that implementation and maintenance costs are significant barriers to environmental management in hotels. Likewise, Vikneswaran et al. (2012) highlighted that insufficient resources, limited knowledge, and weak regulatory support often prevent hotels from fully adopting green practices. Therefore, the challenges identified in this study reflect barriers commonly experienced across the hospitality industry.

The comparison among hotel categories revealed that five-star hotels demonstrate a higher level of sustainability adoption than three-star and four-star hotels. Five-star hotels have invested in advanced technologies, renewable energy systems, and internationally recognized environmental certifications, while lower-category hotels mainly rely on basic and low-cost environmental initiatives. These findings support Kularatne et al. (2019), who reported that larger hotels possess greater financial and technological capabilities to implement sustainability initiatives. Furthermore, Herath (2023) noted that large-scale hotels in Sri Lanka play a leading role in environmental management due to their greater resource availability and international market exposure. This suggests that organizational capacity and financial strength significantly influence the adoption of sustainable practices.

The findings further suggest that stronger policy support and institutional mechanisms are necessary to improve the adoption of green practices and sustainability certification across the hotel sector. Participants emphasized the importance of government incentives, financial assistance, technical training, awareness programs, and simplified certification procedures to encourage sustainability implementation. These findings are consistent with Kamalulariffin et al. (2013), who highlighted that supportive regulations, stakeholder collaboration, and organizational readiness are essential for promoting environmental practices in hotels. Similarly, Fukey and Isaac (2014) emphasized the role of education and awareness in strengthening sustainability performance and fostering environmentally responsible behavior among hotel stakeholders. The findings also align with Lee et al. (2019), who found that green awards and certifications positively influence consumers' perceptions of hotels, strengthen

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green behavioral intentions, and generate economic benefits for the hospitality industry in Sri Lanka. This suggests that sustainability certification not only enhances environmental performance but also serves as a competitive marketing tool that can improve customer trust and business performance. Therefore, greater collaboration among government agencies, tourism authorities, hotel operators, and certification bodies is necessary to create a supportive environment for sustainability adoption and to support Sri Lanka's objective of positioning itself as a leading sustainable tourism destination.

4.1 Recommendations

Based on the findings of the study, several recommendations can be proposed to enhance the adoption of green practices and sustainability certification in Sri Lanka's hotel sector. The recommendations are prioritized according to their importance and feasibility. As a high-priority recommendation, the government should introduce financial incentives such as tax concessions, subsidies, and low-interest green loans to encourage hotels to invest in renewable energy systems, water conservation technologies, and modern waste management infrastructure. Financial support would be particularly beneficial for three-star and four-star hotels that face significant budgetary constraints when implementing sustainability initiatives. Additionally, the National Sustainable Tourism Certification (NSTC) framework should be strengthened by simplifying certification procedures, establishing clearer compliance guidelines, increasing the availability of certified auditors, and conducting capacity-building workshops for hotel managers. These improvements would encourage greater participation in sustainability certification programs while ensuring alignment with Global Sustainable Tourism Council (GSTC) standards.

At a moderate priority level, industry-wide sustainability training programs should be developed through collaborations among universities, hotel associations, and the Sri Lanka Tourism Development Authority (SLTDA). Such programs could enhance knowledge and skills related to waste management, energy efficiency, and stakeholder engagement, thereby improving the effective implementation of sustainable practices. Furthermore, hotels should invest in guest-centric awareness initiatives through digital dashboards, mobile applications, and social media campaigns that communicate sustainability achievements and encourage guests to participate in environmental programs. Increased guest engagement can strengthen the overall impact of hotel sustainability efforts and promote environmentally responsible behaviour among tourists.

As lower-priority but long-term strategic initiatives, hotels should be encouraged to improve transparency by preparing Environmental, Social, and Governance (ESG) reports aligned with Global Reporting Initiative (GRI) standards. Such reporting practices would enhance stakeholder confidence, strengthen corporate accountability, and improve competitiveness in international tourism markets. In addition, industry-wide collaboration platforms should be established to facilitate the sharing of best practices, innovations, challenges, and lessons learned among hotels. These collaborative networks would support continuous improvement and help the hospitality sector collectively advance Sri Lanka's goal of becoming a leading sustainable tourism destination.

4.2 Practical Implications

From the point of view of management, hotel operators looking to integrate sustainability into operations while establishing a balance between cost effectiveness and guest happiness can find practical insights in this research. Important implications include:

Energy and Resource Management: The results show that long-term cost reductions and increased operational efficiency can be achieved by investing in smart energy controls, LED

lighting, solar heating systems, and water recycling technology. Hotels may lower costs and improve their environmental brand image at the same time by giving priority to these measures.

Waste Management: In order to limit environmental effects and improve community connections, hotels should implement thorough plans for garbage segregation, composting, and food donation partnerships.

Engagement of Visitors and Staff: The study demonstrates that successful sustainability is driven by active stakeholder engagement. To raise awareness and promote habit change, hotels should give priority to staff training modules, digital dashboards, and guest education initiatives.

4.3 Policy Implications

The study identifies a number of systemic limitations that necessitate concerted policy actions, including high upfront investment costs, a lack of financial incentives, and unreliable certification systems. The following implications at the policy level emerge:

Government Incentives: To promote investment in waste management infrastructure and renewable energy systems, the Sri Lankan government should create tax breaks, green finance programs, and low-interest loans.

Strengthening the NSTC Framework: To guarantee that hotels have access to trained auditors and clear instructions, the National Sustainable Tourism Certification procedure should be streamlined and brought into line with international GSTC standards.

Platforms for Knowledge Sharing: To disseminate best practices and close implementation gaps, industry groups and the Sri Lanka Tourism Development Authority (SLTDA) could organise webinars, workshops, and cross-hotel partnerships.

4.4 Limitations of the Study

Although this study offers valuable insights, it has several limitations. Since the research was confined to the Colombo District, the findings may not accurately reflect the sustainable practices in resort or rural areas of Sri Lanka. Additionally, the study relied on self-reported statistics, which may be subject to bias or the overestimation of sustainability efforts. Furthermore, the exclusion of guest perspectives made it difficult to assess how customer demand influences the adoption of sustainable practices.

4.5 Future Suggestions

Future studies could address these limitations by expanding the scope to include rural and coastal regions to capture broader sustainability dynamics, incorporating guest perspectives to understand how consumer demand influences hotel strategies, and conducting longitudinal studies to track how sustainability adoption evolves and exploring the financial modelling of sustainability investments to assess cost-benefit outcomes for different hotel categories.

This research came into the conclusion that although the hotel industry in Colombo shows an increasing dedication to sustainable practices, the rate and extent of adoption differ greatly throughout classes.

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THE EFFECTIVENESS OF AI-POWERED MARKETING STRATEGIES IN SUSTAINABLE TOURISM

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Abstract: *The scientific paper examines the current impact of artificial intelligence (AI) driven marketing strategies, within the area of sustainable tourism, and with a special focus on the usage of generative AI. Since the modern approach to tourism marketing relies heavily on hyper-personalization within the concept of smart travel, this paper examines how much automated communication and predictive analytics generally aid in creating sustainable tourism practices. The question is followed by an examination of the critical potentials and limitations of AI-related technologies that affect tourists' behavior, perceptions of sustainability, and the overall competitiveness of travel destinations. The main analysis indicates that AI-based marketing strategies can improve promotion effectiveness and tourist experience, but only if paired with ethical, environmental and social concerns. In conclusion, the use of AI is highly desirable for the development of sustainable tourism, but only when appropriately managed.*

Keywords: *Generative AI marketing, hyper-personalization, smart travel, sustainable tourism.*

1 Introduction

AI has introduced a great paradigm shift in the world of business. This shift is ever-growing and unpredictable. Every day, new data emerges about the discovery of new uses of AI, as well as current ones, including, but not limited to, text, images, and videos (Grewal et al., 2025, p. 702). These uses usually promise significant change in the way business is done, but mostly in a general sense. The type of research that seems most needed is the one that meticulously explains how AI can and will change a specific sector of the economy, while outlining the likelihood and potential of change. The sector that was chosen for this science paper to research and discuss the effects of AI is marketing, specifically in tourism.

Since the mid-20th century, marketing has played a pivotal role in determining business success. The main reason is that marketing relies on customer research, both current and potential customers, from a single company's perspective. This way, a company can reliably identify the most relevant market segments to focus on and how to position its product information so it reaches the targeted audience. To do this, companies would rely on market research and customizable marketing models that can be easily adjusted as circumstances demand. The previous seems almost simplistic, failing to take into account that companies cannot focus solely on customers but also on competitors. This pressure companies to create a marketing strategy that enables them to provide goods and services that are easily differentiated from competitors and easily identifiable to customers. Communicating information is also a significant challenge, given that digital media is a promotional channel available to all market participants and, for the most part, free of charge. This fact pushes market participants to create their own product identity, which is segmented into narrower market segments that address the

specific needs of current and potential customers. For this science paper, the sustainable tourism sector was recognised as particularly modern in its approach, yet highly market-sensitive and in need of contemporary marketing solutions (Ostian, 2024, p. 20).

Tourism consists of activities that generally provide recreation, relaxation, pleasure, education, and other types of activities and experiences. Those are provided to individuals traveling to specific places of interest that are recognised as more abundant in opportunities that allow the fulfilment of such activities. In general, the market value of tourism can only be measured by observing the reactions of potential tourists to what is promoted or the experiences of current tourists to what has been provided. Tourism is an extremely opinion-sensitive industry (Antczak, 2025, p. 452) that must employ modern solutions for both communication and problem-solving. Given the aforementioned opinion sensitivity, marketing research in the tourism industry must be conducted through open channels of communication, where all parties can ask questions and receive direct answers and suggestions. One result of this approach was the idea and popularisation of integrating the tourism industry with principles of sustainability, which has also been endorsed by certain national governments and international bodies like the United Nations World Tourism Organization (UNWTO), currently known as UN Tourism (Trišić, 2024, p. 259). This type of tourism is not defined primarily by the content of its final destination, but by the impact of travel and stay, which sets it apart from most other types. Sustainable tourism is mainly based on minimizing negative impacts and maximizing positive impacts on the environment, leading to and including the final destination. It also focuses on making a positive contribution to the local culture and economy while emphasizing the importance of social responsibility practice from tourists and other tourism stakeholders.

AI, marketing, and sustainable tourism represent modern, useful concepts that are being carefully studied and whose use is evolving rapidly. Even though they are studied as separate entities in distinct fields, they can be interconnected for the research and practice of all three. AI is recognised to provide the technology or means to create a useful marketing strategy (Cillo & Rubera, 2025, p. 1) that enables sustainable tourism to reach its highest goals – more tourists and destinations with greater environmental, cultural, and social responsibility. That allows concepts like AI and marketing, which can be perceived as untrustworthy or potentially dangerous by the general public, to be used for a clear betterment of society.

This is why the main goal of this science paper is to research AI-based sustainable tourism marketing strategies that are business-worthy and socially responsible, and that have an economic and ethical foundation. The science paper includes research from secondary sources and is therefore primarily a theoretical review article, based on an analysis of relevant scientific literature to provide a comprehensive insight into the researched issue.

2 AI in Tourism

As in many fields, AI is increasingly used in tourism. Concrete examples of the use of AI in tourism can be found in the sphere of personalization of offers. The above implies the collection and processing of data about tourists and, in accordance with established preferences, giving suggestions about trips. In the described way, it is possible to achieve a higher level of satisfaction, as well as loyalty towards the tourist offer provider. In order to achieve interactive communication in real time with as little involvement of people in these tasks as possible, AI assistants or so-called chatbots. Additional examples of the use of AI in tourism include analyzing and forecasting demand, forming smart destinations, more optimal promotion, analyzing reviews to adjust the offer, virtual reality (VR), augmented reality (AR), and the like.

Apart from practical examples, another indicator of the growing importance of AI in tourism is scientific and research publications. It can be stated that research interest in this topic

is growing (Kumar et al., 2023; Knani et al., 2022; Kırtıl & Aşkun, 2021). Among the topics that are present in the papers on AI in tourism are "robot, automation, ChatGPT, technology adoption, and mechanical learning" (Şengel & Işkın, 2024).

Papers on the application of robots in tourism show that this technological segment of research is also in progress. Analyzing the topics that have so far been the subject of research papers in the aforementioned field, it is noticeable that in addition to service robots, an important place is also occupied by AI. AI belongs to the same cluster as the topics "technology, hotel, acceptance, COVID19, automation, employee, management, economy, smartness, and information", which indicates their mutual connection (Garabinović & Lukić Nikolić, 2025). Analyzing the papers of researchers from Central and Eastern Europe, it is confirmed that AI is one of the topics that have been frequently discussed in publications on robotics-based services. It belongs to the same cluster as automation, economy, management, and society, so it is stated that one of the main thematic directions is robotics-based services and "Tourism and hospitality economy based on automation and AI – perspective of management and position of society" (Garabinović & Lukić Nikolić, 2024).

In addition to the growing application and theoretical study, AI also brings with it numerous risks. The potential negative effects of AI in tourism are based on its excessive and inadequate use. They can be manifested in social, cultural, economic, and other elements of the environment, so it is therefore necessary to point out some of the key ones. Tourism is primarily a labor-intensive activity in which man occupies a central position, but the use of AI as a carrier of automation can to a certain extent lead to a reduction in the number of employees in certain workplaces. Violation of privacy is one of the serious ethical issues. Methods of collecting, processing and using personal data should be fully legally regulated and possible abuses reduced. In addition to privacy, as a result of relying on AI-generated data, the safety of tourists may be compromised. Excessive use of modern technological solutions by the carriers of tourist offer, demand, and mediation can cause technological dependence, which results in the potential creation of a similar tourist offer, i.e. gradual unification and reduction of differentiation due to the absence of creativity and spontaneity. In the described way, it is possible for individual carriers of the tourist offer, and especially destinations, to lose their authenticity. AI uses a large amount of electricity, which can increase consumption, but it also has an effect on the environment. For the above reasons, the sustainable use of AI is a necessity in order to achieve sustainable tourism and, in a broader sense, sustainable development.

3 Generative AI in Marketing

For many years, AI has been considered an analysis tool based on complex algorithms that can search for, find, and present data. However, the modern understanding and use of AI are mostly based on Generative Artificial Intelligence (GAI), or AI tools that not only measure but also create new data content. These tools have provided a wide range of opportunities across a variety of fields where creative solutions and adaptability are most important, especially when done in a short timespan. Even though modern AI technology is constantly evolving and its ultimate range of use is still not very well defined, its current usefulness has been enough to attract professionals from different fields.

AI is utilized in various aspects of business today (Ağtaş, 2025, p. 18). One of the fields in which adoption was earliest was marketing. That was not an accident, since marketing departments have always had to work with large numbers of ever-changing variables, based on customer thoughts, impressions, and preferences. This is why the process of market research has always been closely tied to modern technology, which has enabled the creation of analyses, models, and even concrete solutions to marketing problems. In today's digital economy, marketing issues are primarily about finding digital solutions.

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Therefore, from a digital marketing point of view, AI technology or individual tools, such as ChatGPT and chatbots, can design customised services and recommendations, as well as specific promotions in digital channels, thereby improving customer satisfaction and experiences (Florido Benítez & del Alcáraz Martínez, 2024, p. 1).

To use this new technology for marketing purposes, every creator should be aware of the GAI tools currently in use (Table 1).

Table 1. *GAI tools and their purpose in digital marketing*

Tools	Purpose
ChatGPT	Content creation, image, and text generation
Midjourney, Canva, DALL-E, Adobe Firefly	Image Generation
Faceless video, Playground	Automated Video Post
ElevenLabs	Voiceovers
Descript	Script and Podcast Preparation
REST Runway	Video Generation
Clearscope	SEO Optimization
FeedHive	Conditional Posting
Fireflies	Meeting Transcription
Promptly	Prompt-Based Content Creation

Source: (Joshi, S. et al. 2025, p. 6)

At the time that the research highlighting various GAI tools (Table 1), these tools were best suited to their purpose and were hence the most popular. However, the situation is bound to change over time as AI technology advances and new uses emerge to meet different digital marketing needs within an industry.

Due to its recognition patterns from data (e.g., text mining, speech recognition, facial recognition), the type of AI that provides personalization benefits is Thinking Artificial Intelligence (TAI). In digital marketing, this type of AI personalizes (Huang, M.H., & Rust, R.T., 2021, p. 34):

- products based on customer preferences,
- prices based on customer willingness to pay,
- frontline interactions.

However, it should be noted that scientific studies have not fully explored how plain GAI or TAI can better engage customers and enhance brand performance across companies. These aspects are particularly crucial because the success of GAI adoption hinges not only on its technological capabilities but also on its ability to drive meaningful engagement and foster loyalty (Giri, A. et al., 2026, p. 2). GAI allows advertisers to create and even automate the customization of content marketing strategies for each user based on their preferences and behaviors, thereby strengthening the bond between consumers, brands, and content (Joshi, S. et al. 2025, p. 1).

In addition to the numerous advantages previously mentioned, GAI use also poses major challenges, including accuracy, reliability, bias, and toxicity (Monteith, S. et al., 2024, p. 34).

To avoid potential risks, four ethical guideline principles are most commonly suggested (Rossi, S. et al., 2024, p. 6):

- GAI results need to be checked, preferably by humans, before they are used for final marketing solutions.
- GAI tool names should be disclosed to the public to avoid suspicion.
- GAI model documentation should be provided, listing all the prompts and parameters used.
- GAI raw data must be saved and made transparent upon request.

4 Hyper-Personalization as a Driver of Tourist Engagement

As previously stated, AI enables hyper-personalization, which entails the capacity to adapt offerings and interactions in real-time to the specific needs and preferences of the user (Dalton, 2025, str. 88). Hyper-personalization uses AI and advanced analytics to create a unique experience for each user, based on their preferences, previous purchases, and online activities (Thangavel & Sinha, 2025). For example, the concept of Big Data enables brands to analyze vast amounts of information and obtain insights into consumer trends, preferences, and user behavior almost in real time (Kostovski & Djukic, 2025, p. 231). Unlike traditional personalization, which relies on past data when tailoring offerings to a target group, Kostovski and his co-author (2025) emphasize that real-time engagement also plays a key role in contemporary marketing strategies. Hyper-personalization, therefore, goes a step further, as it uses AI and real-time user data to create offerings at a given moment. The question arises: Is hyper-personalization important for attracting and retaining tourists in contemporary tourism?

The answer is affirmative, and the explanation can be found in the changing role that tourists have in today's market. Namely, contemporary tourism trends have introduced new types of tourists (Stojanovic, 2023, p. 13), so it can be said that the role of modern tourists has evolved from passive to active. They are no longer merely passive observers guided by price-based vacations. Today's tourists are technologically empowered explorers who, with high standards and a more developed environmental and social awareness, seek authentic and personalized experiences. In addition, with the development of civilization, the status of tourism is shifting from being socially desirable to essential, and in this sense, every individual has the right to participate in tourism, which has a positive impact on emotional well-being, personal development, and the quality of life of individuals (Milovanovic et al., 2022). However, many people face limitations in using tourism services, primarily due to health and economic reasons, as well as lifestyle, lack of foreign language skills, needs arising from religion or culture, the desire to travel with pets, and so on (Milovanovic et al., 2022). Hyper-personalization provides tourism entities with the opportunity to create highly personalized tourism offerings based on monitoring and analyzing tourists' behavior and preferences. In this way, it can greatly enhance the user experience, as tourists receive information and services that are relevant to them.

Hyper-personalization generates a range of positive effects in the tourism sector. By analyzing data on tourists' behavior, preferences, characteristics, and needs, tourism service providers can offer services that are fully aligned with their requirements and desires, which can have a positive impact on their satisfaction and engagement. In addition, hyper-personalization improves the flexibility of the tourism offering, operational efficiency, business performance, and the reputation of tourism service providers. On the other hand, it shortens the search and demand time for the ideal offer and facilitates the decision-making process for tourists. Hyper-personalization also supports the development of sustainable tourism. For example, Stojanovic (2023) refers to so-called eco-tourists, describing them as those tourists who primarily see nature as their main interest, as they protect and explore the environment and pay attention to the local population. Such tourists are often highly educated and members of various ecological movements and environmental protection organizations (Stojanovic, 2023, p. 13). Based on the analysis of such users' interests, the system can guide them toward more environmentally sustainable offerings, which is crucial for the development of sustainable tourism practices. On the other hand, tourism service providers must also consider the potential risks associated with the hyper-personalization process (such as privacy protection, tourists' exposure to large amounts of information, ethical aspects, etc.) and, accordingly, strive to mitigate the risks while maximizing the benefits.

5 Smart Travel

Travel is an indispensable component of tourism. The reason for the above is the geographical difference between the destination where the tourist lives and the destination to which he travels. Modern technologies provide numerous opportunities to improve travel and thereby improve the tourist experience. Smart travel is the basis of smart tourism. Gretzel et al. (2015) define smart tourism as "tourism supported by integrated efforts at a destination to collect and aggregate/harness data derived from physical infrastructure, social connections, government/organizational sources and human bodies/minds in combination with the use of advanced technologies to transform that data into on-site experiences and business value-propositions with a clear focus on efficiency, sustainability and experience enrichment." They distinguish three of its components, which are smart: (1) experiences, (2) business ecosystem, and (3) destination. They also emphasize that e-tourism and smart tourism should not be equated. It could be concluded that smart travel includes the use of modern technological solutions in all stages of the travel process (from planning to implementation), at destinations (emissive, transit, receptive), by persons involved in the tourism-hospitality process (tourists as carriers of demand, intermediaries and carriers of tourism offers) with the aim of more adequate tourism-hospitality services (personalization, better experience, sustainability, etc.).

The most significant keywords, which show the main topics in scientific papers from the sphere of smart tourism, are (in order of decreasing number of occurrences and total link strength): smart tourism, digital technology, smart city, internet of things, big data, AI, augmented reality, digital transformation, mobile application, intelligent systems, smart destination, information and communication technologies (ICT) (Shasha et al., 2025).

In the analysis of smart travel experiences, it was established that there are several main domains of knowledge (Au et al., 2024):

- Experiences design,
- Structural equation modeling methodology,
- Role of technology,
- Destination ecosystem.

Also, five current fields of research were highlighted (Au et al., 2024):

- Conceptualization,
- Technology adoption,
- Destination management,
- Innovation,
- Co-creation.

Smart destinations are an important element of smart tourism. Scientific and professional papers on smart destinations started to be relevant in the second decade of the 21st century. The most important keywords in these papers are foundation, city, and technology. Internet, experience, hospitality, ICT, China, information technology, and management are represented in a smaller number. Taking into account the centrality degree, the most important topics are technology, hospitality, experience, foundation, management, internet, value creation, model, city, and co-creation (Ercan, 2023).

In accordance with the increasing use of mobile devices, mobile applications have a growing importance in the field of tourism. The analysis of mobile travel apps showed that as a form of smart technology, they are highly rated by users and thus well received by them. Three main functions of such applications have been identified: (1) geolocation tracking, (2) travel itinerary generators, and (3) real-time personalization and recommendations. Location, investment and privacy are the main challenges of their use (Sia et al., 2023). Factors influencing the adoption of smart itineraries in travel planning applications are (Khan & Mehmood, 2024):

- Usage,
- Value,
- Risk,
- Traditional barriers.

The use of different devices and their connection via the Internet is also used in the sphere of smart tourism. Rosário & Dias (2024) discussed the role of the Internet of Things (IoT) in the sphere of smart tourism from the aspects of technology, usage and challenges. In accordance with the above, they singled out:

- IoT Technologies for Smart Tourism: Big Data, Cloud Computing, Machine Learning and AI, Smart Sensors, Wearable Devices and Mobile Applications, Virtual Reality and Augmented Reality;
- Applications of IoT in Smart Tourism: Recommender Systems, Smart Cities, Payment Transactions, Electronic Ticket Systems, Sustainable Tourism Destinations, Intelligent Tour Guide System, Area Capacity Early Warning System, Voice Assistant, Smart Support System, Health Tourism Monitoring System;
- Challenges Hindering Effective Application of IoT in Smart Tourism: Security and Privacy, Software Complexity, Scalability, and Interoperability.

6 AI-Based Sustainable Tourism

Sustainable development represents one of the most pressing topics of today, permeating all spheres of society, including the tourism sector. The intensive development of tourism has both positive and negative implications. Although it significantly contributes to economic growth, cultural exchange, and the creation of new jobs, its uncontrolled expansion often leads to environmental degradation, erosion of cultural systems, and socio-economic imbalances (Rane et al., 2023). The increase in the number of travelers generates higher greenhouse gas emissions, leads to excessive waste production, the destruction of natural habitats, and increasing pressure on local infrastructure, among other issues. Venice is a typical example of a city where mass tourism disrupts the quality of life of the local population and threatens the cultural identity of the destination (Nolan & Séraphin, 2019, p. 139). This leads us to the conclusion that the positive effects of tourism on the economy and society can be nullified if tourism directly threatens the environment, making it therefore important for tourism to develop in a sustainable manner (Tenderis & Usta, 2026, p. 2). Sustainability impacts every facet of business and demands to be recognised, at a global level, as a strategic pillar to be tackled by the wider organization (Adejuge, 2024, p. 166). In this context, the concept of sustainable tourism has emerged, taking into account the economic, ecological and social aspects of its activities.

AI represents one of the fundamental technological tools that can facilitate the implementation of sustainable models in the tourism sector. It becomes an important mechanism for establishing a dynamic balance between tourism growth, the needs of the local population, and environmental protection. The application of AI enables personalized services, optimizes operational efficiency, and supports sustainable activities (Trifunovic, Spalevic & Markovic, 2024, p. 130). As such, it offers innovative solutions that directly contribute to the development of sustainable tourism practices. Some of these include:

- automation and optimization of activities,
- waste reduction,
- smart energy management,
- preservation of biodiversity and water resources,
- promotion of local destinations,
- protection of cultural and historical heritage,

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- educating tourists through personalized notifications (for example, about choosing accommodation with an eco-certification, selecting transportation that contributes to reducing harmful gas emissions, and similar),
- changing the way tourism services are created,
- simplifying the travel planning and organization process for tourists,
- guiding tourists toward sustainable decisions,
- promoting environmentally responsible behavior among tourists.

In addition, Alves and co-authors (2025) emphasize that by using AI, recommendation systems and chatbots offer personalized offerings and thereby help in the even distribution of visitors. In this way, the problem of overtourism is directly addressed, and a more stable development of destinations is promoted, leading to balanced and sustainable tourism. However, Hermosa and co-author (2024) emphasize that despite the continuous development of high-tech services, innovative technologies have still not been fully considered, nor have they been sufficiently utilized to improve the quality and sustainability of travel and tourism experiences. Areas where the potential of AI has still not been fully utilized particularly include the application of robotics for monitoring and protecting natural and cultural heritage, the development of information systems for detecting inappropriate behavior in protected zones (Hermosa & Castro, 2024, p. 161), and the involvement of local populations in the decision-making process regarding the development of local tourism. In addition, there is significant room for advancement in digital visitor education and early warning systems for natural disasters, which represents a priority in the fight against climate change (Hermosa & Castro, 2024, p. 162). AI systems promise widespread benefits for society, while also presenting substantial risks in almost all sectors (Puran, 2024, p. 245). Caution regarding the broader and faster application of AI may also stem from its inherent limitations. Data privacy, digital literacy, the digital divide based on economic inequality, over-reliance on AI leading to a loss of authenticity, and biased information are just some of them. Considering the fact that the contemporary environment faces increasingly pronounced ecological, economic, and social challenges, the promotion of sustainable tourism becomes a fundamental prerequisite for the long-term stability of the modern tourism sector. In this context, it is essential to engage all available resources and maximize the potential offered by AI.

7 Conclusions

Today, the world faces significant economic, ecological, and social challenges. In addition to other actors, the intensive development of the tourism sector makes a significant contribution. That is why there is a need to identify innovative approaches that can advance sustainable practices in tourism. AI is one such approach, and it can play an important role in the development of sustainable tourism. However, for it to become a key ally in the creation of sustainable tourism practices, it needs to be used effectively, that is, in a way that maximizes its positive aspects and neutralizes its negative sides. That is why the main objective of this scientific paper was to identify and explain the current impact of generative AI-driven marketing strategies, specifically in sustainable tourism, to increase the competitiveness of these travel destinations. That was successfully done by proving and concluding that the use of generative AI is highly desirable in creating, controlling, analyzing, and evolving marketing strategies. Furthermore, this scientific paper points out that hyper-personalization in marketing can contribute most to the sustainable development of tourism by creating a unique, personalized offer that respects the ecological, social, and economic aspects of tourism. In addition, it can positively impact the business performance of the tourist organization and the satisfaction and trust of tourists.

The theoretical implication of the science paper is to broaden a very limited body of knowledge that combines research on AI, marketing, and sustainable tourism. For the same reason, the practical implications are also connected to the prior combination, but with a focus on increasing the effectiveness of AI-based digital marketing strategies to improve business operations. One notable shortcoming of the science paper is the absence of a conceptual model, developed and explained as a possible tool to enhance the effectiveness of AI-powered marketing strategies in sustainable tourism. To rectify the previously mentioned shortcoming, the introduction of an original conceptual model would be a logical addition to the research presented in this science paper.

This science paper also supports existing theoretical views that AI can significantly enhance the effectiveness of marketing strategies, especially through process automation and personalized offers. Regarding sustainable tourism, the science paper confirms that AI facilitates the establishment of a balance among the economic, environmental, and social aspects of tourism development.

What makes this science paper stand out compared to existing research is the connection of AI with the concept of hyper-personalization in the context of sustainable tourism, which led to the most significant finding of the science paper - an adequately used AI can simultaneously increase tourist satisfaction, improve the performance of tourist organizations, and enable the sustainable development of the tourism sector.

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THE PRACTICAL MODEL MOTIVATION 4.0 AND ARTIFICIAL INTELLIGENCE AS FACTORS FOR BUILDING A DIGITAL ORGANIZATIONAL CULTURE

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Abstract: *The article explores the role of the Motivation 4.0 Practical Model and artificial intelligence as key factors in building a digital organizational culture in modern organizations. The aim of the study is to analyze how the integration of motivation-based management models with artificial intelligence-driven tools supports organizational adaptability, employee engagement, and value-oriented digital transformation. Using a conceptual and analytical approach, the article examines the interaction between Motivation 4.0 and artificial intelligence in the context of learning, communication, and decision-making processes. The findings suggest that artificial intelligence may enhance the practical applicability of Motivation 4.0, particularly in digitally mature business organizations. At the same time, the model provides a human-centered framework that balances emotional intelligence, green human resource management, corporate social responsibility, and benchmarking. The study concludes that the synergy between Motivation 4.0 and artificial intelligence contributes to the sustainable development of a digital organizational culture based on trust, innovation, and continuous learning.*

Keywords: *digital organizational culture, Motivation 4.0, artificial intelligence, digital transformation*

1 Introduction

In recent years, organizations across both public and private sectors have been undergoing profound transformations driven by rapid digitalization and technological advancement. The emergence of artificial intelligence (AI), automation, and data-driven decision-making has not only redefined operational processes but has also fundamentally reshaped organizational structures, work practices, and cultural dynamics. In this evolving context, the development of a digital organizational culture has become a critical factor for ensuring adaptability, innovation, and long-term sustainability. The concept of employee motivation has expanded beyond traditional economic and managerial perspectives, incorporating psychological, social, and ethical dimensions. Contemporary approaches emphasize intrinsic motivation, employee engagement, and the alignment between individual values and organizational goals. For this reason, the integration of human-centered and sustainability-oriented practices is increasingly recognized as essential for fostering resilient and high-performing organizations.

Within this framework, the role of artificial intelligence extends beyond its technological function. AI is increasingly viewed as a transformative force that influences not only productivity and efficiency but also communication patterns, decision-making processes, and employee perceptions. Its implementation raises important questions related to trust, job

security, ethics, and the overall readiness of organizations to adapt to digitally mediated environments. In response to these challenges, the “Motivation 4.0” model (Vasilev & Icheva, 2025) proposes an integrated approach that combines key elements such as *emotional intelligence*, *green human resource management*, *corporate social responsibility*, and *benchmarking with storytelling*. This model reflects the need to align individual capabilities, organizational values, and learning mechanisms within a broader digital and sustainable context.

Despite the growing body of research on digital transformation and organizational behavior, there remains a need for integrative frameworks that explicitly link motivational factors, artificial intelligence, and organizational culture (Aškerc Zadavec, Weis, & Gorenc, 2025). Furthermore, comparative studies between public and business sectors are still limited, particularly in the context of emerging digital environments.

The aim of this study is to examine the role of the *Motivation 4.0 model* and *artificial intelligence* as factors in the development of *digital organizational culture*. The research further seeks to explore the relationships between motivation, AI, and organizational culture through an empirical analysis and to compare these dynamics across public and business sector organizations. To achieve the stated aim, the study pursues several tasks. It first examines the *theoretical foundations* of the Motivation 4.0 model and its core components. It then *analyzes* the role of artificial intelligence as a factor influencing motivation and organizational culture. Furthermore, *the study explores* the relationships between motivation, AI, and digital organizational culture. Finally, it conducts a *comparative analysis* between public and business sector organizations in Bulgaria and proposes an integrated conceptual model.

Based on the theoretical framework and the proposed conceptual model, four hypotheses are formulated - H1: employee motivation is positively associated with digital organizational culture; H2: artificial intelligence is positively associated with digital organizational culture; H3: motivation is positively associated with artificial intelligence adoption; and H4: the relationships among motivation, artificial intelligence, and digital organizational culture differ between public and business sector organizations.

2 Practical Model “Motivation 4.0”

In the context of dynamic digital transformation and the increasing need for sustainable organizational development, the issue of human resource motivation acquires a new dimension. In this regard, the practical model “Motivation 4.0,” developed by Vasilev and Icheva (2025), is of particular importance, as it offers an integrative approach to motivation by conceptualizing it as the result of interactions between individual, organizational, and social factors.

The conceptual framework of the model is based on four key elements: emotional intelligence, green human resource management, corporate social responsibility, and benchmarking in combination with storytelling. These components form an interconnected system aimed at building a sustainable motivational environment that supports both the individual development of employees and the long-term effectiveness of organizations.

2.1 Emotional Intelligence as a Foundation of Organizational Behavior

The relationship between emotional intelligence, modern management practices, and the transformation of organizational culture has become increasingly important in the digital age. Emotional intelligence is considered a fundamental factor at the individual level, influencing employees’ ability to understand and manage their own emotions, as well as to build effective interpersonal relationships (Mayer, Caruso, & Salovey, 2016). It creates the conditions for increased engagement, adaptability, and readiness to embrace change, including the implementation of new technologies.

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Emotional intelligence (EI) is defined as the ability to perceive, understand, use, and manage emotions in ways that support thinking and behavior (Mayer & Salovey, 1997). According to the Four-Branch Model, EI consists of four interrelated abilities: perceiving emotions, facilitating thought through emotions, understanding emotions, and managing emotions (Mayer, Caruso, & Salovey, 2016).

In the context of modern organizations, EI is not merely a personality trait but a critical competency that influences employee well-being, the quality of social interactions, and leadership effectiveness (Brackett & Salovey, 2006). High levels of emotional competence among leaders are directly associated with greater employee satisfaction and lower levels of burnout (Palomera, Fernández-Berrocal, & Brackett, 2008). To facilitate the practical application of emotional intelligence in organizations, several developmental frameworks have been proposed.

The RULER model, developed by Marc Brackett (2019), is a practical framework for developing emotional intelligence that focuses on recognizing, understanding, labeling, expressing, and regulating emotions. It supports emotional literacy and facilitates the effective application of emotional competencies in everyday and organizational contexts.

The effective management of emotions contributes to improved well-being, interpersonal effectiveness, and organizational performance, making emotional intelligence an important competency in contemporary organizations (Brackett, 2019).

In the context of digital transformation, emotional intelligence supports trust, collaboration, and adaptability, thereby facilitating the successful integration of artificial intelligence. Organizations increasingly seek to develop EI-supportive cultures that promote emotional awareness, empathy, and constructive interpersonal interactions, all of which contribute to the development of a digital organizational culture (Levitats, Ivcevic, & Brackett, 2022).

2.2 Green Human Resource Management

Green human resource management functions as a strategic tool at the organizational level. It reflects the organization's orientation toward sustainability, ethics, and social engagement, while contributing to building a value system that motivates employees through belonging to a meaningful and responsible organizational mission.

Green Human Resource Management (GHRM) focuses on aligning employee engagement with environmental goals, which requires a high level of emotional commitment and shared values related to sustainability (Vasilev, 2023). GHRM is defined as the strategic alignment of human resource management practices with an organization's environmental objectives, aimed at fostering sustainable development for both present and future generations (Blagova & Vasilev, 2022). This approach is increasingly important for organizational attractiveness, as younger job seekers tend to prefer employers that demonstrate strong environmental and ethical commitments.

According to Blagova and Vasilev (2022), the concept of GHRM is operationalized through five strategies. The first is green recruitment, which focuses on attracting candidates with an environmental mindset whose values align with the organization's sustainability orientation (Jabbour, 2016). This is followed by green training, which includes both theoretical and practical programs designed to encourage employees to adopt environmentally responsible behaviors. The effectiveness of such training can be enhanced by linking it to appropriate reward mechanisms (Afsar, Badir, & Kiani, 2016). Green motivation further supports employee engagement by promoting a clear environmental vision and fostering a collaborative learning climate that encourages knowledge sharing and participation in green initiatives (Renwick, Redman, & Maguire, 2013).

To reinforce these practices, green reward systems combine financial incentives with non-monetary recognition, such as certificates or public acknowledgment, thereby strengthening employees' sense of responsibility and organizational commitment (Jackson, Renwick, Jabbour, & Muller-Camen, 2011). Finally, environmental performance management ensures the effectiveness of these initiatives through regular evaluation based on predefined environmental indicators and continuous feedback. In the context of digital transformation, Green HRM practices can be further supported by AI-driven tools that enhance environmental monitoring, employee engagement, and data-driven decision-making.

2.3 Corporate Social Responsibility

Corporate social responsibility (CSR) is grounded in organizational values that contribute to collective well-being and sustainable development (Serafimova et al., 2025). Within the framework of the Motivation 4.0 model, CSR represents an important element that aligns organizational goals with broader social and ethical considerations. It enhances employee motivation by fostering a sense of purpose, belonging, and alignment with socially responsible values.

The relationship between motivation and CSR can be considered causal, as the underlying motives of an organization determine both the nature and scope of its social practices. Understanding these internal drivers is essential, as they directly influence managerial decisions and the selection of stakeholders targeted by CSR initiatives (Campopiano, De Massis, & Cassia, 2012).

The literature generally distinguishes between economic and ethical motivations for CSR. While economic motives emphasize reputation, competitiveness, and stakeholder trust, ethical motives focus on social responsibility and environmental sustainability. In practice, organizations often combine both perspectives when designing CSR initiatives (Campopiano, De Massis, & Cassia, 2012).

Organizations characterized by higher levels of emotional intelligence are more likely to adopt CSR practices, as their leaders are better able to understand stakeholder needs and recognize the broader social and emotional impact of their decisions (Levitats, Ivcevic, & Brackett, 2022). In this sense, CSR functions not only as a strategic management approach but also as a motivational mechanism that strengthens employee engagement and organizational commitment. Furthermore, CSR contributes to a positive organizational image and enhances organizational attractiveness, particularly among younger employees who increasingly value ethical and sustainable practices. As part of the Motivation 4.0 model, CSR supports the creation of a value-driven organizational culture that facilitates long-term sustainability and effective adaptation to digital transformation.

2.4 Benchmarking and Storytelling

Benchmarking and storytelling are essential components of the Motivation 4.0 model, functioning as mechanisms for organizational learning, knowledge sharing, and communication. Benchmarking enables organizations to compare their practices and performance with industry standards and best practices, thereby facilitating continuous improvement and informed decision-making (Vasilev & Icheva, 2025). Through benchmarking, organizations can identify gaps, adopt innovative approaches, and enhance their competitiveness in a rapidly changing digital environment (Serafimova & Vasilev, 2024). It also supports the evaluation of organizational capabilities, including those related to human resource management and employee motivation.

Storytelling plays an important role in shaping organizational identity and reinforcing shared values (Davies, 2007). It serves as a powerful tool for developing emotional awareness

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and strengthening the connection between employees and organizational goals. By communicating experiences, successes, and challenges through narratives, organizations can foster empathy, trust, and a sense of belonging.

Together, benchmarking and storytelling complement each other by combining analytical and emotional dimensions of organizational development. While benchmarking provides data-driven insights, storytelling facilitates the internalization of values and meaning. As part of the Motivation 4.0 model, these tools contribute to enhancing intrinsic motivation and support the development of a digital organizational culture characterized by learning, innovation, and adaptability.

In its entirety, the Motivation 4.0 model offers a holistic approach that integrates the human factor, sustainable management practices, and organizational learning. This makes it particularly relevant in the context of developing a digital organizational culture, where motivation is increasingly shaped by emerging technological and social dynamics. In this regard, the growing role of artificial intelligence introduces new opportunities and challenges, further transforming the way organizations motivate employees, manage knowledge, and build adaptive cultural environments.

3 The Role of Artificial Intelligence in Digital Organizational Culture

Artificial intelligence (AI) plays an increasingly significant role in shaping digital organizational culture by transforming both technological processes and human interactions. One of the ways in which AI contributes to this transformation is through tools such as sentiment analysis in digital communication, which can be viewed as a technological extension of the human ability to perceive and interpret emotions. The integration of emotional intelligence into organizational processes (ranging from human resource management practices to leadership approaches) remains essential for creating a sustainable and engaging work environment (Levitats, Ivcevic, & Brackett, 2022).

The integration of AI in modern organizations is not merely a technological shift but a profound transformation that reshapes work practices, decision-making processes, and the very fabric of organizational culture. Digital organizational culture can be understood as a system of shared values, beliefs, and norms that define how organizations operate within a digital environment. As such, it can either facilitate or hinder the successful adoption of AI technologies (Akyazı, 2023). Empirical evidence suggests that there is a significant positive relationship between employees' attitudes toward AI and organizational culture, highlighting the importance of cultural readiness in technology adoption (Shokrollahi, 2025).

Artificial intelligence is commonly defined as the capability of machines and software systems to perform tasks that typically require human intelligence, such as reasoning, learning, and decision-making. The implementation of AI leads to the automation of routine tasks, allowing employees to focus on higher value-added activities that require creativity, critical thinking, and complex problem-solving (Shokrollahi, 2025). Consequently, this shift transforms job roles and necessitates the development of advanced digital, analytical, and cognitive skills.

AI technologies including chatbots, robotics, and pattern recognition systems contribute to increasing employees' digital awareness and technological competence. These tools enhance knowledge acquisition and facilitate interaction with digital systems, thereby fostering a more flexible and adaptive workforce (Sherba et al., 2025). Research indicates that artificial intelligence positively influences digital capabilities and awareness, which in turn support organizational performance and effectiveness (Akyazı, 2023).

The relationship between organizational culture and AI is dynamic and reciprocal. Organizational culture acts both as a mediator and a moderator in the process of digital

transformation. Studies show that cultures characterized by innovation, openness to change, and data-driven decision-making are more successful in adopting AI technologies (Sherba et al., 2025). In contrast, organizations with rigid hierarchical structures and risk-averse cultures tend to experience difficulties and delays in AI implementation. Leadership also plays a crucial role in fostering an AI-supportive culture by clearly communicating the benefits of AI and aligning technological initiatives with organizational values and strategic goals.

Despite its numerous advantages, the integration of AI presents several challenges for organizational culture. Employee resistance often arises from uncertainty and concerns about job displacement, while ethical issues related to privacy, transparency, and algorithmic bias may undermine trust in AI systems (Sherba et al., 2025). Additionally, the successful adoption of AI requires significant investments in upskilling and reskilling, as well as the development of digital competencies among employees. The role of AI in digital organizational culture is inherently bidirectional. While AI drives changes toward innovation, continuous learning, and data-driven practices, organizational culture simultaneously determines the extent to which these technologies can be effectively implemented. Successful integration depends on achieving a balance between technological efficiency and the preservation of meaningful human interactions within organizations.

The relationship between organizational culture and artificial intelligence is complex and multidimensional, as culture functions both as a mediator and a moderator in the process of digital transformation. The successful implementation of AI technologies depends not only on technological readiness but also on the cultural context within which these technologies are introduced (Sherba et al., 2025). Different cultural characteristics can either facilitate or hinder the adoption of AI, depending on the level of openness to innovation, risk tolerance, and leadership support. In this regard, key cultural dimensions influencing AI integration are summarized in Table 1.

Table 1. *Organizational Culture Factors Influencing AI Integration*

Cultural Dimension	Characteristics	Impact on AI Integration
Innovation and Data-Driven Culture	Encourages innovation, flexibility, and data-based decision-making	Facilitates successful AI adoption
Hierarchical and Risk-Averse Culture	Rigid structures, low tolerance for risk	Delays and hinders AI implementation
Digital Leadership	Clear communication, alignment with strategy, employee involvement	Enhances trust and reduces resistance

Source: Author's elaboration based on Akyazı (2023), Shokrollahi (2025), and Sherba et al. (2025).

Organizational culture acts as both a mediator and moderator in the relationship between artificial intelligence and digital transformation. As illustrated in Table 1, organizational culture plays a decisive role in shaping the outcomes of AI implementation. Innovation-oriented and data-driven cultures create favorable conditions for the successful adoption of AI by encouraging experimentation, flexibility, and evidence-based decision-making (Shokrollahi, 2025; Sherba et al., 2025). In contrast, hierarchical and risk-averse cultures tend to slow down technological change and create barriers to innovation.

Digital leadership emerges as an important factor in aligning technological initiatives with organizational values and strategic goals. By actively involving employees in the transformation process and clearly communicating the benefits of AI, leaders can reduce resistance and foster trust (Shokrollahi, 2025; Akyazı, 2023). These findings highlight that the effectiveness of AI integration is not determined solely by technological capabilities, but also by the cultural environment in which it is embedded (Sherba et al., 2025; Aliane et al., 2023).

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Therefore, organizations aiming to successfully implement AI must simultaneously invest in technological development and cultural transformation.

The integration of artificial intelligence in organizations, while offering significant benefits in terms of efficiency and productivity, also introduces substantial challenges related to organizational culture. These challenges include employee resistance, ethical concerns, and the need for new competencies, all of which influence the success of AI implementation (Shokrollahi, 2025; Aliane et al., 2023). Previous studies highlight that resistance to technological change is often driven by uncertainty and perceived job insecurity, while ethical issues such as bias and lack of transparency may undermine trust in AI systems (Akyazı, 2023; Shokrollahi, 2025). The growing demand for advanced digital skills requires organizations to invest in continuous learning and development, emphasizing the importance of upskilling and reskilling initiatives (Aliane, Gharbi, & Semlali, 2023). The main challenges associated with AI integration and their implications for organizational culture are summarized in Table 2.

Table 2. *Challenges of AI Integration and Their Impact on Organizational Culture*

Challenge	Description	Impact on Organizational Culture	Required Response
Employee Resistance	Fear of job displacement and uncertainty about AI	Decreased trust and engagement	Change management and communication
Ethical Considerations	Bias, privacy concerns, lack of transparency	Reduced organizational trust	Ethical governance and AI regulation
Skills Gap	Lack of digital and analytical competencies	Limited adaptability and innovation capacity	Upskilling and reskilling programs

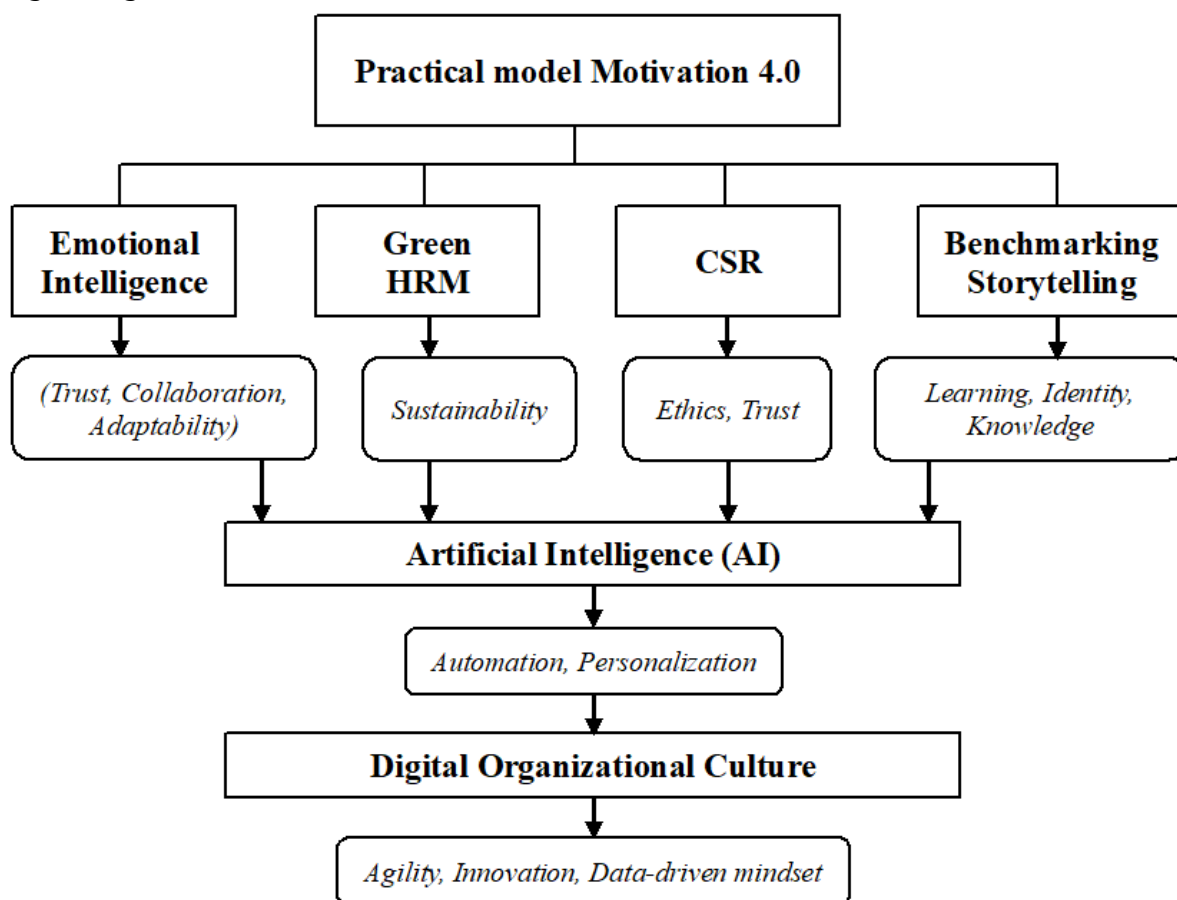
Source: Adapted by the author based on Akyazı (2023), Aliane et al. (2023), and Shokrollahi (2025).

AI integration requires balancing technological efficiency with human-centered organizational values. As shown in Table 2, the integration of artificial intelligence introduces a set of interrelated challenges that significantly influence organizational culture (Sherba et al., 2025; Shokrollahi, 2025). Employee resistance, ethical concerns, and the lack of necessary digital skills represent key barriers that organizations must address in order to ensure successful AI implementation (Akyazı, 2023; Aliane et al., 2023). These challenges, however, should not be viewed solely as obstacles, but also as drivers of cultural transformation. Overcoming employee resistance requires transparent communication and inclusive leadership, while addressing ethical concerns demands the establishment of clear governance frameworks and responsible AI practices (Shokrollahi, 2025). At the same time, bridging the skills gap highlights the importance of continuous learning and organizational investment in human capital. Artificial intelligence acts as a catalyst for change, encouraging organizations to evolve toward more adaptive, learning-oriented, and human-centered cultures. The successful integration of AI depends on achieving a balance between technological efficiency and the preservation of trust, ethical standards, and meaningful human interaction within the organization.

The challenges associated with artificial intelligence integration highlight the necessity of adopting comprehensive frameworks that go beyond purely technological considerations. Addressing issues such as resistance to change, ethical risks, and skills gaps requires a coordinated approach that integrates human, organizational, and strategic dimensions (Sherba et al., 2025; Aliane et al., 2023). This reinforces the need for models that combine motivational drivers, value-based management practices, and learning mechanisms, in order to support both technological adoption and cultural transformation (Levitats et al., 2022). Such an integrative perspective provides a foundation for understanding how organizations can effectively align digital innovation with human-centered principles and long-term sustainability.

Due to the increasing digitalization and the need to build adaptive organizational environments, there is a growing demand for an integrated approach that combines motivational, managerial, and technological factors. The present study is based on the “Motivation 4.0” model, extending it by incorporating artificial intelligence as a key mediator and catalyst of organizational transformation. The proposed conceptual model integrates four main components (emotional intelligence, green human resource management, corporate social responsibility, as well as benchmarking and storytelling) which operate at different organizational levels and jointly contribute to the development of a digital organizational culture. Within this model, artificial intelligence plays a central role by connecting and amplifying the impact of the individual elements through automation and intelligent data analysis (Figure 1).

Figure 1. Conceptual model of the impact of Motivation 4.0 and artificial intelligence on digital organizational culture



Source: Authors' elaboration based on Vasilev and Icheva (2025).

Figure 1 presents an integrated model that illustrates the interaction between the key elements of Motivation 4.0 and the role of artificial intelligence in the development of a digital organizational culture. At the individual level, emotional intelligence contributes to the development of trust, collaboration, and adaptability, which are essential for effective functioning in a digital environment and for the acceptance of technological innovations (Pellitteri, 2021). At the organizational level, green human resource management and corporate social responsibility establish a value framework oriented toward sustainability, ethics, and social engagement. These factors not only enhance employee motivation but also foster trust in the implementation of new technologies, including artificial intelligence. Benchmarking and

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storytelling, in turn, function as mechanisms for organizational learning and knowledge transfer. They support the development of a shared organizational identity and facilitate the adoption of best practices in a digital context.

At the core of the model lies artificial intelligence, which acts as both a mediator and a catalyst in the interactions between the different components. Through automation, data analysis, and the personalization of managerial processes, AI amplifies the impact of motivational and organizational factors and accelerates the transition toward a digital organizational culture. The overall outcome of these interactions is the formation of an organizational environment characterized by agility, innovation, and a data-driven mindset. While the proposed conceptual framework provides a theoretical explanation of how Motivation 4.0 and artificial intelligence contribute to the development of digital organizational culture, empirical validation is necessary in order to assess the practical relevance and applicability of these relationships in real organizational settings. The study proceeds with an empirical investigation aimed at testing the proposed conceptual assumptions and examining the strength of the relationships between the variables across public and business sector organizations.

The relationships illustrated in Figure 1 should be understood as a dynamic process of mutual reinforcement. Emotional intelligence contributes to the development of trust, collaboration, and adaptability, creating favorable conditions for the acceptance of digital technologies and AI-supported decision-making. Green human resource management and corporate social responsibility provide a value-based framework that strengthens employee engagement, ethical awareness, and organizational trust, which are essential for the responsible adoption of artificial intelligence. At the same time, benchmarking and storytelling facilitate organizational learning, knowledge sharing, and the dissemination of best practices, supporting employees in adapting to technological change. Artificial intelligence acts as a connecting mechanism that enhances these effects through automation, data analytics, personalization, and intelligent decision support. As a result, the interaction among these factors contributes to the development of a digital organizational culture characterized by innovation, continuous learning, flexibility, and data-driven thinking.

4 Research Methodology

The empirical part of the study adopts a quantitative research design aimed at examining the relationships between the components of the Motivation 4.0 model, artificial intelligence, and digital organizational culture. In order to explore these relationships, a cross-sectional survey-based approach was employed, allowing for the collection of comparable data from respondents across both public and business sector organizations in Bulgaria.

The empirical sample consisted of 60 respondents, including 30 employees from Bulgarian municipalities and 30 employees from private sector organizations. Data were collected between March and April 2026. The questionnaire was administered online. The business sector group consisted of employees from private organizations operating in various industries, including services, trade, manufacturing, and consulting. Respondents participated voluntarily and anonymously in the study and were selected through a convenience sampling approach. The research instrument consisted of a structured questionnaire developed specifically for the purposes of this study. It included ten statements measured on a five-point Likert scale, where 1 indicated strong disagreement and 5 indicated strong agreement. The questionnaire was designed to assess respondents' perceptions regarding motivational factors, the implementation and impact of artificial intelligence, and the characteristics of digital organizational culture.

Pearson correlation coefficients were calculated to examine the relationships between motivation, artificial intelligence, and digital organizational culture. Statistical significance was assessed at the 0.05 and 0.01 levels. The methodological approach was selected in order to provide empirical validation of the proposed conceptual framework and to assess the practical applicability of the Motivation 4.0 model in digitally transforming organizational environments.

4.1 Measurement Instrument

The questionnaire consisted of ten statements measured on a five-point Likert scale ranging from 1 (“Strongly disagree”) to 5 (“Strongly agree”). The items were grouped into three main dimensions: Motivation, Artificial Intelligence, and Organizational Culture. An additional integrative item was included to assess the perceived influence of artificial intelligence on organizational culture.

Table 3. *Questionnaire Structure and Measurement Items*

Dimension	Code	Item
Motivation	Q1	I have sufficient autonomy to make decisions in my work.
Motivation	Q2	My organization supports the development of my digital skills.
Motivation	Q3	I feel motivated to improve my performance in a digital work environment.
Artificial Intelligence	Q4	I use artificial intelligence tools in my daily work activities.
Artificial Intelligence	Q5	Artificial intelligence increases my work efficiency.
Artificial Intelligence	Q6	I am concerned that artificial intelligence may replace my job in the future.
Organizational Culture	Q7	My organization encourages innovation and experimentation.
Organizational Culture	Q8	Knowledge sharing is an integral part of my organization’s culture.
Organizational Culture	Q9	My organization supports digital transformation initiatives.
Integrative Item	Q10	The use of artificial intelligence positively influences the organizational culture in my organization.

Source: Developed by the authors.

The questionnaire was designed specifically for the purposes of the present study and was based on the conceptual relationships proposed in the Motivation 4.0 model and the literature on artificial intelligence and digital organizational culture. The selected items aimed to capture respondents’ perceptions regarding motivation, AI adoption, and organizational culture in digitally transforming organizational environments.

4.2 Reliability Analysis

To assess the internal consistency of the questionnaire, Cronbach’s alpha coefficients were calculated for the three main dimensions of the instrument. Results are presented in Table 4.

Table 4. *Reliability Analysis of the Questionnaire*

Dimension	Items	Cronbach’s α
Motivation	Q1–Q3	0.235
Artificial Intelligence	Q4–Q6	0.722
Digital Organizational Culture	Q7–Q9	0.345

Source: Authors’ calculations based on survey data.

The results indicate acceptable internal consistency for the Artificial Intelligence dimension ($\alpha = 0.722$), while lower reliability coefficients were observed for the Motivation ($\alpha = 0.235$) and Digital Organizational Culture ($\alpha = 0.345$) dimensions. These values suggest that the items within these dimensions capture related but not necessarily homogeneous aspects of the examined constructs. Given the exploratory nature of the study and the limited number of

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items included in each scale, the questionnaire should be regarded as a preliminary research instrument rather than a fully validated psychometric measure. Therefore, the findings should be interpreted with caution and viewed as indicative of broader trends that require further validation in future research.

5. Empirical Results

5.1 Descriptive Statistics

The descriptive analysis reveals notable differences between public and business sector organizations regarding motivation, AI adoption, and digital organizational culture. Business sector respondents report consistently higher mean values across all three constructs, indicating greater perceived motivation, stronger AI integration, and a more developed digital organizational culture. Table 5 presents the descriptive statistics for the examined variables across the two sectors.

Table 5. *Descriptive Statistics of the Main Variables by Sector*

Variable	Public Sector	Business Sector
Motivation	3.40	4.36
AI	2.37	3.82
Digital Organizational Culture	3.56	4.24

Source: Authors' calculations based on survey data.

Most notably, the mean value for AI-related variables in the public sector remains comparatively low ($M = 2.37$), suggesting limited practical implementation of AI-supported processes. In contrast, business organizations demonstrate significantly higher AI readiness ($M = 3.82$), reflecting a more advanced stage of digital transformation.

5.2 Correlation Analysis

The correlation analysis demonstrates substantial sectoral differences in the relationships between the examined variables.

Table 6. *Public Sector Correlations*

Relationship	r	p
Motivation - AI	-0.399	0.029*
Motivation - Culture	0.015	0.939
AI - Culture	-0.054	0.777

Source: Authors' calculations based on survey data.

Note: * $p < 0.05$.

The results presented in Table 6 reveal a statistically significant moderate negative relationship between motivation and artificial intelligence ($r = -0.399$, $p = 0.029$). This finding suggests that employees who perceive a higher level of AI implementation tend to report lower levels of motivation. Such a relationship may reflect concerns regarding job security, increased monitoring, reduced professional autonomy, or uncertainty associated with technological change.

In contrast, the relationships between motivation and digital organizational culture ($r = 0.015$, $p = 0.939$) and between AI and digital organizational culture ($r = -0.054$, $p = 0.777$) are extremely weak and statistically insignificant. These findings indicate that artificial intelligence has not yet become a meaningful driver of digital organizational culture within the examined public organizations. The results may reflect the relatively slow pace of digital transformation in public administration, where technological initiatives are often implemented through administrative requirements rather than through employee-driven innovation and organizational learning.

Table 7. *Business Sector Correlations*

Relationship	r	p
Motivation - AI	0.539	0.002**

Motivation - Culture	0.337	0.069
AI - Culture	0.556	0.001**

Source: Authors' calculations based on survey data.

Note: ** $p < 0.01$.

The results presented in Table 7 demonstrate substantially stronger relationships among the examined variables in the business sector. A moderate positive correlation is observed between motivation and artificial intelligence ($r = 0.539$, $p = 0.002$), indicating that employees who perceive greater use of AI also report higher levels of motivation. This relationship is statistically significant at the 0.01 level.

Similarly, a moderate positive and statistically significant relationship exists between AI and digital organizational culture ($r = 0.556$, $p = 0.001$). This finding suggests that AI adoption is closely associated with organizational environments characterized by innovation, flexibility, and data-driven decision-making.

Although motivation is positively related to digital organizational culture ($r = 0.337$), the relationship does not reach statistical significance ($p = 0.069$). Nevertheless, the positive direction of the coefficient indicates that motivation may still contribute to the development of digital organizational culture, although the effect is weaker than the direct influence of AI.

Table 8. Hypothesis Testing

Hypothesis	Result
H1: Motivation is positively associated with digital organizational culture.	Partially supported
H2: Artificial intelligence is positively associated with digital organizational culture.	Supported in the business sector; not supported in the public sector
H3: Motivation is positively associated with artificial intelligence adoption.	Supported in the business sector; not supported in the public sector
H4: The relationships among motivation, AI, and digital organizational culture differ between public and business sector organizations.	Supported

Source: Authors' interpretation based on correlation analysis.

The hypothesis testing results indicate that the role of artificial intelligence differs substantially across organizational contexts. While AI demonstrates positive and statistically significant associations with both motivation and digital organizational culture in the business sector, similar relationships are not observed in public organizations. These findings support the view that organizational culture and digital maturity influence the effectiveness of AI adoption and its contribution to organizational development. H1 was considered partially supported because the relationship between motivation and digital organizational culture remained positive in both sectors, although statistical significance was not achieved.

Overall, the findings reveal a clear sectoral contrast. While AI implementation in the public sector is associated with lower motivation and has no significant relationship with digital organizational culture, the business sector demonstrates positive and statistically significant relationships between AI, motivation, and digital organizational development. These results support the argument that organizational context plays a critical role in determining how artificial intelligence influences employee attitudes and cultural transformation.

5.3 Comparative Interpretation

These findings suggest that business organizations are more successful in integrating motivational practices and AI technologies into a coherent digital organizational culture. Public sector organizations, however, appear to remain in an earlier stage of digital transformation, where technological implementation may still be perceived as externally imposed rather than culturally embedded.

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The observed differences may be explained by the more flexible structures, stronger innovation orientation, and higher digital readiness typically found in private sector organizations, compared to the more hierarchical and risk-averse nature of public administration.

6. Discussion

The empirical findings of the present study provide substantial support for the proposed conceptual relationship between the Motivation 4.0 model, artificial intelligence, and digital organizational culture. The results also reveal significant sectoral differences between public and business organizations, indicating that the effectiveness of these relationships is strongly influenced by organizational context.

The positive relationship between AI and digital organizational culture in the business sector is consistent with the findings of Shokrollahi (2025) and Sherba et al. (2025), who reported that organizations characterized by stronger digital readiness and innovation-oriented cultures achieve more successful AI integration. Similarly, the observed resistance toward AI in the public sector corresponds with the findings of Akyazı (2023), who identified employee concerns and organizational culture as important determinants of AI acceptance.

The negative correlation observed in the public sector may also reflect concerns regarding job security, digital surveillance, and limited employee participation in technological change processes. These factors have been identified in previous studies as common barriers to AI acceptance and may partially explain the lower levels of motivation associated with AI implementation in public administration (Akyazı, 2023; Shokrollahi, 2025).

The business sector demonstrates consistently stronger positive correlations among motivation, AI, and digital organizational culture, suggesting that private organizations are more successful in integrating motivational practices and technological innovation into coherent digital transformation strategies. In particular, the strong positive relationship between AI and digital organizational culture confirms that artificial intelligence functions as an important enabler of agility, innovation, and data-driven organizational behavior in digitally mature business environments.

In contrast, the public sector exhibits weak or negative correlations between AI-related variables and organizational culture. These findings suggest that artificial intelligence has not yet been fully embedded as a supportive mechanism for cultural transformation in public administration. One possible explanation lies in the structural and managerial characteristics of public sector organizations, particularly municipalities, which are often characterized by more rigid bureaucratic systems, hierarchical decision-making structures, and slower adaptation to organizational change. Such environments tend to reduce flexibility and innovation capacity, thereby limiting the effectiveness of AI implementation and its positive influence on motivation and culture. The moderate negative relationship between motivation and AI in the public sector may indicate that employees perceive AI not as a supportive technology but rather as an externally imposed change associated with uncertainty, increased control, or potential job insecurity. This finding aligns with existing literature suggesting that employee resistance to AI adoption is more pronounced in organizations with lower digital readiness and less adaptive organizational cultures.

From a theoretical perspective, the results extend the Motivation 4.0 model by demonstrating that its practical effectiveness is contingent upon organizational readiness and digital maturity. While the model provides a relevant framework for fostering digital organizational culture, its successful implementation appears to depend on the presence of supportive structural, cultural, and technological conditions.

The findings confirm that artificial intelligence should not be viewed merely as a technological instrument but as a transformative organizational factor whose impact is

mediated by cultural readiness, leadership practices, and employee perceptions. Consequently, organizations seeking to build digital organizational cultures must invest not only in AI technologies but also in cultural transformation, digital leadership, and employee development initiatives.

An additional limitation of the study relates to the use of convenience sampling, which may restrict the generalizability of the findings beyond the organizations included in the sample. Future studies could employ larger and more representative samples in order to enhance the external validity of the results.

The results should also be interpreted with caution due to the exploratory nature of the questionnaire and the relatively limited sample size. Although the study provides valuable insights into the relationships between motivation, artificial intelligence, and digital organizational culture, future research should employ larger samples and validated measurement scales to further examine the proposed conceptual relationships.

Overall, the empirical evidence provides preliminary support for the conceptual pathways proposed in Figure 1, particularly regarding the central role of artificial intelligence as a catalyst linking motivational factors with the development of digital organizational culture.

7 Conclusion

The present study examined the role of the Motivation 4.0 model and artificial intelligence as factors contributing to the development of digital organizational culture. By integrating theoretical analysis with empirical evidence, the research confirms that digital organizational culture emerges through the interaction of motivational, managerial, and technological factors rather than through technological implementation alone.

The findings demonstrate that the components of the Motivation 4.0 model (emotional intelligence, green human resource management, corporate social responsibility, and benchmarking with storytelling) provide a relevant conceptual foundation for understanding how organizations can foster adaptive, value-driven, and innovation-oriented cultures in the digital era. At the same time, artificial intelligence functions as both a mediator and a catalyst that amplifies the impact of these motivational and organizational factors through automation, intelligent data processing, and enhanced decision-making.

The empirical results reveal significant differences between public and business sector organizations. While business organizations demonstrate positive relationships between motivation, AI, and digital organizational culture, with statistically significant associations involving AI, public sector organizations show weaker and in some cases negative relationships, indicating lower digital maturity and slower adaptation to technological change. These findings suggest that the successful implementation of AI and digitally oriented motivational practices depends heavily on organizational readiness, leadership support, and cultural flexibility.

From a practical perspective, the study highlights the need for organizations (particularly in the public sector) to invest not only in technological infrastructure but also in employee development, digital leadership, and cultural transformation initiatives. Without such complementary efforts, AI implementation may fail to generate the expected improvements in motivation and organizational effectiveness. Despite its contributions, the study is subject to certain limitations, including the relatively limited sample size and the focus on Bulgarian organizations, which may restrict the generalizability of the findings. Future research may expand the sample, include additional sectors and countries, and apply more advanced statistical methods to further validate the proposed conceptual model. Furthermore, the use of a convenience sampling approach may limit the broader generalizability of the findings.

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In conclusion, the study confirms that the integration of Motivation 4.0 principles and artificial intelligence represents a promising pathway for building sustainable digital organizational cultures capable of responding effectively to the challenges of contemporary digital transformation.

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TRANSFORMING JOB ROLES WITH GENERATIVE AI: EVIDENCE FROM JOB POSTINGS IN THE GEORGIAN LABOR MARKET

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Abstract: *This paper examines how generative artificial intelligence (GenAI) is reshaping business roles in the Georgian labor market. Based on a dataset of job postings collected from major hiring platforms, the study applies a five-type transformation typology: role expansion, enrichment, redesign, merging, and new role creation to identify patterns of change. The findings show that GenAI is primarily integrated into existing roles while also contributing to the emergence of new AI-focused positions. More disruptive transformations, such as role redesign and merging, remain less widespread, indicating that deeper structural changes are still developing. Overall, the results suggest that the Georgian labor market is in an early but active phase of AI adoption, where augmentation dominates but institutionalization is increasing within technical fields. The study provides structured empirical evidence on GenAI-driven role transformation in Georgia and offers implications for workforce policy, education systems, and employer strategies.*

Keywords: *generative AI, labor market, role transformation, Georgia, workforce, occupational change.*

1 Introduction

The emergence of generative AI (GenAI) tools including large language models, code-generation platforms and multimodal systems accelerating changes in how job roles are structured globally. As Georgian firms in sectors such as marketing, IT services, communications, and media begin integrating GenAI into their operations, the impact extends well beyond task automation. GenAI is prompting organizations to reimagine job responsibilities, redistribute tasks between humans and AI systems and in some cases create entirely new occupational categories. Yet this transformation is occurring with limited institutional visibility: job postings and role descriptions in Georgia now contain observable signals of this shift, but they have not been systematically studied.

Understanding how roles are changing in the Georgian labor market is critical for aligning higher education, vocational training, and workforce policy with the rapidly evolving demands of a GenAI-influenced economy. Georgia occupies a distinctive position among emerging economies: it has a growing technology services sector, an internationally oriented ICT outsourcing industry, and a rapidly digitalizing business environment, yet it lacks the deep AI infrastructure and large-firm dominance that characterize the economies where most existing evidence has been collected. The patterns of GenAI-induced role change documented in the United States, Northern Europe, or China cannot be straightforwardly assumed to hold in Georgia they must be empirically investigated.

This paper addresses that gap. Drawing on job postings from the Georgian labor market collected in January, 2025, we apply a five-type transformation typology to classify how GenAI is being integrated into actual job requirements. The typology is grounded in recent international literature on AI and work and enables systematic comparison of transformation patterns across occupational categories and industry sectors.

2 Literature Review

The literature on generative AI and the future of work has grown dramatically since the public release of large language models in late 2022. What the empirical record reveals is that GenAI transforms work through at least five distinct patterns not a single-directional process of automation or augmentation, each operating through a different mechanism and in a different organizational context. This review traces each pattern as documented in real labor markets and job postings.

2.1 Role Expansion

Role expansion is the most pervasive entry point through which GenAI enters existing labor market structures. Existing job titles remain unchanged while task content expands to include AI-assisted content drafting, automated reporting, and routine integration of large language models into professional output. Ahmadi et al. (2023), analyzing ChatGPT-related U.S. job advertisements from mid-2023, identify general familiarity and creative content generation as the most widely distributed skill clusters both embedded within existing titles rather than new AI-designated positions. Acemoglu et al. (2022), examining the near-universe of U.S. online vacancies from 2010 to 2018, show that AI-exposed establishments broaden AI-related task demands within existing postings while reducing non-AI vacancy volume. Dillon et al. (2025) find in a field experiment across 66 firms and 7,137 knowledge workers that GenAI access reduced email time by two hours per week without any detectable shift in the formal composition of task portfolios indicating productivity gains are reabsorbed as additional capacity within the same role. Hui et al. (2023) add a distributional qualification: even highly rated freelancers in AI-exposed categories experienced employment and earnings declines post-ChatGPT, suggesting firm-level expansion can coexist with individual-level displacement.

2.2 Role Enrichment

A more consequential pattern emerges when managing GenAI tools becomes a substantive professional responsibility. In enriched roles, workers are governors of AI designing prompts, evaluating output reliability, and optimizing AI integration into complex workflows. Peng et al. (2023), in a controlled experiment with professional developers using GitHub Copilot, document a 55.8% task completion advantage for AI-assisted workers. Hoffmann et al. (2025), studying open-source software developers, find Copilot access shifts work toward core coding and away from project management, while increasing exploratory over exploitative work styles. Gulati et al. (2025), analyzing 8.4 million postings from 596 U.S. firms, find GenAI roles demand 43.7% higher cognitive skill intensity, with a 4.5% post-ChatGPT decline in social skill demands. Bluemelhuber and Langer (2026), processing 22,352 GenAI postings on Stepstone, identify 32 distinct KSA clusters, finding GenAI roles layer new AI-specific competencies atop established professional foundations.

2.3 Role Redesign

Role redesign describes positions where GenAI substitutes for the generative core of a role, redirecting human effort toward supervision, verification, and correction of machine-produced outputs. Acemoglu (2024) establishes the economic logic: AI substitutes first where the ratio of AI to human task-specific productivity is highest typically content generation and structured text production. Capraro et al. (2024) identify communication, legal services, and customer support as the sectors where redesign is most visible. Eriksson and Nordin (2025), analyzing Swedish software engineering job advertisements, document that as AI code generation tools become standard, postings increasingly emphasize code review and output validation over independent authorship. Rahouli (2025) finds a perception-performance gap:

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workers report higher confidence using GenAI yet show no measurable improvement in independent analytical reasoning, suggesting redesign can progressively hollow out underlying cognitive capabilities.

2.4 Role Merging

Role merging occurs when GenAI enables a single worker to produce what previously required multiple specialists. Dillon et al. (2025) find that GenAI time savings are absorbed into broadened task coverage within the same role, implying firms extract cross-functional value in ways that effectively merge distinct task domains. De Cremer, Morini Bianzino and Falk (2023) illustrate this in creative industries: image generators and text tools enable individuals to simultaneously cover copywriting, visual production, and content strategy. Nakash and Peretz (2025), analyzing LinkedIn job postings, identify an explicit shift from unifunctional to multifunctional role expectations and a T-shaped professional model. Salari et al. (2025) confirm merging is most prevalent in digital-first and startup environments where multi-capability AI platform adoption is most rapid.

2.5 New Role Creation

New role creation represents the emergence of entirely novel occupational categories with no pre-AI equivalent positions such as Prompt Engineer, AI Content Strategist, GenAI Consultant, and AI Ethics Officer. Ahmadi et al. (2023) identify product development and prompt engineering skill clusters concentrated in newly titled positions with no close predecessor in pre-2022 job market data. Gulati et al. (2025) show GenAI-proficiency roles have grown substantially post-ChatGPT and exhibit a structurally distinct skill profile constituting a genuinely new occupational category. Chen et al. (2025), studying the Chinese labor market, find a positive correlation between occupational LLM exposure scores and vacancy growth rates consistent with expanding professional demand driven by the AI capability frontier. Nakash and Peretz (2025) identify Quality and Compliance and Career Development as newly institutionalized AI job categories crystallized only in the GenAI era.

2.6 Transformation Typology

Drawing on the five streams of evidence reviewed above, Table 1 presents the formal typology of GenAI-induced role transformations applied in this study, specifying the core description, identification criteria, and supporting empirical literature for each type. This typology provides the coding framework applied to the Georgian job posting sample.

Table 1. *Typology of GenAI-Induced Role Transformations*

Type	Description	Identification Criteria	Supporting Literature
1. Role Expansion	Traditional job title unchanged; GenAI tasks added to existing responsibilities.	Title unchanged (e.g., Manager, Analyst). Description includes tasks involving specific GenAI tools as part of regular work.	Ahmadi et al. (2023); Acemoglu et al. (2022); Dillon et al. (2025); Salari et al. (2025)
2. Role Enrichment	Role deepened to require strategic or technical GenAI mastery: prompt engineering, workflow optimisation, output governance.	Mentions advanced GenAI use: design prompts, evaluate AI output, develop workflows. Common in senior-level listings.	Peng et al. (2023); Hoffmann et al. (2025); Gulati et al. (2025); Bluemelhuber & Langer (2026)

Type	Description	Identification Criteria	Supporting Literature
3. Role Redesign	GenAI replaces part of the role's original tasks; worker focus shifts to supervision, review, or QA.	Job description centers on editing or validating AI-generated outputs. Oversight and QA language is prominent.	Acemoglu (2024); Gries & Naude (2022); Tona et al. (2025); Eriksson & Nordin (2025)
4. Role Merging	Single role combines tasks from formerly distinct domains, made viable by GenAI support.	One job includes tasks from two or more distinct domains. Multiple GenAI tools referenced. Common in SMEs.	Dillon et al. (2025); Hoffmann et al. (2025); De Cremer et al. (2023); Nakash & Peretz (2025)
5. New Role Creation	Entirely new GenAI-focused occupations emerge with distinct titles and no pre-AI equivalent.	Title includes AI Specialist, Prompt Engineer, GenAI Consultant. Role centered on GenAI use or development.	Ahmadi et al. (2023); Gulati et al. (2025); Bluemelhuber & Langer (2026); Chen et al. (2025)

Note. Identification criteria are the operational coding rules applied in this study.

3 Methodology

This study adopts a qualitative content analysis design applied to a purposive sample of job postings from the Georgian labor market. The methodological foundation is the five-type transformation typology developed in the literature review. The design is cross-sectional, capturing a snapshot of the market at a specific point in time, with a second-round data collection planned for a subsequent period to enable longitudinal comparison.

The empirical phase involved systematic collection of all publicly available job postings published during a January, 2026 on LinkedIn, Jobs.ge, HR.ge and Facebook job boards the major hiring platforms in Georgia. From this list, only advertisements explicitly mentioning GenAI-related tasks, tools, or skills were selected, including references to ChatGPT, Gemini, Copilot, Midjourney, LLMs, prompt engineering and analogous technologies in both English and Georgian.

Before transformation type coding was applied, each posting underwent an applicability assessment. A posting was classified as Applicable if GenAI constituted an active task requirement (assigned responsibility, formal skill requirement, or title indicator) rather than a background mention, passive awareness clause, or nice-to-have qualifier. This yielded 88 applicable postings retained for full coding and rest were designated Not Applicable and excluded.

Each applicable posting was coded against the five-type typology using manual review to add coding. Each posting was further classified using ISCO-08 occupational codes (four-digit unit group level) and NACE Rev.2 sector codes.

Table 2. *Coding Criteria for GenAI Transformation Types*

Type	Description	Identification Criteria	Characteristic Indicators
1. Role Expansion	Title unchanged; GenAI tasks added as productivity add-on.	Title unchanged; GenAI tools in responsibilities or required skills, not only company overview.	'Use ChatGPT to write reports'; 'AI-assisted content generation'; tool names (Midjourney, Copilot) in required skills.

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Type	Description	Identification Criteria	Characteristic Indicators
2. Role Enrichment	Role deepened to require AI governance, not just AI use.	Advanced GenAI use: prompt engineering, AI workflow design, LLM integration. Core requirement, not supplementary.	'Design and optimize prompts'; 'develop GenAI workflows'; 'evaluate AI outputs'; 'LLM integration expertise required'.
3. Role Redesign	GenAI assumes generative tasks; human shifts to oversight and QA.	Description centers on editing, reviewing, or validating AI-generated outputs rather than creating from scratch.	'Review and edit AI drafts'; 'validate generated summaries'; 'QA AI outputs'; 'test model responses'.
4. Role Merging	Single role covers formerly distinct functional domains via GenAI.	Tasks from two or more distinct domains in one posting. Multiple GenAI tools from different domains referenced.	'Create content, visuals, and data reports with AI support'; multiple tool names across domains.
5. New Role Creation	Entirely novel GenAI-centric occupation with no close pre-AI equivalent.	Title explicitly signals GenAI function. Responsibilities center on designing, developing, or governing AI systems.	Title: AI Engineer, Prompt Engineer, MLOps Engineer, AI Ethics Specialist, GenAI Consultant.

Note. Where a posting exhibits features of more than one type, the dominant type is assigned based on the primary function and task focus of the role.

Several limitations apply. The sample is concentrated in the ICT sector, and internationally oriented software firms account for a significant share of postings, which may inflate New Role Creation and Role Enrichment relative to the broader Georgian economy. The cross-sectional design captures a snapshot of a rapidly evolving market. Job postings reflect demand signals rather than actual employment outcomes.

4 Results

4.1 Distribution of Transformation Types

Table 3 presents the distribution across the 88 applicable postings. Role Expansion is the most prevalent type by a substantial margin ($n = 48$, 54.5%): traditional occupational roles are being augmented by AI tool requirements without fundamental recharacterization of occupational identity. New Role Creation is the second most prevalent type ($n = 19$, 21.6%), concentrated predominantly in AI and ML engineering roles. Role Enrichment ($n = 13$, 14.8%) captures roles where GenAI competencies have become core strategic requirements. Role Redesign ($n = 5$, 5.7%) and Role Merging ($n = 3$, 3.4%) are the least frequent types, confirming that deep task displacement and cross-domain consolidation remain comparatively rare in the current Georgian posting landscape.

Table 3. *Distribution of GenAI Transformation Types ($n = 88$ applicable postings)*

Transformation Type	n	% of Applicable	Primary Occupational Domain
Role Expansion	48	54.5%	Marketing, content creation, design, software dev
Role Enrichment	13	14.8%	ICT professionals, data science

Transformation Type	n	% of Applicable	Primary Occupational Domain
Role Redesign	5	5.7%	QA, testing, data operations
Role Merging	3	3.4%	Creative/media, content writing
New Role Creation	19	21.6%	AI & ML engineering, data science, consulting
Total	88	100.0%	—

Note. Percentages are of the 88 applicable postings.

4.2 Occupational Analysis (ISCO-08)

Table 4 cross-tabulates transformation types against ISCO-08 major groups across all 88 applicable postings. ISCO Major Group 2 (Professionals) accounts for 72 postings (81.8%), the dominant group by a substantial margin. ISCO Major Group 1 (Managers) accounts for 14 postings (15.9%), with Role Expansion the most frequent type (9 postings) among managers, followed by New Role Creation (3) covering AI director and team lead positions, Role Enrichment (1), and Role Redesign (1). ISCO Major Group 3 (Technicians) accounts for only 2 postings (2.3%), both classified as Role Redesign an audio transcriptionist and a QA tester whose tasks are structured around validating AI-generated outputs.

Table 4. Transformation Type by ISCO-08 Major Occupational Group (n = 88)

ISCO-08 Major Group	Expansion	Enrichment	Redesign	Merging	New Role	Total
Managers (ISCO 1)	9	1	1	0	3	14
Professionals (ISCO 2)	39	12	2	3	16	72
Technicians (ISCO 3)	0	0	2	0	0	2
Total	48	13	5	3	19	88

Note. All 88 applicable postings have ISCO-08 codes assigned. Exp. = Expansion; Enr. = Enrichment; Red. = Redesign; Mrg. = Merging; New = New Role Creation.

At the four-digit ISCO unit group level (Table 5), ISCO 2519 (Software and Applications Developers NEC) is the largest group across all 88 postings (n = 27, 30.7%), with Role Expansion (12) the most frequent type, followed by New Role Creation (9) and Role Enrichment (5). ISCO 2512 (Software Developers, n = 12, 13.6%) is the second largest, with Expansion (6), Enrichment (3), Redesign (1), and New Role Creation (2). ISCO 2431 (Advertising and Marketing Professionals, n = 10, 11.4%) is primarily Expansion (5) with New Role Creation (3) covering Technical AI Consultant and AI specialist postings. ISCO 1330 (ICT Services Managers, n = 10, 11.4%) is predominantly Expansion (6), with 2 New Role Creation cases (ML/AI Engineering Team Lead; AI & IT Director). ISCO 2166 (Graphic and Multimedia Designers, n = 8, 9.1%) spans Expansion (5), Merging (1), Enrichment (1), and New Role Creation (1), reflecting the differentiated transformation pattern in creative occupations. The two ISCO Major Group 3 postings are ISCO 3514 (Onboarding QA Tester) and ISCO 3319 (Audio Transcriptionist), both Role Redesign, representing the clearest cases of AI-driven task displacement in the sample.

Table 5. ISCO-08 Unit Groups in GenAI-Affected Roles, by Transformation Type (n = 88)

ISCO	Occupational Group	n	%	Exp.	Enr.	Red.	Mrg.	New
2519	Software & App. Developers NEC	27	30.7%	12	5	1	0	9
2512	Software Developers	12	13.6%	6	3	1	0	2
2431	Advertising & Marketing Profs.	10	11.4%	5	1	0	1	3

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ISCO	Occupational Group	n	%	Exp.	Enr.	Red.	Mrg.	New
1330	ICT Services Managers	10	11.4%	6	1	1	0	2
2166	Graphic & Multimedia Designers	8	9.1%	5	1	0	1	1
2522	Systems Administrators	4	4.5%	3	1	0	0	0
2422	Management & Org. Analysts	4	4.5%	3	1	0	0	0
2641	Authors & Related Writers	4	4.5%	2	0	0	1	1
1219	Business Services Managers NEC	4	4.5%	3	0	0	0	1
3514	Web & Multimedia Developers	1	1.1%	0	0	1	0	0
3319	Admin. & Secretarial Workers NEC	1	1.1%	0	0	1	0	0
2432	Public Relations Professionals	1	1.1%	1	0	0	0	0
2611	Lawyers	1	1.1%	1	0	0	0	0
2342	Primary School Teachers	1	1.1%	1	0	0	0	0

Note. All 88 applicable postings have ISCO codes. Percentages are of n = 88. Exp. = Expansion; Enr. = Enrichment; Red. = Redesign; Mrg. = Merging; New = New Role Creation. ISCO 3319 = Administrative & Secretarial Workers NEC (Audio Transcriptionist).

4.3 Sectoral Analysis (NACE Rev.2)

Table 6 presents transformation types by NACE Rev.2 sub-sector across all 88 postings. The Information and Communication sector (NACE J) accounts for 68 postings (77.3%), heavily dominated by J62.01 (Custom software programming, n = 43, 48.9%), which concentrates Role Expansion (26), New Role Creation (9), and Role Enrichment (7). NACE J62.09 (Other IT and computer services, n = 13) has 5 New Role Creation and 2 Redesign cases the highest Redesign share of any sub-sector. The Professional, Scientific and Technical Activities sector (NACE M) accounts for 13 postings (14.8%): M70.22 (Management consultancy, n = 6) includes 2 New Role Creation cases (Technical AI Consultant roles), and M73.11 (Advertising agencies, n = 6) includes 1 Merging case (AI Content Creator) and 1 New Role Creation. The remaining 7 postings span diverse sectors including artistic creation (R90.03, n = 2, both Role Merging music content production using Suno and Udio), construction, real estate, event organization, legal activities, and education.

Table 6. Transformation Types by NACE Rev.2 Sub-sector (n = 88)

NACE Sector	Sub-sector	Expansion	Enrichment	Redesign	Merging	New Role
J – Information & Communication (n=68, 77.3%)	J62.01 Custom software programming (n=43)	26	7	1	0	9
	J62.09 Other IT & computer services (n=13)	4	2	2	0	5
	J62.02 Computer consultancy (n=9)	5	2	2	0	0
	J61.20 Wireless telecom (n=2)	1	0	0	0	1
	J60.10 Radio/media broadcasting (n=1)	1	0	0	0	0
M – Professional, Scientific &	M70.22 Business & management consultancy (n=6)	3	1	0	0	2

NACE Sector	Sub-sector	Expansion	Enrichment	Redesign	Merging	New Role
Technical (n=13, 14.8%)						
	M73.11 Advertising agencies (n=6)	3	1	0	1	1
	M69.10 Legal activities (n=1)	1	0	0	0	0
Other Sectors (n=7, 8.0%)	R90.03 Artistic creation – music/media (n=2)	0	0	0	2	0
	F41.20 Construction (n=2)	2	0	0	0	0
	L68.10 Real estate (n=1)	1	0	0	0	0
	N82.30 Event organization (n=1)	0	0	0	0	1
	P85.59 Other education (n=1)	1	0	0	0	0
Total	—	48	13	5	3	19

Note. All 88 applicable postings have NACE codes. NACE J = Information and Communication (77.3%); M = Professional, Scientific and Technical Activities (14.8%); Other sectors = 8.0%.

4.4 Broad Occupational Groups and Illustrative Job Titles

Table 7 synthesizes the occupational analysis by presenting broad occupational groups author-defined aggregations of ISCO-08 unit groups alongside dominant transformation types, secondary types, and illustrative job titles drawn from the Georgian posting sample. All 88 postings are now assigned to a group.

Table 7. *GenAI Transformation Types by Broad Occupational Group with Illustrative Job Titles (n = 88)*

Occupational Group	ISCO-08 Codes	n	Dominant Type	Secondary Types	Illustrative Job Titles
AI & ML Engineering	2519 (part)	19	New Role Creation	Expansion, Enrichment	Senior AI Engineer; Lead AI Python Engineer; Senior MLOps Engineer; GenAI Ops Engineer; AI Solution Architect; AI/ML Engineer Lead; AI Specialist
Software & Systems Engineering	2512, 2519 (part), 2522	23	Role Expansion	Enrichment	Cloud Native .NET Engineer (AI Integration); Senior iOS/Android Developer; Senior .NET Developer; Solution Architect – MS Copilot; Senior Software Engineer (Go, LLM); Associate Software Engineer
Data Science & Analytics	2519 (part)	8	New Role Creation / Enrichment	Expansion	Data Science Team Lead; Senior Data Scientist; Lead Data Scientist; Data Solution Architect / AI Architect; Senior Infrastructure Automation Engineer
QA, Testing & Data Operations	3514, 3319	2	Role Redesign	—	Onboarding QA Tester; Audio Transcriptionist

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Occupational Group	ISCO-08 Codes	n	Dominant Type	Secondary Types	Illustrative Job Titles
Marketing & Advertising	2431, 2432	11	Role Expansion	New Role Creation, Merging	PR Specialist (AEO focus); Digital PR & AEO Specialist; Technical AI Consultant; Growth Marketing Specialist; AI Advertising Intern; Digital Marketing & Product Coordinator
Creative Design & Media	2166, 2641	12	Role Expansion	Merging, Enrichment	Graphic Designer (Marketing Content); UI/UX Designer; Marketing Video Artist; AI Content Creator; AI Content Manager; Music Content Author (Suno/Udio); Video Editor; Lead AI Python Engineer
Management & Consulting	1330, 1219, 2422	22	Role Expansion	New Role Creation, Enrichment	AI & IT Director; ML/AI Engineering Team Lead; AWS Technology Leader; Client Engagement Leader; Senior Delivery Manager; Sr. Manager/Director Cloud Consulting; Operations Director; Business Monitoring Manager
Education, Legal & Other	2342, 2611	4	Role Expansion	—	Programming & Robotics Trainer; Corporate Lawyer (AI tools); IT Specialist; Project Manager

Note. Dominant Type indicates the most frequent transformation type within the group. Job titles are representative examples drawn from the Georgian posting sample.

5 Discussion

The results reveal a Georgian labor market in which **Role Expansion** is the dominant mode of GenAI integration, accounting for more than half of all applicable postings. This pattern is visible across every occupational major group from Managers to Professionals and across diverse sectors including marketing agencies, law firms, construction companies, event management, education providers and media firms, confirming that the additive pattern is economy-wide rather than sector-specific. Even within the most technically advanced subsector, Custom Computer Programming (NACE J62.01), role expansion outpaced all other transformation types. The most immediate workforce development priority is therefore AI tool fluency at scale, distributed across non-technical degree programs and vocational training rather than concentrated in engineering alone.

New Role Creation accounts for just over a fifth of applicable postings and is concentrated primarily among Software and Applications Developers (ISCO 2519) and Other IT and Computer Services firms (NACE J62.09), where positions such as Senior AI Engineers, GenAI Ops Engineers and AI Solution Architects represent genuinely new professional identities. A notable share of Technical AI Consultant roles appears in management consultancy (NACE M70.22), serving enterprise clients across sectors. This pattern reflects a dynamic in which internationally oriented ICT firms are generating genuinely new AI occupations while the broader Georgian market primarily absorbs GenAI into existing roles, consistent with the dual-track pattern Chen et al. (2025) document in emerging market technology sectors.

Role Enrichment is concentrated among software and applications developers and software developers, almost entirely within ICT programming and consultancy services

(NACE J62), reflecting the technical depth required for AI governance competencies in internationally oriented software firms. **Role Redesign** is the most structurally distinctive type: both identified cases are in technician-level occupations, specifically an Audio Transcriptionist and an Onboarding QA Tester where AI now performs the primary task and the human contribution has been fully redirected toward output validation. Perception-performance gap warning is particularly relevant here: workers in such roles may report confidence gains while losing the independent reasoning competencies the redesigned role nominally retains. Finally, **Role Merging** is confined to creative and media environments — two music content creation roles in artistic creation (NACE R90.03) and one AI Content Creator in advertising (NACE M73.11) confirming that cross-domain consolidation is an early-stage phenomenon where GenAI tools span text, image, audio and video production simultaneously.

6 Conclusions

This study provides the first structured empirical evidence on how generative AI is reshaping job roles in the Georgian labor market. Applying a five-type transformation typology to job postings collected from major Georgian hiring platforms, we find that **all five patterns of GenAI-induced role transformation** identified in the international literature are empirically present in Georgia, confirming that the framework captures real and observable dynamics rather than theoretical projections.

Several specific findings stand out. First, role expansion is the dominant transformation mode, concentrated in marketing, content creation, design and general software development, where AI tool requirements are being appended to existing job profiles without reconceiving occupational identity. This additive pattern is consistent across sectors and seniority levels, suggesting that Georgia's labor market is in an early but active phase of GenAI integration where augmentation precedes structural change.

The new role creation is the second most prevalent pattern and is concentrated in technology services, particularly among AI engineering and data science positions where genuinely new professional identities have emerged with no pre-AI equivalent. Role enrichment appears primarily in senior and specialist ICT positions where managing and governing AI systems has become a core competency requirement, rather than simply using AI as a productivity tool. Additionally, role redesign and role merging remain rare, but they are not absent: redesign is identifiable in testing and data annotation roles where AI has assumed the primary task and humans have shifted to output validation, while merging appears in creative and media roles where generative tools enable one worker to span domains previously requiring multiple specialists.

Several directions for future research follow from these findings. The most immediate priority is temporal replication: applying the same methodology to a new sample of Georgian job postings collected six to twelve months later would enable direct comparison and detection of whether the current dominance of role expansion is shifting toward enrichment, redesign or new role creation as employers deepen their GenAI integration. Second, combining posting analysis with employer interviews or employee surveys would allow researchers to examine whether the transformations encoded in job advertisements are materializing in actual work practices. Third, the sample's concentration in the ICT sector points to the need for a sector-diversified study targeting industries where GenAI adoption may be less visible in public postings, such as healthcare, finance, legal services and education. Finally, the Georgian findings invite comparison with other South Caucasus and post-Soviet economies, enabling the development of a region-specific account of how emerging economies absorb general-purpose AI technologies into their labor market structures.

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THE EFFECTS OF THE ECONOMIC CRISIS ON THE ROMANIAN ECONOMY IN THE PERIOD 2024–2026

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Abstract: During the period 2024–2026, the Romanian economy went through a difficult phase, characterized primarily by a strong fiscal impulse in 2024, persistent inflationary pressures, and policy adjustments in 2025. To understand why these problems accumulated, it is useful to look at preceding years as well: in 2022–2023, Romania had relatively loose fiscal policies and rapid wage growth, and these trends created vulnerabilities that were amplified in 2024–2025. The earlier years thus explain why the 2024 impulse had such a powerful impact, and the analysis must focus in particular on what happened in 2024 and 2025, when the imbalances became evident.

Keywords: public, investments, fiscal, policies, economic, crisis, Romania.

1. Introduction

In brief, in 2024 the government increased expenditure and wages, which stimulated consumption but also raised imports. At the same time, supply-side shocks emerged (higher energy prices, climate-related issues) that kept prices elevated. In 2025, the first corrective measures were adopted (expenditure freezes or cuts and a medium-term fiscal plan), yet the effects of the 2024 policies and external shocks were still being felt throughout the economy.

The aim of this paper is to assess the effects of the economic crisis on the Romanian economy in the period 2024–2026 and to formulate public policy recommendations for restoring macroeconomic sustainability and improving competitiveness.

1. How did private and public investment evolve in Romania in the period 2024–2026, and what were the main causes?
2. To what extent did the fiscal policies of 2024 influence the current account and the structure of external financing?
3. What role did the NRRP play in stabilising economic activity and offsetting private-sector contraction?
4. What are the main risks for 2026 and which policies are advisable?

2. Theoretical Framework

2.1 Twin Deficits and the Open Economy Identity

Twin deficits describe the situation in which a budget deficit (public expenditure exceeds revenues) is accompanied by a current account deficit (imports and external payments exceed exports). A persistent budget deficit tends to increase domestic demand and imports, thereby deteriorating the current account, with consequences for the external position and financing costs. This can be demonstrated through the macroeconomic identity:

$$CA = S - I$$

CA is the current account of a country. S represents the total savings of the economy, whilst I represent total investment. This identity states that the surplus or deficit of the current account equals the difference between what a country saves and what it invests. Two cases emerge: if $S > I$, the economy saves more than it invests, resulting in a current account surplus (net export of capital abroad); or if $S < I$, the economy invests more than it saves, resulting in a current account deficit (external financing must be attracted).

2.2 Supply Shocks vs. Demand Shocks

Supply shocks are events that affect the capacity or cost of production of the economy, reducing the supply of goods and services or increasing input prices. For example, a sudden rise in energy prices or a drought that reduces agricultural output. Demand shocks are events that abruptly change the level of aggregate demand for goods and services, either upwards or downwards; for instance, a sharp increase in public expenditure or a sudden drop in consumer confidence that reduces consumption.

Macroeconomic policies must be calibrated to distinguish between these two types of shocks.

2.3 Public Investment

Public investment refers to expenditure undertaken by public authorities for the creation, maintenance, or improvement of physical and human capital (infrastructure, education, health, digitalisation), with the aim of enhancing productive capacity and well-being over the medium and long term.

3. Macroeconomic Context

3.1 Twin Deficits

In 2024, Romania recorded a significant deficit: the budget deficit rose to 8.7% of GDP, driven by wage increases and pension expenditure (European Commission, 2025). This fiscal loosening generated a demand impulse that increased imports and, in turn, a current account deficit (Eurostat, 2024–2026).

3.2 Monetary Policy

The National Bank of Romania (NBR) maintained a prudent monetary policy in 2024–2025, keeping the policy rate at elevated levels to guard against inflationary pressures: “The NBR Board of Directors decided to maintain the monetary policy interest rate at 6.50 per cent per annum” (National Bank of Romania [NBR], 2026).

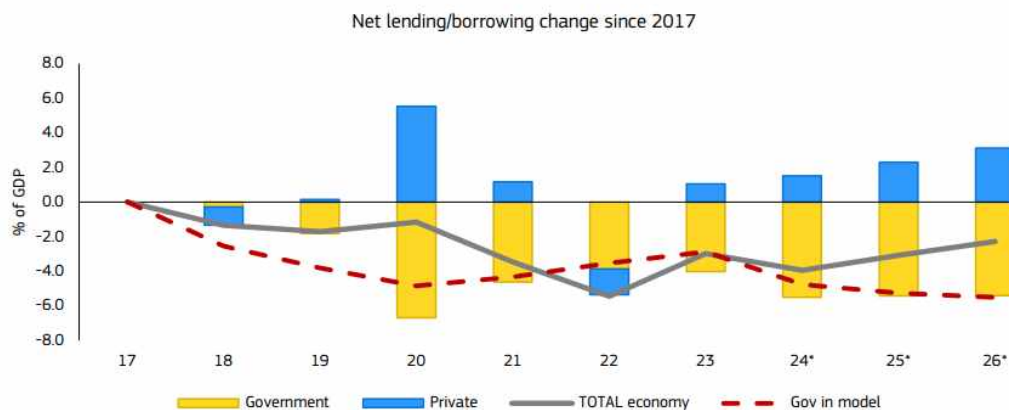
3.3 External Shocks and Energy

Energy shocks (the removal of price caps, oil price volatility) and geopolitical tensions increased pressure on prices and the trade balance, a vulnerability also highlighted in assessments of Romania’s external position (International Monetary Fund, 2023–2025). The liberalisation of energy prices for businesses represents an additional risk for costs and inflation.

4. Main Effects of the Crisis

4.1 Investment Trends 2024–2026

Figure 1. Change in Net Position (government, private sector, total economy) as % of GDP



Source: (European Commission, 2025)

This section presents and interprets the chart “Change in Net Position (government, private sector, total economy) as % of GDP”, briefly explaining what each series (Government, Private, Total) measures and the significance of the projections for 2024–2026. The inflection point of 2024 and its link to investment dynamics are highlighted.

In 2024, a strong fiscal impulse is observable: **government expenditure** increased significantly, and public investments (including NRRP projects) amplified short-term activity. In parallel, **private investment** contracted. Firms postponed large-scale projects owing to uncertainty (including the electoral context), financing costs, and weak external prospects. Part of the additional demand generated by the state was met through imports of inputs, which reduced the multiplier effect on domestic production and deepened the economy’s net financing position.

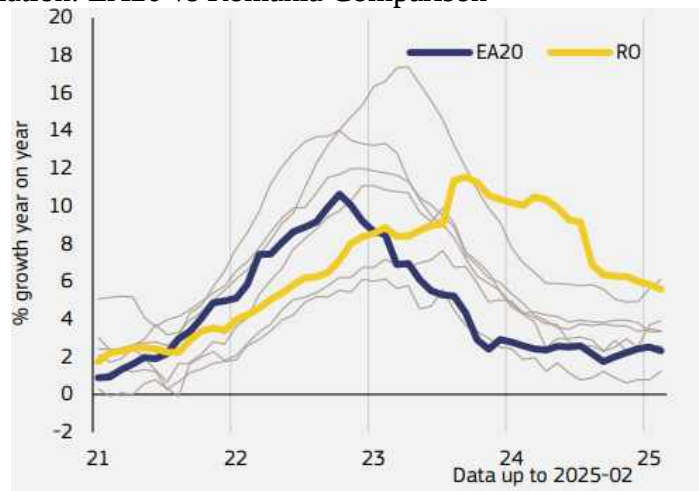
Fiscal consolidation measures and the acceleration of NRRP absorption led to a partial reallocation of resources towards productive public investments in 2025, with signs of stabilisation beginning to appear in the second half of the year. Nevertheless, the recovery of private investment remained incomplete: access to credit for SMEs was still restricted, and investor confidence was being restored only slowly; in sectors intensive in imported inputs (e.g., construction), the positive effect of public investment was attenuated by the weight of imports.

Should consolidation prove credible and reforms improving productivity and access to financing be implemented, 2026 could bring a moderate recovery in private investment and a gradual reduction of the external deficit; absent these conditions, vulnerabilities persist and the recovery will be slow. Policies that increase domestic procurement, facilitate SME credit, and prioritise NRRP projects with productivity effects will be decisive for transforming the public impulse into a durable investment driver.

4.2 Inflation

Inflation in Romania during 2024–2026 was driven simultaneously by demand-side and supply-side factors. On the demand side, nominal wage growth, which outpaced productivity gains, strongly fuelled domestic demand and raised unit labour costs. On the supply side, energy shocks and increases in indirect taxes (VAT and excise duty rises in 2025) pushed up production costs. The cost-price transmission mechanism meant that a significant proportion of these costs was passed on to final prices, keeping core inflation at elevated levels and affecting the competitiveness of exporters.

Figure 2. Core Inflation: EA20 vs Romania Comparison

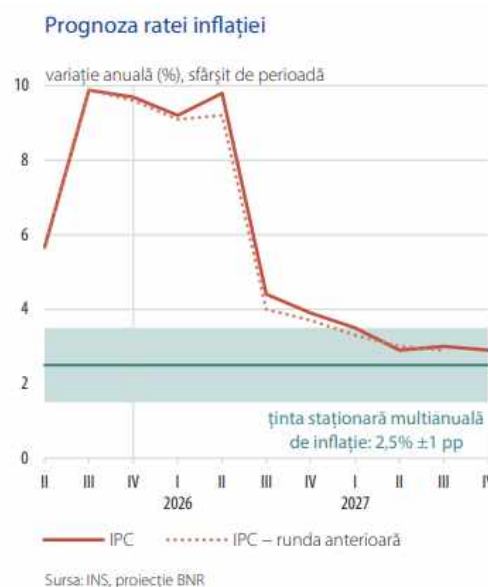


Source: (European Commission, 2025)

Core inflation: EA20 vs Romania comparison (2021–2025). The comparative chart shows that Romania recorded a much steeper rise in core inflation in 2022–2023 compared with the EA20 average, reaching a peak around 2023, followed by a slow moderation in 2024–2025. This trajectory reflects the combination of the domestic fiscal and wage impulse alongside external shocks: whilst the euro area (EA20) also experienced inflation, the amplitude and persistence of the phenomenon were greater in Romania.

The NBR’s forecast chart shows a two-phase trajectory: a period of elevated levels and volatility in the first phase (through the second half of 2026), followed by a relatively rapid decline towards the multi-annual target ($2.5\% \pm 1$ pp) in 2027. The projected peak around early 2026 reflects base effects and the impact of earlier measures (the removal of price caps, tax increases), and the subsequent correction is conditional upon the effects of fiscal consolidation, the moderation of domestic demand, and the normalisation of international energy and food prices.

Figure 3. Inflation Rate Forecast (annual change %, end of period). Shaded band: multi-annual stationary inflation target of $2.5\% \pm 1$ pp. Red line: CPI; dotted line: CPI – previous round.



Source: NIS, NBR projection.

4.3 Labour Market

Based on NBR assessments, the evolution of unemployment in 2025–2026 is driven more by the correction of aggregate demand than by an immediate structural labour market crisis. Redundancy pressures driven largely by wage growth are easing. Nevertheless, the compression of economic activity in Q3 2025 creates a context in which a moderate increase in the unemployment rate in 2026 remains probable, concentrated in demand-sensitive sectors (trade, consumption-oriented services, construction) and in industrial branches affected by costs and weak external demand.

Table 1. Unemployment Rate

Year	Unemployment Rate
2024	5.4%
2025	5.7% – 6.1%
2026	5.7% – 5.8% (moderate growth forecast)

5. Stabilisation and Destabilisation Mechanisms

Stabilisation involves reducing cyclical variations in GDP and prices through automatic stabilisers (taxes, social benefits), counter-cyclical fiscal policy, and monetary policy (Ailincă, 2019). **Destabilisation** refers to external shocks (fuel prices), delays in investment implementation, loss of fiscal credibility, and administrative bottlenecks.

5.1 The Role of the NRRP as a Stabilisation Mechanism

During 2024–2026, the National Recovery and Resilience Plan (NRRP) functioned as Romania's principal macroeconomic stabilisation mechanism, in a context marked by high inflation, slowing economic growth, and external pressure on energy prices. By virtue of its scale, representing over €28 billion directed towards infrastructure, energy, digitalisation, and structural reforms (Ministry of European Investments and Funds, n.d.), the NRRP compensated for the weakness of private investment and sustained aggregate demand during a period of fiscal consolidation. Investments in infrastructure and energy played an anti-cyclical role, maintaining activity in construction and related industries, whilst green transition projects reduced vulnerability to energy shocks. Overall, the NRRP acted as an economic buffer, limiting the destabilising effects of external shocks and providing a reform framework that strengthens economic resilience over the medium term.

5.1.1 Case Study: Impact of NRRP Investments on Public Construction Works

This case study evaluates how NRRP payments in 2025–2026 influenced the volume, pace, and structure of public construction works in Romania.

The documents analysed include payments from the period 2025–2026 in accordance with the reports of the Ministry of Environment (Ministry of Environment, Waters and Forests, n.d.) for: water and sewerage networks, road modernisation, municipal infrastructure, afforestation and environmental works, eco-islands, and waste management. These are categories of works that directly involve construction firms, designers, materials suppliers, and equipment providers.

A relevant project is that of the National Administration “Romanian Waters”, with large payments for hydraulic works (some exceeding RON 80 million).

The analysis reveals the following: the large volume of payments indicates a period of expansion in the public construction sector; projects are distributed uniformly across regions, reducing seasonality and dependence on a few areas; construction firms benefit from predictability, as payments are recurrent and projects span multiple years; pressure on supply chains increases, particularly for materials (concrete, pipes, aggregates); and the workforce becomes a critical factor given the large number of simultaneous projects.

In conclusion, NRRP investments represent a major stimulus for the construction sector, generating a high volume of public works that are diverse and nationally distributed. The documents analysed confirm an acceleration in fund absorption and a structural dependence of the sector on public investment. For construction firms, the period 2025–2026 is one of opportunity but also of operational pressure.

5.2 The Iran Shock – Destabilisation

The events of March 2026, marked by the escalation of conflict in Iran, represent an unpredictable occurrence with massive consequences. The primary cause of this shock is the disruption of global energy flows, which pushed the Brent crude price above the critical threshold of USD 110 per barrel. For Romania, a country that relies on energy imports to supplement its domestic requirements, this signified an immediate “supply shock”. Unlike a crisis caused by excessive consumer demand, this shock directly increased the cost of the economy's basic “ingredients”: transport, industrial production, and utilities. The knock-on

effect was inevitable, leading to a re-acceleration of inflation at precisely the moment when forecasts had indicated a relaxation, thereby forcing the National Bank to block any attempt to lower the benchmark interest rates in order to protect the stability of the national currency.

6. Public Policy Recommendations

6.1 Immediate Priorities

The most urgent need is intelligent fiscal consolidation. This would entail reducing the budget deficit not through undifferentiated cuts, but through the elimination of waste and improved collection efficiency. A critical priority is the full digitalisation of the National Agency for Fiscal Administration (ANAF), a measure that allows the state to increase revenues without placing additional pressure through new taxes on an already fragile private sector; strengthening institutional and governance capacity in this way is consistent with indicators of government effectiveness (World Bank, 2024). Furthermore, in the face of the oil price shock from Iran, the state must replace generalised energy subsidies with protection measures targeted strictly at vulnerable groups. This approach frees up essential financial resources that can be redirected towards “high-multiplier” projects, that is, investments that generate added value and long-term employment.

6.2 Medium-Term Priorities

Over the medium term, the financial strategy must be linked to the rigorous implementation of the NRRP. This is not merely a capital flow, but an instrument of structural reform (OECD, 2026). The priority must be to advance energy infrastructure projects and the transition towards renewable sources, so as to reduce economic dependence on Brent oil price volatility.

Another strategic step concerns the labour market: the allocation of funds for large-scale retraining programmes, necessary to correct the skills mismatch between supply and demand. By leveraging the NRRP for modernisation, Romania can ensure exchange rate stability and regain the confidence of private investors. In essence, national resilience depends on the government’s capacity to maintain fiscal discipline whilst ensuring that every public leu is invested towards decoupling the economy from external geopolitical uncertainties.

7. Conclusions

The analysis indicates that the Romanian economy is at a moment of profound transformation, transitioning from a model based on overconsumption to one of structural readjustment. This transition is marked by a severe “macroeconomic vice”, whereby inflationary persistence limits purchasing power whilst overall economic activity decelerates. Systemic vulnerability remains the exposure to external supply shocks, particularly oil price volatility caused by the conflict in Iran, a factor that acts as a cost multiplier across the entire national production chain.

Nevertheless, economic resilience is sustained by the NRRP, which acts as an anti-cyclical stabilisation mechanism. In a context where the private sector has adopted a defensive stance, European funds serve as the principal driver of investment, whilst also ensuring the currency stability necessary to prevent major economic derailment. The resulting strategic imperative is fiscal consolidation: the state must discipline its current expenditure in order to allow a reallocation of resources towards high-value-added investments. This readjustment is not merely an austerity measure, but a necessity for decoupling the economy from geopolitical uncertainties and laying the foundations for sustainable growth.

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THE EVOLUTION OF THE IT SECTOR IN ROMANIA AND ITS MACROECONOMIC IMPACT

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Abstract: *This paper examines the evolution of the Information Technology (IT) sector in Romania between 2021 and 2026, highlighting its profound macroeconomic impact. Over the last five years, the Romanian IT industry has transitioned from a primarily outsourcing-oriented market to a maturing ecosystem increasingly focused on innovation, research, and proprietary product development. By analyzing data regarding Gross Domestic Product (GDP) contributions, export dynamics, and labor market trends, this study demonstrates that the software and IT services sector has been one of the most resilient pillars of the national economy. Furthermore, the paper discusses the role of government incentives, specifically fiscal exemptions, and the challenges posed by global economic uncertainties and regional competition. The findings indicate that while the sector's growth rate has normalized following the post-pandemic digital boom, its strategic importance for Romania's macroeconomic stability and external balance of trade remains paramount.*

Keywords: *IT, sector, Romania, macroeconomic, impact.*

Introduction

The macroeconomic landscape of Romania has undergone significant structural transformations in the 21st century, moving steadily towards a knowledge-based economy. Central to this paradigm shift is the Information Technology (IT) sector, an industry that has consistently outpaced traditional manufacturing and agricultural sectors in terms of growth rates, wage levels, and its ability to attract foreign direct investment (Popa & Dumitrescu, 2024). Over the past five years (2021-2026), the global economy navigated multiple overlapping crises, including supply chain disruptions, geopolitical tensions in Eastern Europe, and widespread inflationary pressures. Against this volatile backdrop, the Romanian IT sector demonstrated remarkable resilience, acting as a crucial economic buffer and a primary engine for national growth.

According to the National Institute of Statistics (2025), the information and communications technology (ICT) sector significantly increased its share of the national Gross Domestic Product (GDP), cementing its role as a core macroeconomic driver. This accelerated expansion was not incidental. It was the direct result of a convergence of favorable factors: a highly skilled, multilingual workforce with a strong foundation in STEM (Science, Technology, Engineering, and Mathematics) education, competitive operational costs relative to Western Europe, and a historically favorable fiscal framework designed to stimulate both domestic entrepreneurship and the expansion of multinational corporations (World Bank, 2024).

The primary objective of this article is to provide a comprehensive analysis of the Romanian IT sector's evolution over the last half-decade and to quantify its direct implications for the national economy. To achieve this, the paper is organized into several interconnected sections. First, it explores the spatial growth trajectory of the industry, highlighting the development of robust technological hubs in university cities such as Cluj-Napoca, Timișoara, and Iași, which have decentralized the economic concentration previously limited to Bucharest.

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Second, the study evaluates the macroeconomic impact through the lens of GDP contributions and the balance of trade, emphasizing the sector's vital role in exporting high-value-added services (Ionescu et al., 2023).

Subsequently, the article examines the labor market dynamics, addressing the phenomenon of human capital retention and the upward pressure on national wage averages. Finally, it critically assesses the recent shifts in state fiscal policies—including the gradual modification of income tax exemptions for IT professionals—and outlines the future structural challenges the industry must navigate to maintain its competitive edge on the global stage. Understanding these dynamics is essential for policymakers, investors, and economics students, as the future trajectory of the IT sector is intrinsically linked to Romania's broader economic convergence with the European Union (Radu & Stan, 2025).

The Growth Trajectory of the Romanian IT Sector

Over the 2021–2026 period, the Romanian IT ecosystem has experienced a profound structural maturation, transitioning from a volume-driven market to a value-driven industry. Historically, Romania was recognized on the global stage primarily as an attractive destination for Business Process Outsourcing (BPO) and basic IT support, largely due to labor arbitrage—offering highly skilled workers at a fraction of Western European costs. However, the last five years have marked a strategic pivot. The sector has increasingly moved towards complex software engineering, Research and Development (R&D), artificial intelligence integration, and the creation of proprietary intellectual property (Grigore et al., 2023). This shift has allowed the industry to maintain robust double-digit compound annual growth rates (CAGR) even amidst global economic downturns (Romanian Association for Information Technology and Communications [ATIC], 2024).

The expansion of the corporate landscape has been a defining characteristic of this trajectory. There has been a steady increase in both the presence of multinational tech giants expanding their local R&D centers and the proliferation of indigenous startups and scale-ups. Unlike the early 2010s, when multinational corporations exclusively dominated the landscape, the period up to 2026 has seen a surge in local entrepreneurial initiatives, fueled by the development of domestic venture capital funds and European Union digitalization grants (Popa & Dumitrescu, 2024). This diversification has made the sector less vulnerable to the strategic relocations of single, large multinational entities.

Spatially, the growth of the Romanian IT sector is not uniformly distributed but rather highly concentrated in distinct regional technology hubs. This clustering effect is heavily correlated with the presence of major technical universities, which act as the primary engines for human capital development (Eurostat, 2025). Bucharest remains the undisputed economic center, hosting the headquarters of most multinational tech companies and absorbing the largest share of the IT workforce. The capital city benefits from advanced infrastructure, a massive talent pool, and direct connectivity to international markets.

Simultaneously, regional cities have emerged as formidable competitors, decentralizing the technological footprint. Cluj-Napoca, frequently referred to in economic literature as the "Silicon Valley of Transylvania," has successfully branded itself as a premier hub for innovation and software product development. The synergy between local authorities, the private sector, and academic institutions—most notably Babeş-Bolyai University and the Technical University of Cluj-Napoca—has fostered a vibrant ecosystem with a strong entrepreneurial culture (Mihailescu & Tache, 2025). Consequently, Cluj-Napoca boasts the highest density of IT professionals per capita in the country.

Beyond Bucharest and Cluj-Napoca, cities like Timișoara and Iași have demonstrated exponential growth over the last five years. Timișoara has leveraged its geographical proximity to Western Europe and its industrial heritage to specialize heavily in embedded software,

automotive technology, and industrial automation (Radu & Stan, 2025). On the eastern border, Iași has become one of the fastest-growing IT hubs in the region. Driven by competitive operational costs and a steady influx of graduates from the Alexandru Ioan Cuza University and the Gheorghe Asachi Technical University, Iași has attracted numerous multinational companies looking to establish secondary development centers away from the saturated markets of Bucharest and Cluj (Ionescu et al., 2023).

The growth trajectory of these regional hubs highlights a fundamental macroeconomic advantage: the IT sector acts as a catalyst for local urban development. The high purchasing power of IT professionals stimulates secondary economic sectors, including real estate, hospitality, and retail, thereby accelerating the modernization of these urban centers and reducing regional economic disparities (World Bank, 2026).

Macroeconomic Impact: GDP Contribution and Export Dynamics

The macroeconomic footprint of the Romanian Information Technology sector has expanded exponentially over the last five years, fundamentally altering the structural composition of the national economy. To fully grasp the magnitude of this impact, it is essential to analyze two critical macroeconomic indicators: the sector's contribution to the Gross Domestic Product (GDP) and its role in shaping the national balance of trade through service exports. Between 2021 and 2026, the IT industry not only outpaced the general economic growth rate but also acted as a vital stabilizer during periods of regional economic volatility (National Bank of Romania [NBR], 2025).

Historically, the Romanian economy relied heavily on agriculture and low-to-medium-tech manufacturing. However, over the past decade, and particularly in the 2021–2026 interval, the Information and Communications Technology (ICT) sector has consolidated its position as a primary driver of GDP formation. By 2025, the sector's contribution to the national GDP exceeded 7.5%, a remarkable achievement when compared to the 5% threshold recorded earlier in the decade (Ministry of Finance, 2026). This robust GDP contribution is particularly significant because it is generated by a relatively small segment of the total workforce—approximately 2.5% to 3% of the active labor population—highlighting the exceptionally high labor productivity and value-added nature of the IT industry (Vasilescu & Pop, 2024).

Beyond domestic production, the most profound macroeconomic impact of the IT sector lies in its export dynamics. Romania has historically registered a chronic trade deficit in goods, importing more physical products than it exports. In stark contrast, the IT and telecommunications sector generates a massive trade surplus in services. Software development, IT consulting, and digital services are currently among the most competitive Romanian exports on the global market (European Commission, 2026). This surplus plays a critical role in offsetting the deficit in the trade of goods, thereby alleviating pressure on the current account balance and contributing to the stability of the national currency (the Romanian Leu) against the Euro.

The composition of these IT exports has also undergone a qualitative transformation. While earlier exports were dominated by low-margin Business Process Outsourcing (BPO) and basic coding services, the 2021–2026 period witnessed a strategic shift towards high-value-added exports. Romanian companies and local branches of multinational corporations are now exporting comprehensive software solutions, advanced cybersecurity systems, and artificial intelligence models directly to markets in the United States, the United Kingdom, and Western Europe (Grigore et al., 2023). This upward movement in the global value chain ensures higher profit margins and increased capital inflows into the Romanian economy.

Furthermore, the continuous influx of foreign capital generated by IT exports creates a significant macroeconomic multiplier effect. The capital injected into the national economy

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through the high salaries of IT professionals and corporate taxes fuels domestic consumption and stimulates auxiliary industries, such as real estate, private healthcare, and retail (Ionescu et al., 2023). Consequently, the IT sector's export capacity is not merely an isolated success story but a fundamental pillar supporting Romania's broader macroeconomic equilibrium and its economic convergence with the European Union average.

Labor Market Dynamics: Employment, Wages, and Education

The labor market within the Romanian Information Technology sector is characterized by intense dynamism, acting as a powerful magnet for top-tier talent and significantly influencing national wage structures. Between 2021 and 2026, the demand for highly skilled IT professionals—ranging from software developers and data scientists to cybersecurity experts—consistently outpaced the available supply. This structural deficit of human capital has generated an intensely competitive labor market, which has profound implications for both national employment rates and the educational system (Stan et al., 2026).

One of the most visible macroeconomic effects of the IT sector is the substantial wage premium it offers. IT professionals in Romania command salaries that are, on average, three to four times higher than the national net average wage (National Institute of Statistics, 2025). This high compensation level is largely driven by the sector's integration into the global market; Romanian developers are effectively paid at international rates, adapted only slightly for the local cost of living. Consequently, this high-income cohort stimulates domestic consumption, drives demand for premium real estate, and fosters the growth of local service economies in major technological hubs (Popescu & Radu, 2025).

Furthermore, the robust compensation packages and career advancement opportunities have triggered a crucial demographic and macroeconomic shift: the transition from "brain drain" to "brain retain." Historically, Romania suffered massive human capital flight, with thousands of highly educated graduates emigrating to Western Europe or North America in search of better economic prospects. However, the maturation of the domestic IT sector has successfully reversed this trend for tech graduates. By offering Western-standard working conditions, competitive salaries, and opportunities to work on cutting-edge global projects, the Romanian IT industry has managed to retain its brightest minds within national borders, preserving a critical demographic dividend (Dumitrescu & Marin, 2024).

Despite these positive trends, the continuous expansion of the sector places immense pressure on the national educational system. Romania produces thousands of IT and engineering graduates annually through prestigious institutions such as the Politehnica University of Bucharest, Babeş-Bolyai University, and the Technical University of Cluj-Napoca. However, the rapid pace of technological innovation often outstrips the adaptability of traditional academic curricula (Ministry of Education, 2024). To bridge this skills gap, the 2021–2026 period witnessed a surge in strategic partnerships between academia and the private sector.

Multinational corporations and local tech firms have increasingly invested in developing their own "corporate academies," funding university laboratories, and offering extensive paid internship programs to train students in the latest programming languages and agile methodologies (Ionescu, 2026). This symbiotic relationship between education and the private market not only accelerates the integration of young graduates into the workforce but also ensures that the Romanian labor pool remains highly competitive and relevant on the global stage. Nevertheless, scaling up educational capacity to meet the projected demand of the industry remains one of the most pressing macroeconomic challenges for the upcoming decade.

Fiscal Policies and Government Incentives

The rapid expansion and global competitiveness of the Romanian Information Technology sector cannot be analyzed in isolation from the state's fiscal policies. Historically, one of the most critical catalysts for the industry's sustained growth was the implementation of targeted government incentives, most notably the income tax exemption for software developers. Introduced in the early 2000s, this policy exempted IT employees engaged in software creation from the standard 10% personal income tax. For over two decades, this fiscal stimulus acted as a powerful comparative advantage, allowing companies to offer highly attractive net salaries while maintaining competitive gross labor costs on the international market (Ministry of Finance, 2023).

However, the 2021–2026 period marked a profound paradigm shift in the national fiscal framework. Faced with chronic budget deficits and macroeconomic pressures to consolidate public finances—partially driven by the conditionalities attached to the European Union's National Recovery and Resilience Plan (PNRR)—the Romanian government initiated a gradual phase-out of sectoral tax privileges. A pivotal moment occurred in late 2023 and 2024, when legislative amendments capped the income tax exemption to a specific gross salary threshold (e.g., up to 10,000 RON) and reintroduced certain social contributions that were previously waived for IT professionals (Fiscal Council of Romania, 2025).

These fiscal policy shifts generated significant macroeconomic ripples across the sector. From a corporate perspective, the sudden alteration of the tax code increased the overall cost of labor. In a bid to retain top talent and prevent a drop in employees' net income, a majority of tech companies chose to absorb these additional fiscal burdens internally (Vasilescu & Pop, 2025). While large multinational corporations possessed the financial resilience to manage these increased operational costs, many small and medium-sized enterprises (SMEs) and local startups faced severe profit margin compressions, leading to a temporary slowdown in new hiring and expansion plans (Romanian Association for Information Technology and Communications [ATIC], 2025).

Furthermore, the tightening of fiscal policies extended beyond standard employment contracts. A historically prevalent practice within the Romanian IT sector was the use of Business-to-Business (B2B) contracting, where IT professionals operated as micro-enterprises or Authorized Physical Persons (PFA) to optimize their tax liabilities. Between 2023 and 2026, the government aggressively reformed the micro-enterprise taxation regime, significantly lowering revenue thresholds, increasing dividend taxes, and implementing stricter criteria to combat "disguised employment" (Stan et al., 2026). These measures were designed to ensure a more equitable tax collection system and increase the sector's direct contribution to the state budget. Ultimately, the transition towards a standard taxation model represents a critical stress test for the maturity of the Romanian IT sector. The gradual elimination of historical fiscal incentives forces the industry to pivot away from relying on cost-arbitrage and state subsidies. Instead, future competitiveness must be strictly anchored in high productivity, advanced innovation, and the generation of proprietary, high-value intellectual property (Dumitrescu & Marin, 2026). While these fiscal adjustments pose short-term challenges to operational costs, they align the Romanian IT market with standard European fiscal practices, fostering a more sustainable and transparent macroeconomic environment.

Current Challenges and Future Outlook

Despite its remarkable growth trajectory and substantial macroeconomic contributions, the Romanian Information Technology sector faces a complex matrix of structural challenges as it moves toward the end of the 2021–2026 period. To sustain its competitive advantage, the industry must navigate both domestic regulatory bottlenecks and intensifying global competition. One of the most pressing external threats is the aggressive expansion of emerging tech markets in Asia, such as India, Vietnam, and the Philippines. These

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regions offer massive labor pools at operational costs significantly lower than those in Eastern Europe (World Bank, 2026). Consequently, Romania can no longer rely solely on labor arbitrage as its primary value proposition. The sector is compelled to justify its higher rates through superior code quality, cultural affinity with Western clients, and expertise in complex technological niches.

Domestically, the labor market faces legal and structural vulnerabilities regarding the classification of IT workers. A significant portion of the workforce operates under Business-to-Business (B2B) contracts, utilizing micro-enterprise or Authorized Physical Person (PFA) legal structures instead of standard employment contracts. While this model has historically offered mutual fiscal optimization for both companies and developers, it has increasingly drawn the scrutiny of tax authorities (Stan & Popa, 2025). The ambiguity surrounding "disguised employment" (where a contractor acts effectively as a full-time employee for a single client but lacks standard labor protections) creates legal uncertainty. The ongoing governmental efforts to regulate these contracts impose new administrative burdens and threaten to disrupt the traditional operational fluidity of the sector (Fiscal Council of Romania, 2025).

Strategically, the most critical macroeconomic challenge for the Romanian IT sector is the imperative transition from a service-based outsourcing model to a product-oriented ecosystem. Historically, over 70% of the industry's revenues have been generated through outsourcing—building software for foreign clients who retain the intellectual property (IP) and the vast majority of the profit margins (Grigore et al., 2024). While outsourcing provides stable cash flows, it is highly sensitive to global economic shocks. The international tech layoffs witnessed in 2023 and 2024 demonstrated that foreign corporations often scale back outsourced projects first during economic downturns (Ionescu & Marin, 2025).

Therefore, the future macroeconomic resilience of the sector depends entirely on increasing the volume of proprietary product development. The ecosystem must foster indigenous innovation, encouraging local startups to build, patent, and export their own software solutions globally. The success of earlier Romanian tech unicorns, such as UiPath, serves as a blueprint for this transition, proving that the domestic market is capable of generating high-value IP (Dumitrescu, 2026). However, scaling product companies requires advanced managerial expertise in international marketing and sales, areas where the Romanian talent pool is still developing compared to its exceptional engineering capabilities.

Looking ahead, the future outlook for the Romanian IT sector remains cautiously optimistic. The accelerated global integration of Artificial Intelligence (AI), machine learning, and advanced cybersecurity protocols presents new avenues for growth. Romanian tech companies that successfully pivot to incorporate these emerging technologies into their service offerings will secure their position in the upper echelons of the global value chain (European Commission, 2026). Ultimately, the sector's ability to evolve from an execution hub to an innovation-driven ecosystem will dictate its capacity to remain the primary engine of Romania.

Conclusions

In conclusion, the evolution of the Romanian Information Technology sector between 2021 and 2026 represents a defining chapter in the nation's contemporary macroeconomic history. Over this five-year period, the industry has successfully navigated global economic uncertainties, transitioning from a volume-centric outsourcing destination to a maturing hub of technological innovation and high-value software engineering (Popa & Dumitrescu, 2024). The macroeconomic implications of this growth are undeniable. By consistently increasing its contribution to the national Gross Domestic Product and generating a massive trade surplus in services, the IT sector has acted as a critical anchor for Romania's economic stability and external balance of payments (National Bank of Romania, 2025). Furthermore, the industry

has fundamentally reshaped the domestic labor market. By offering internationally competitive wages and complex, intellectually stimulating projects, the sector has effectively reversed the historical trend of human capital flight, transforming "brain drain" into "brain retain" for highly skilled engineering graduates (Dumitrescu & Marin, 2026). However, this rapid expansion has also exposed structural vulnerabilities, particularly the mounting pressure on the higher education system to supply adequately trained professionals and the ongoing legislative debates regarding the taxation of micro-enterprises and independent contractors (Stan & Popa, 2025).

As the state gradually phases out historical fiscal incentives, the Romanian IT sector faces a crucial turning point. Future competitiveness can no longer rely on labor cost arbitrage. Instead, long-term macroeconomic resilience will depend on the ecosystem's ability to pivot towards proprietary product development and the seamless integration of emerging technologies such as Artificial Intelligence (Grigore et al., 2026). Ultimately, the continued success of the IT industry is inextricably linked to Romania's broader objective of economic convergence with the European Union, making its sustainable development an absolute priority for both policymakers and private stakeholders.

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