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FOREWORD

Presented number of Silesian University of Technology. Scientific Papers. Organization and Management Series. Presented papers contain result of researches conducted by various universities. The number consists of 39 papers.

The papers presented in the number concentrate on many topics connected with organization and management. There are in the number papers about: business models; entrepreneurship; the implementation of AI in management; strategic management; human resource management; innovation management; smart manufacturing; smart cities; cybersecurity; quality management; sustainable development; logistics; knowledge management; waste management; organizational resilience; production management; public management; digital maturity; environmental management and economics.

Bożena Skotnicka-Zasadzień

Radosław Wolniak

THE IMPACT OF CYBER THREAT EVOLUTION ON ENTERPRISE MANAGEMENT

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Purpose: The aim of the paper is to define the evolution of cyber threats in the years 2017-2025 and assess their impact on enterprise management, with a key emphasis on the need for transformation towards building cyber resilience.

Design/methodology/approach: The study is based on a comparative analysis of a case study of nine cyber incidents from 2017 to 2025 from the moment when ransomware became massive and destructive to modern, targeted attacks on infrastructure and supply chains.

Findings: Based on the analysis, it was concluded that cyberattacks have evolved towards total operational paralysis and attacks on the supply chain. Key takeaways for management include: the need to implement MFA as an absolute minimum, the urgent need for OT/IT network segmentation, and shifting management attention from security alone to vendor resiliency and liquidity management.

Research limitations/implications: The analysis is based on publicly available data and official company communications, which can lead to limitations in fully understanding the internal mechanisms and vectors of an attack. Further research may focus on the effectiveness of AI in repelling cyberattacks and the long-term impact of NIS2 regulation on enterprise risk management.

Practical implications: The article provides practical recommendations for boards, focusing on: Investing in BCP testing and total paralysis scenarios, recognizing the Cyber-CISO as an integral board member, Establishing supply chain audits as a critical process.

Social implications: The increase in attacks on Critical Infrastructure requires strengthening public-private partnerships and creating crisis communication standards to counter disinformation.

Originality/value: The work is distinguished by a holistic approach to the evolution of cyber threats (2017-2025) and the transfer of the emphasis of cybersecurity from technology to business management.

Keywords: enterprise management, cyber threats, cyber resilience.

Category of the paper: Case study.

1. Introduction

In the age of digitalization, where the boundaries between the virtual and real worlds are becoming increasingly fluid, cybersecurity has evolved from a niche area of concern to a key element of national, economic, and corporate security strategies. Enterprises, regardless of their size or industry, are on the brink of this change, facing increasingly complex and advanced digital threats. In a turbulent environment, characterized by rapid technological, political and social changes, cybersecurity management requires not only reactive actions, but above all a proactive attitude and adaptive strategies (Antczak, 2024). As a result, cybersecurity has become a fundamental strategic challenge, not just information technology, directly affecting operational continuity, reputation and market trust. The dynamic evolution of threats, especially in the area of hybrid warfare and attacks on supply chains, requires managers to fundamentally change their approach to risk.

The global cost of cybercrime is projected to reach \$10.5 trillion annually by 2025. The average global cost of a data breach in 2024 was \$4.88 million, an increase of 10% from the previous year. The healthcare sector remains the most costly in terms of data breaches, with an average cost of more than \$9.77 million in 2024 (IBM Security. Cost of a Data Breach Report, 2024). The use of artificial intelligence (AI) and automation has made it possible to reduce the cost of data breaches by up to \$1.88 million. (IBM Security. Cost of a Data Breach Report, 2024). Phishing remains the main breach vector, accounting for the majority of human incidents, which occurs in about 68% of cases, while the growing identity attacks, accounting for more than 99% of all attacks, are increasingly focused on circumventing Multi-Factor Authentication (MFA) (IBM Security. Cost of a Data Breach Report, 2024; Verizon – Data Breach Investigations Report, 2024; Microsoft – Digital Defense Report, 2024).

Generative AI has become a key tool for cybercriminals, the number of attacks based on algorithm-assisted social engineering has increased by 442%, and about half of criminal groups have incorporated AI into their strategies. At the same time, attacks on supply chains, the main consequence of which are financial losses, and ransomware, the number of which in the first quarter of 2025 increased by 126% compared to the previous year, reaching a record level (Fortinet – Cyberthreat Predictions, 2024; Fortinet – State of Operational Technology and Cybersecurity Report, 2024; SentinelOne – Annual Threat Hunting Report, 2024; Check Point Research – Cyber Security Report, 2024; Proofpoint – State of the Phish Report, 2024).

The U.S. remains a prime target for cyberattacks due to its economic, technological, and political importance, recording the highest number of data breaches and ransomware incidents and the highest costs averaging more than \$9 million in 2024, with attacks focusing on industrial espionage, critical infrastructure, and the financial and technology sectors (IBM Cost of a Data Breach Report, 2024). The UK remains one of the most targeted countries in Western Europe, particularly in the financial, government and healthcare sectors, with many

incidents linked to Russian and Chinese APT groups using advanced economic and political espionage techniques (CERT-EU – Threat Landscape Report, 2024). The Eastern European region remains the most vulnerable to hybrid warfare cyberattacks, with Ukraine becoming the most attacked country since the beginning of the full-scale invasion, with 90% of sabotage activities carried out by groups linked to Russia. Poland, due to its role as a logistics center and NATO border, is a prime target for disinformation and attacks disrupting government, media and transport, recording one of the largest increases in the number of advanced attacks in Europe (Microsoft Digital Defense Report Microsoft Digital Defense Report, 2024 and 2025). Asian countries such as Japan and South Korea remain the main targets of cyberattacks targeting the manufacturing and technology sectors, particularly semiconductors, and many incidents linked to China and North Korea focus on intellectual property theft and supply chain violations (CERT-EU – Threat Landscape Report, 2024).

Modern business management is based on the assumption of operational stability. The evolution of cyber threats after 2017 completely invalidated this assumption. Cybersecurity has ceased to be the exclusive domain of IT departments and has become a major business risk that directly affects strategic goals, financial stability, and corporate reputation.

2. Literature review

The management of modern enterprises is characterized by high complexity and variability of conditions. On a daily basis, managers have to face such challenges as: globalization, dynamic ICT development, cultural diversity, variability of legal and systemic regulations, increasing dynamics of business processes and growing customer expectations. In these conditions, professionalization of management, consisting in creating system solutions and managing them with the use of specific tools, becomes a necessity. An intuitive approach, variability of operating rules, lack of vision and low efficiency of organizational processes are the main factors of failure in modern management (Czekaj, Ziębickiego, 2021). Enterprise management is an integrated set of activities, processes and functions aimed at planning, organizing, motivating and controlling an organization's resources (human, financial, technological) in order to achieve its strategic goals and maximize value for stakeholders (Fayol, 1949). Every company, in order to function properly in a competitive environment, must be properly managed. Management is a complex process that involves all links of an organization's operations. The specificity of the organization is always associated with a multifaceted management process. Management is about making the right management decisions, thanks to which the organization is able to function properly and achieve the assumed goals (Antczak, 2020).

In the context of risk analysis, enterprise management includes, m.in: corporate governance and risk management. Corporate governance deals with the ways in which suppliers of finance to corporations assure themselves of getting a return on their investment (Shleifer, Vishny, 1997). As part of corporate governance, rules and a framework for supervision and decision-making structure are established, which is crucial for the placement of cybersecurity at the strategic level.

Risk management ensures that enterprise risk related to the use of information technology is identified, analyzed, and mitigated so that it is kept within acceptable levels and aligned with the enterprise's overall risk appetite and business objectives (ISACA, 2019).

As part of enterprise risk management, it is crucial to establish an IT governance and management framework that integrates technology risk into business objectives by systematically identifying and allocating resources to mitigate cyber threats. In the era of digital transformation, enterprise management includes not only the classic processes of planning, organizing and control, but also systematically taking into account cyber threats as a key element of the risk environment, affecting the stability and achievement of strategic goals.

National Initiative for Cybersecurity Careers Studies (NICCS) It defined cybersecurity as a strategy, policy and norms concerning both cyberspace security and activities in it, encompassing a full range of activities aimed at reducing threats, reducing vulnerability and deterrence, international engagement taking into account relevant operations in the computer network and providing information, activities of law enforcement agencies, diplomacy, military, intelligence services, relating to security and global stability information and communication infrastructure (Banasiński, 2023). Cybersecurity for the company is of great importance, in addition to, of course, the security of the company's assets and customer data, cyber defense has an impact on the valuation of a given company. It is a solid pillar ensuring the stability of operations, which is increasingly placed higher in the hierarchy of investment ratings by investors (Bolland). It is inextricably linked to cyberspace, understood as "[...] the global domain of the information environment consisting of the interdependent networks created by information technology (IT) infrastructure and the data contained therein, including the Internet, telecommunications networks, computer systems, as well as the processes and controllers embedded in them (Chałubińska-Jentkiewicz, 2019).

Cybersecurity management is a comprehensive strategic and operational process, including the identification, assessment and mitigation of risks related to cyber threats. Cybersecurity management integrates technologies, policies, procedures, and human resources to protect the integrity, confidentiality, and availability of data and information systems. Effective cybersecurity management involves continuous monitoring and analysis of threats, proactive implementation of protective measures, education and training of employees, as well as cooperation with external entities in the field of information exchange and best practices. The foundation of cybersecurity management is adaptation to the dynamically changing

technological and regulatory environment, taking into account the specifics of the organization's operations and its strategic business goals (Antczak, 2024).

A cyber threat is a potential threat or malicious intent that could exploit a vulnerability (weakness in a system, process, or control) to compromise the confidentiality, integrity, or availability of digital assets (data, systems, IT/OT infrastructure) (NIST, 2018).

Hacking into an end device, i.e. a smartphone, tablet, laptop, computer, printer, or multifunctional device, connected to a company or official network, used by an employee or official, is a simple way for a hacker to steal closely guarded internal data and information, or even a possibility of endangering the functioning of an entire organization or an important structure of the state. To do this, cybercriminals are using increasingly sophisticated methods, often based on carelessness and carelessness in the use of modern devices by their users (Cyberbezpieczeństwo w Polsce, 2019).

Cyberattack methods include, m.in: bots and viruses, phishing and pharming, ransomware, juice jacking, clickjacking, eavesdropping and man-in-the-middle (MITM) attacks, SPAM (shoulder pork and ham), advanced targeted attacks (APT – advanced persistent threat), denial of service/distributed denial of service (DoS/DDoS) attacks, malware data leaks, employee data theft, data leakage due to theft or loss of media or mobile devices, application bug attacks, attacks on wireless networks, data theft due to physical security breaches, hacking of mobile devices (Antczak, 2024).

Cyber threats are a source of cyber risk, which is a measure of the likelihood and scale of a negative impact of an attack on a company's operations.

Cybersecurity risk is the effect of uncertainty about information and technology, referring to the potential loss of confidentiality, integrity or availability of data and information systems, as well as possible negative effects on the operations of an organization, its resources, individuals, other entities and the state (CSRC).

The evolution of cyber threats has shifted cyber risk from the operational to the strategic level, making it an integral part of enterprise risk management. Critical incidents prove that neglecting cyber hygiene is a strategic mistake that prevents business goals from being achieved. In accordance with the COSO ERM guidelines (COSO 2017), vertical and horizontal integration of technological risk is necessary with decision-making processes. Cyber threats are forcing executives to undergo organizational transformation in which resilience, rather than prevention itself, has become a new, overarching strategic value.

The evolution of cyber risk to the level of strategic risk and the blurring of the security boundary has been directly reflected in the European legal framework. Ensuring security in the company is also of key importance from the perspective of the applicable laws and regulations, especially the most important ones, established by the European Union. The NIS2 Directive (Directive (EU) 2022/2555 of the European Parliament and of the Council of 14 December 2022 concerning measures for a high common level of cybersecurity across the Union) establishes common standards for ensuring a high level of security of network and information

systems in the Member States. It requires organizations to implement risk management systems, report major security incidents, and maintain appropriate technical and organizational measures. The CER Directive (Directive (EU) 2022/2557 of the European Parliament and of the Council of 14 December 2022 on the resilience of critical entities and repealing Council Directive 2008/114/EC) complements the NIS2 regulations and focuses on the resilience of entities in charge of critical infrastructure. Its aim is to ensure the continuity of operations of essential services such as energy, transport, communications and healthcare, even in situations of disruption or cyberattacks. The General Data Protection Regulation (Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC) imposes an obligation on organizations to protect personal data by implementing appropriate technical and organizational measures. This regulation aims not only to ensure the privacy of EU citizens, but also to increase trust in digital services.

3. Methodology

The evolution of cyber threats has forced a strategic paradigm shift in enterprise management. The dynamic development of attack methods – from mass ransomware to targeted actions on Critical Infrastructure and supply chains – has made cyber risk a key element of Corporate Governance and Strategic Risk Management. The aim of the research is to define the evolution of cyber threats and assess its impact on the strategic priorities of the board.

Achieving the goal of the research was possible thanks to the use of methodological triangulation, including literature analysis, examination of existing documents and case studies.

The analysis covered nine cyberattacks from 2017 to 2025, which began with an attack on the National Health Service in 2017, where the target was an easy, widely available vulnerability (EternalBlue) and quick profit, and ended with an attack on Jaguar Land Rover in 2025, which caused paralysis of IT systems, several weeks of production shutdown in factories and financial losses:

1. On May 12, 2017, the National Health Service (NHS), the UK's public health service, Europe's largest employer and a key component of the state's critical infrastructure, was paralyzed by the WannaCry cyberattack. This attack exploited the EternalBlue vulnerability to automatically scan and infect the non-patched Windows operating system. The malware quickly encrypted files by demanding a ransom. The incident led to the paralysis of IT systems in medical facilities, resulting in the cancellation of thousands of appointments and surgeries, demonstrating how neglecting basic cyber hygiene can endanger public safety.

2. On October 20, 2020, Sopra Steria, a European leader in technology and consulting services, a key part of the supply chain for sectors such as banking and defense, fell victim to a Ryuk ransomware attack. The attack, which likely began with a phishing email, led to the encryption of some systems throughout the organization. Despite reducing the scale of data leakage due to rapid network isolation, the company incurred significant operational costs related to restoring the efficiency of systems.
3. In December 2020, an unprecedented attack on SolarWinds, an American technology company whose network management software (Orion) is a critical point in the supply chain, was revealed. It was a sophisticated supply chain attack in which hackers (APT group) injected malicious code into a legitimate Orion software update. Once installed, this code opened a backdoor, allowing long-term, stealthy access and spying on the systems of thousands of customers around the world, including key government agencies.
4. On May 7, 2021, Colonial Pipeline, the largest fuel pipeline operator in the United States and a strategic component of Critical Infrastructure, supplying approximately 45% of the U.S. East Coast, was paralyzed by a DarkSide ransomware attack. The attack, which likely exploited stolen remote access credentials (VPNs) in the absence of MFA, prevented access to billing and operating systems. The company preemptively halted the entire pipeline, which triggered a fuel crisis and a buying panic, forcing the operator to pay a ransom to regain control.
5. On February 8, 2021, CD Projekt Red, a Polish video game development studio whose value is largely based on intellectual property (source codes for The Witcher and Cyberpunk 2077 games), fell victim to a ransomware attack. The attack led to the encryption of servers in the company's network and the theft of confidential data. The hackers demanded a ransom for the decryption key and not disclosing the stolen codes. The studio refused to pay, proceeding to restore systems from its own backups, demonstrating resistance to double extortion tactics.
6. On February 5, 2021, there was sabotage at the Florida Water Treatment Plant, a critical infrastructure utility facility whose operating systems (OT/ICS) control chemical processes and the distribution of drinking water. The hackers gained remote access through an unsecured connection and attempted to increase the level of poison in the water. This incident highlighted the direct threat to life and public health resulting from the lack of segmentation of the OT/ICS network.
7. On May 31, 2023, there was a massive attack on MOVEit Transfer software (from Progress Software), used globally to manage the Secure Transfer of Sensitive Files (MFT). The attack exploited a previously unknown Zero-Day vulnerability, allowing hackers to launch an SQL Injection attack. As a result, data was stolen from the databases of hundreds of customers and millions of people around the world were affected, making this incident an example of a large-scale attack on the supply chain.

8. On 29 May 2024, the Polish Press Agency (PAP) – the central, public news service and part of the Critical Communication and Media Infrastructure – fell victim to an act of disinformation and sabotage. The incident involved taking control of an account in the editing system (possibly by social engineering or malware), which made it possible to publish two false cables about military mobilization. The attack, although not ransomware, had a major social impact, demonstrating the use of cyberspace for information destabilization purposes.
9. On August 31, 2025, Jaguar Land Rover Group (JLR), a British multinational car manufacturer (a subsidiary of Tata Motors) that relies on a complex global supply chain and logistics, was attacked by ransomware. The attack began over the weekend, giving the attackers time to encrypt key IT systems, deliberately paralyzing production and logistics management systems. As a result, the factories were shut down, which immediately resulted in significant financial losses and leaks of confidential projects, exposing the vulnerability of Just-in-Time processes.

The analysis of selected cases was carried out on the basis of standardized comparative criteria, such as: type of incident, attack vector, effects of the event and the resulting management conclusions.

The selection of nine breakthrough cyberattacks from 2017 to 2025 provides a sufficient basis for a case study. The analyzed incidents do not serve statistical purposes, but focus on the most transformative moments that directly affected the global economy and national security, while forcing fundamental changes in the way risk management is evaluated in terms of business continuity, reputation, regulatory compliance and management decision-making processes.

4. Results

The analyzed attacks (Table 1) illustrate four main trends that shaped the landscape and indicated important directions for the evolution of cyber threats in the years 2017-2025:

1. The Dominance and Evolution of Ransomware - The trend shows how ransomware attacks have evolved from massive, untargeted infections (e.g. the NHS, exploiting common vulnerabilities like EternalBlue) to a dominant and targeted financial attack model. Nowadays (e.g. Colonial Pipeline, JLR) these attacks are aimed at maximizing losses and extorting ransoms, which in 2021 (e.g. Colonial Pipeline) proved that a cyberattack can cause a social and fuel crisis.
2. Operational Paralysis and Critical Infrastructure Targeting - there has been a shift from targeting only IT networks to attacking OT (Operational Technology) and Critical Infrastructure systems (e.g. Colonial Pipeline, Water Treatment Plant, JLR). The main

goal of these evolutionary attacks has ceased to be encryption itself, but has become a direct disruption of business processes and production halts (e.g. JLR). These effects go beyond financial losses, leading to physical hazards and a public crisis.

3. Increased supply chain risk – Supply chain attacks (e.g., SolarWinds, MOVEit Transfer, Sopra Steria) have become the most sophisticated method of infiltration. Using trust as a vector, hackers inject malicious code into legitimate software or exploit vulnerabilities in common tools. This allows hundreds or thousands of organizations to be compromised en masse and silently at once, making detection much more difficult.
4. Reputational, geopolitical and information warfare risk – the trend represents the evolution of attack targets beyond pure financial gain. The increase in the importance of information warfare (e.g. PAP) and political sabotage shows that cyberspace is used to destabilize society and lose trust in sources of information. The theft of key intellectual property (e.g. CD Projekt Red) is also treated on a par with ransom, and the result is a direct threat to the strategic stability of the organization.

Table 1.
Analysis of selected cyberattacks from 2017-2025

Attack	Incident type	Attack vector	Effects of the attack	Conclusions for management
National Health Service (NHS) (2017)	Ransomware (WannaCry)	Exploitation of an unpatched bug (vulnerability) in Windows systems (EternalBlue vulnerability).	Cancelled near Paralysis of the NHS, cancellation of thousands of surgeries, global financial losses	The need to immediately patch management and withdraw obsolete software.
Sopra Steria (2020)	Ransomware (Ryuk)	Initial infection (possibly via Phishing or remote access).	Limited data leakage but significant operational disruption (a few weeks to fully restore systems).	Network segmentation and improvement of detection and rapid response to new malware variants.
SolarWinds (2020)	Supply Chain Attack / Espionage (APT)	Introduction malicious code for a legitimate Orion software update (the so-called <i>backdoor</i>).	To compromise thousands of organizations around the world, including U.S. government agencies. Long-lasting, hidden data leakage.	Verify and monitor code in the software supply chain and strengthen oversight of third-party program permissions.
Colonial Pipeline (2021)	Ransomware (DarkSide)	Probably through hijacked user account/VPN, no MFA.	Suspension of fuel supplies on the East Coast of the USA, buying panic. A ransom of \$4.4 million was paid.	Separation of OT/IT systems and mandatory implementation of strong authentication (MFA) in remote access systems.
CD Projekt (2021)	Ransomware	Undisclosed, but typically by phishing or exploitation of a remote access vulnerability.	Network encryption and leakage of confidential company data (game source codes, employee documents). Refusal to pay the ransom.	Restriction of privileged accounts and improvement of secure backup processes.

Cont. table 1.

Water Treatment Plant (2021)	Sabotage of the water supply system	Hacking into OT systems through unsecured remote access.	Potential water contamination, a direct threat to life and public health.	Absolute segmentation of OT/ICS networks from IT; implementation of NIS2 standards and audits
MOVEit (2023)	Supply Chain Attack / Data Leak	Exploitation of the Zero-Day SQL Injection vulnerability in MOVEit.	Stealing the data of millions of people and hundreds of companies that are MOVEit customers.	Immediate patching of zero-day vulnerabilities and caution when using third-party data management software.
Polish Press Agency (PAP) (2024)	Disinformation / Sabotage	Using malware to infiltrate and take over an employee's account.	Publishing two false cables about the alleged mobilization. Major information disruption.	Strengthening pre-publication identity verification protocols and educating staff in social engineering.
Jaguar Land Rover (JLR) (2025)	Ransomware	Probably phishing or exploitation of a VPN/Remote Access vulnerability (no MFA).	Paralysis of production for several weeks, billions in financial losses, leakage of confidential projects and data.	Separation of OT/IT systems, implementation of the principle of least privilege and provision of isolated backups (immutable backups).

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The evolution of cyber threats between 2017 and 2025 is a transformation of motivations and attack vectors from massive, opportunistic ransomware (e.g. the NHS) to targeted and strategic actions. These activities focus on achieving operational paralysis (e.g., Colonial Pipeline, JLR, Water Treatment Plant), using the supply chain as the main channel of infiltration (e.g., SolarWinds, MOVEit, Sopra Steria), intellectual property theft (e.g., CD Projekt), and geopolitical destabilization (e.g., attack on PAP). This evolution is forcing the Board to shift priorities from security alone to enterprise-wide resiliency management.

5. Discussion

This article is part of the dominant trend of scientific literature in the years 2024-2025 (e.g. Antczak, 2024; Banasiński, 2023; Al-Shattarat et al., 2025), which redefines cybersecurity from a technological problem to a key challenge of corporate governance. This phenomenon, described in the literature as a transition to strategic resilience (cyber-resilience), emphasizes

that in the era of regulations such as NIS2 and DORA, the responsibility for operational continuity lies directly with management bodies, which requires them to develop the so-called dynamic adaptability (Li, Liu, 2021).

In the publication, Y. Harel and A. Carmeli similarly argue that cybersecurity is a "dynamic capability" that must be constantly renegotiated by the board (Harel, Carmeli, 2025). The authors analyze strategic supervision as a dynamic management capability. They point out that cybersecurity must evolve from technical aspects to tools for creating long-term value. This article complements this theory with practical evidence, indicating that cybersecurity has become a major business risk affecting strategic goals and reputation. M. Alshammari et al., on the other hand, analyze the evolution from "cybersecurity" to "cyber resilience", which confirms that in a turbulent environment, it is impossible to avoid an attack, so management must focus on the ability to survive (Alshammari et al., 2023). What has been analyzed on the example of JLR and CD Projekt Red). This article corresponds with the latest findings of Abdullah et al. (Abdullah et al., 2025) on the evolution of cyber threats. Abdullaha et al. present a broad historical and statistical background for AI-driven attacks targeting supply chains. This article fills a gap in the area of management sciences, translating these trends into specific models of management responsibility and decision-making processes in the era of implementation of the NIS2 directive. M. Smith, P. Daniel focus mainly on fiduciary duties and financial consequences of ransomware attacks, this article expands this approach to include the dimension of strategic management and organizational theory (Smith, Daniel, 2025). By analyzing cases such as Jaguar Land Rover (2025), the paper shows that modern cybersecurity is not just a matter of oversight, but a process of continuous reconfiguration of resources in order to maintain business continuity in a turbulent geopolitical environment, which is an important complement to the achievements presented in current market analyses.

Al-Shattarata et al. analyze a review of the literature in the field of business and accounting (Al-Shattarat et al. 2025), while this article is an analysis of the study of cyberattacks on the decision-making processes of management boards. Both works agree on a key paradigm shift: cybersecurity has ceased to be a technical issue for IT departments, becoming the foundation of corporate governance and strategic resilience of the company.

Based on the analysis of cyberattacks (Table 1), the following conclusions can be drawn:

1. Operational resilience (in the IT/OT area) is becoming a new priority, replacing security itself as the main goal of cybersecurity activities.
2. The supply chain has now become one of the main attack vectors used by cybercriminals.
3. Businesses are entering a new era of risk, where geopolitical threats and reputational loss are critical to security.

Incident analysis (Colonial Pipeline, JLR, Water Station) proves that the main goal of attacks is to completely paralyze key operations, not just steal data. The hacking of water treatment plants and attacks on IK (Colonial Pipeline) show that operational technology

systems must be completely isolated from the office network. Lack of segmentation is treated as critical negligence. The attack on Colonial Pipeline was made possible by a breach of a VPN account without multi-factor authentication (MFA). MFA has become an absolute, mandatory minimum of cyber hygiene for every user, including remote and privileged access. The attack on JLR, which halted production, shows that management needs to test Business Continuity Plan / Disaster Recovery (BCP/DR) plans for a scenario of total paralysis, not just the loss of individual servers.

The attacks on SolarWinds, MOVEit Transfer and Sopra Steria have proven that the weakest link in security is often the supplier. Management must treat the risks associated with third-party software and services on an equal footing with insider risk. This requires tough audits of suppliers (e.g. compliant with NIS2 standards) and regular assessment of their cyber maturity. The WannaCry attack and the Zeroday vulnerabilities in MOVEit show that keeping your software up-to-date and quickly patching known vulnerabilities (even for systems withdrawn from support) is crucial for global security.

The attacks on CD Projekt Red and PAP indicate that the motivation of cybercriminals is increasingly to destabilize and steal a competitive advantage, and not just ransom. The attack on the Polish Press Agency (PAP) proves that managers must think in terms of hybrid warfare. It is necessary to develop Crisis Communication procedures aimed at combating disinformation and quickly regaining control over the narrative. The CD Projekt Red incident (source code leak) confirms that knowledge-based companies need to strengthen Data Loss Prevention (DLP) mechanisms and tightly control access to critical intellectual property. Ransomware can only be a cover for a more destructive target, which is industrial espionage.

The analysis of 9 cyberattacks clearly shows that effective enterprise protection is based on a culture of resilience that goes beyond traditional security. As a result, effective business management requires constant measurement of resilience levels and incorporating cyber risk into every strategic business decision, from supplier selection to expansion planning.

6. Summary and conclusions

On the basis of the analyzed incidents, the following key conclusions can be drawn in the field of enterprise management in the area of cybersecurity:

1. Managers should treat basic cyber hygiene (such as MFA and Patch Management) as a strategic priority, as neglecting these elements is still the main attack vector (conclusion from cyberattacks: NHS, Colonial Pipeline, Water Treatment Plant).
2. Enterprises should implement strict network segmentation (Zero Trust) so that malware cannot automatically spread from the infected part of the network to key production

systems (OT) and backup servers (conclusion from cyberattacks: JLR, CD Projekt, Water Treatment Plant).

3. Risk management should include rigorous audits and continuous monitoring of the security of vendors' services and software, as each vendor is a potential attack vector for the organization (conclusion from cyberattacks: SolarWinds, MOVEit, Sopra Steria).
4. Effective defense requires the provision of isolated, immutable backups and regular testing of recovery plans to enable a quick recovery from a successful attack, while minimizing reputational and disinformation losses (conclusion from cyberattacks: JLR, Colonial Pipeline, PAP).

Recommendations for management:

1. Recognizing operational paralysis and physical sabotage as a major strategic threat.
2. Prioritize funding and implement isolation of OT/ICS networks from IT networks.
3. Implement MFA as an absolute policy for every remote access and adopt a Zero Trust model for the entire network.
4. Establish a rigorous Vendor Risk Management (VRM) and monitor the Patch Compliance Rate in short timelines.
5. Investments in isolated, immutable backups (3-2-1 strategy) to ensure reproducibility after a ransomware attack.
6. Annual, mandatory testing of BCP/DR plans in "scorched earth" scenarios to shorten the RTO.
7. Investments in modern EDR/XDR systems to quickly detect and isolate ongoing attacks.
8. Development and testing of the Crisis Communication Plan (anti-disinformation procedure) and implementation of DLP systems for the protection of key intellectual property.

The implementation of these recommendations requires the recognition of cybersecurity as a business risk, not just a technical one, and the active involvement of the management and supervisory boards.

Methodological limitations can be identified in the study. The subjective selection of the nine breakthrough incidents focuses mainly on large organizations such as JLR, SolarWinds and the NHS, which, despite their representativeness, is a limitation of the study by potentially omitting the specific challenges of the SME sector. The data from the years 2017-2025 used in the article is a time limitation. The dynamic development of artificial intelligence means that the forecasts contained in it may need to be updated very quickly.

The results of the research have important implications for the wider field of management and can be used in management education and in audit and compliance. The results obtained from the research may form the basis for further research in the field of management in hybrid threat conditions.

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THE BUSINESS MODEL OF AN ENTERPRISE AS AN OBJECT OF INTELLECTUAL PROPERTY PROTECTION

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Purpose: The purpose of this article is to answer the question of whether business models that affect the resilience of entrepreneurs can be protected by them against their use by other entities, and if so, on the basis of what regulations, what claims entrepreneurs can use and in what proceedings they can pursue them.

Design/methodology/approach: The article uses critical analysis. First, it analyses regulations concerning copyright, databases, industrial property and combating unfair competition. Next, civil procedure regulations concerning separate proceedings in intellectual property cases were analysed. The considerations in this article are also based on literature on the subject and the case law of common and administrative courts. The adopted method of critical analysis constitutes the basic method of analysing legal regulations, taking into account the views of doctrine and jurisprudence, allowing conclusions to be drawn, although the small number of publications and court rulings on the subject matter discussed constituted a shortcoming of the research carried out in the article.

Findings: The analysis leads to the conclusion that a business model of an enterprise cannot be subject to exclusive rights, and only the protection of its elements, under certain conditions, is possible as a trade secret based on the provisions on combating unfair competition, while the use of someone else's business model may be classified as an atypical act of unfair competition.

Practical implications: The use of a specific business model by an entrepreneur necessitates its protection against use by other entrepreneurs. The article defines the legal basis for such protection, creating a framework for its practical application.

Originality/value: The issue of classifying business models from the perspective of intellectual property law has not yet been the subject of research, particularly in Polish literature. This research is aimed in particular at entrepreneurs who use diverse business models in their activities.

Keywords: business model of an enterprise, organisational resilience, intellectual property, know-how, intellectual property courts.

Category of the paper: viewpoint.

1. Introduction

The ability of a system or society exposed to threats to adapt to a new situation by resisting or introducing changes in order to maintain an acceptable level of functioning is referred to as resilience (United Nations, 2007). As K. Sienkiewicz-Małyjurek notes, resilience is considered a trait of individuals, organisations and communities that allows them to cope with threats. It can be a driving force for entrepreneurship in crisis situations. In turn, entrepreneurship, as the ability to use resources in the right way and at the right place and time, builds resilience to future threats, even in the event of failure (Sienkiewicz-Małyjurek, 2020). As J. Brzózka points out, dynamic and often turbulent changes in the environment require the application of new methods and principles of business management (Brzózka, 2009). One of the instruments that allows entrepreneurs to counteract threats arising in the environment in which they operate is the choice of a business model that allows them to counteract threats to the greatest extent possible. In this context, the issue of protecting the chosen business model from being exploited by other competing entrepreneurs operating in the same environment becomes particularly important. Consequently, analysis of this issue becomes important from the point of view of an entrepreneurs who wants to protect the business model they use. The aim of this article is to use critical analysis to answer the question of whether, and if so, on the basis of what regulations and in what proceedings, an entrepreneur can seek legal protection against such actions, and in particular whether a specific business model can be protected as the subject of exclusive rights or only under regulations combating unfair competition?

2. Qualification of a business model as an object of exclusive rights

There are many definitions of the concept of a business model in the literature. The lack of consistency in defining this term stems, among other things, from the different contexts in which it is use (Gajda, 2014; Bartczak, 2023). As a result, it is impossible to find a single generally accepted definition. At the same time, however, there are significant similarities between them. Consequently, it is recommended that any discussion of business models begin with an explanation of how the business model will be defined in that discussion. It is emphasised that reaching a consensus on the definition for the purposes of a given discussion is particularly important, as financiers, engineers, lawyers, operational and strategic management specialists, due to their education and the tasks they perform, usually have different approaches to defining and understanding the concept of a business model (Kliniewicz, 2016; Wierzbicka, 2020).

The concept of a business model appears in both Polish and EU legislation in various contexts. However, there is no legal definition of this concept. For the purposes of further discussion, let us therefore assume that a business model is a company plan that defines how the company creates, delivers and earns value for its customers, thereby generating profits and maintaining a competitive advantage. A business model therefore includes key elements such as customer segments, value proposition, key activities, resources, partners, distribution channels, customer relationships, cost structure and revenue sources.

Before analysing the possible classification of a business model as an intangible asset, attention should be paid to the principle of *numerus clausus* governing intangible assets. This principle assumes that it is not possible to create new subjective rights of an absolute nature in any way other than by statute, in particular by means of a legal act or court ruling (Kurosz, 2021; Dybowski, 2003). Therefore, in order to protect a business model, it is necessary to classify it as one of the objects of exclusive rights specified by the legislator.

3. Classification of a business model as an object of exclusive rights

Firstly, it should be noted that Article 1(2¹) of the Act of 4 February 1994 on Copyright and Related Rights (consolidated text, Journal of Laws of 2025, item 24, hereinafter referred to as CRRA) explicitly excludes ideas and methods, among other things, from copyright protection. It is emphasised that, on the one hand, they are part of reality, being immanent in it, although they have not been noticed so far for various reasons, and therefore cannot be considered the result of creative activity, and on the other hand, that granting property rights to such intangible assets would mean their monopolisation and the impossibility of free access to them by other persons (Ferenc-Szydełko, 2021). This is how the following should be assessed in the provision of Article 1(2¹) of CRRA ideas that form the basis of a business model. It was previously possible for an entrepreneur to operate on the basis of a specific business model using specific methods, although this possibility was not recognised, and the monopolisation of a specific model would prevent its use in relation to a given type of organisation by other entities.

At this point, it is necessary to distinguish between a given business model of an enterprise as a potential subject of exclusive rights and its description. The model itself, like its description, is intangible, with the difference that the description of a given business model may be recorded on a tangible medium (*corpus mechanicum*). However, while the business model itself cannot be subject to copyright under Article 1(2¹) of CRRA, as is clear from that provision, its description may be classified as a work within the meaning of Article 1(1) of CRRA. For this to happen, the description of the business model must meet four conditions – it must be the result of human activity, it must be the result of creative activity aimed at the creation of a new product, i.e. it must be original, it must have an individual character,

i.e. bear the mark of the creator, and it must be fixed, i.e. externalised in a manner that allows it to be perceived by third parties (Article 1(1) of CRRA). The fact that a business model description is a literary work (Article 1(2)(1) of CRRA) should not pose any major difficulties in qualifying it as a work. However, it is the description itself that will be protected as a work, not the business model embodied in that description. In other words, copyright protection will cover the use of the business model description in any field of exploitation (Article 50 of CRRA), but not the model itself. This means that although a specific business model description will be protected as a work, the use of a given model for the purposes of another entrepreneur will be permissible.

While it will not be possible to protect a business model of enterprise under copyright law, it will be possible to protect the customer database used by a specific entrepreneur in activities based on a given business model. Protection of such a database may be sought in copyright law (Article 3 of CRRA) or in the provisions of the Act of 27 July 2021 on the Protection of Databases (consolidated text, Journal of Laws of 2024, item 1769; hereinafter referred to as PDA), and consequently covered by *sui generis* right. The condition for benefiting from such protection in the first case is that the specific database is classified as a work within the meaning of Article 1(1) of CRRA, provided that the creative nature of the database is manifested in the selection, arrangement or compilation of its elements, in this case the customers of a given entrepreneur. In the second case, the condition for the protection of an entrepreneur's customer database will be that the database meets the requirements specified in Article 2(1)(1) of PDA, in particular those relating to the significant financial outlay involved in creating the database, verifying its content (e.g. the accuracy of customer data) or its presentation.

Moving on to the assessment of the possibility of protecting the business model of enterprise under the Act of 30 June 2000 on Industrial Property Law (consolidated text, Journal of Laws of 2023, item 1170; hereinafter referred to as IPL), it should be noted that Article 28(1)(3) of IPL, which, based on Article 100(1) of IPL, applies *mutatis mutandis* to utility models, excludes the possibility of classifying as an invention, as well as a utility model, schemes, rules and methods for performing mental acts, playing games or conducting business activities. The lack of technical character of such solutions is cited as justification for this exclusion (Demendecki et al., 2015; Kostański, 2010). The sphere of technology does not extend beyond the domain of natural sciences, and its subject matter is the use of inanimate or animate matter. Therefore, the field of technology does not include solutions whose subject matter is abstract and conceptual ideas, including organisational ones, as they solve intellectual or organisational problems (Kondrat, 2021), and business models of enterprises fall into this category. The list contained in Article 28(1)(3) of IPL – similarly to the list contained in Article 1(2¹) of CRRA – explicitly lists the schemes (rules and methods) of conducting business activity, and therefore it should be considered that business models of enterprises are excluded from industrial property protection due to their non-technical but organisational nature.

4. Protection of business models outside the system of exclusive rights

When seeking protection for business models, the first step is to consider the possibility of classifying them as rationalisation projects. According to Article 7(2) of IPL, any solution that is suitable for use and is not an invention subject to patenting, a utility model, an industrial design or an integrated circuit topography may be considered a rationalisation project. This means that a business model could be classified as a non-technical, organisational solution constituting a business action plan aimed at solving a specific problem, i.e. the achievement of specific strategic and operational objectives in the conditions of a given type of enterprise. However, for such a model to be considered a rationalisation project, this type of company action plan must be recognised as a rationalisation project by the entrepreneur in the rationalisation regulations adopted by them (Article 7(2) *in principle* in conjunction with Article 7(3) of IPL). As follows from the above, the possibility of classifying a given business model as a rationalisation project applies only to those entrepreneurs who have adopted rationalisation regulations (Article 7(1) of IPL). However, it should be noted that the model of protection of rationalisation projects adopted by the legislator differs from other industrial property rights, which have been shaped as subjective rights of an absolute nature. As a result, an entrepreneur whose employee has created a rationalisation project in the form of a specific business model for the enterprise is not entitled to the protection afforded by absolute subjective civil rights. (judgment of the Provincial Administrative Court in Wrocław of 12 January 2010, I SA/Wr 1602/09, LEX No. 559606; Skubisz, 2012; Żelechowski, 2021)

Next, therefore, consideration should be given to the possibility of protecting the business model of an enterprise on the basis of tort liability regulated by the Act of 16 April 1993 on Combating Unfair Competition (consolidated text, Journal of Laws 2022, item 1233; hereinafter referred to as CUCA). Pursuant to Article 3(1) of CUCA, an act of unfair competition is an act contrary to the law or good practice if it threatens or infringes the interests of another entrepreneur or customer. It is assumed that an act should also be understood as an omission, i.e. a situation in which an entity committing an offence defined in the CUCA should behave in a certain way in order not to commit an act of unfair competition (Nowińska, Szczepanowska-Kozłowska, 2022; Michalak, 2013).

Article 3(1) of CUCA defines unfair competition in general terms, while paragraph 2 of that article lists examples of certain acts, which are further specified in Articles 5-17 of CUCA, which should be interpreted in such a way that the general definition and the provisions specifying acts of unfair competition remain in the following relationship: the acts listed in the Act do not constitute a closed catalogue, and actions not listed in Articles 5-17 of CUCA may also be considered unfair competition provided that they meet the conditions defined in Article 3(1) of CUCA (the so-called supplementary function); the requirements specified in the definition in Article 3(1) of CUCA refer to the acts listed in Articles 5-17 of CUCA,

and the general clause has a corrective function in relation to the specific provisions. When the facts of a case formally meet the conditions of Articles 5-17 of CUCA, but in reality the act does not display any of the characteristics of Article 3(1) of CUCA, it cannot be considered an act of unfair competition.

In the context of business model protection, it is worth noting the typified act of unfair competition in the form of a breach of trade secrets through the disclosure, use or acquisition of another party's information constituting trade secrets (Article 11(1) of CUCA) and the classification of the use of another entrepreneur's business model as a non-typical act of unfair competition, which will be protected on the basis of the general clause contained in Article 3(1) of CUCA, using its supplementary function.

Processes, including production, construction or design processes, marketing or organisational methods in business, work organisation or external relations may be classified as specific know-how. This term covers both know-how that is commonly known (so-called public know-how) and know-how that is confidential (so-called non-public, confidential know-how). The basis for the protection of the latter can be found in Article 11(2) of CUCA, which states that trade secrets are understood to mean not only technical or technological information, but also organisational information or other information of economic value which, as a whole or in a specific combination and collection of their elements, are not generally known to persons normally dealing with this type of information or are not easily accessible to such persons, provided that the person entitled to use or dispose of the information has taken, with due diligence, measures to keep it confidential. Trade secrets protected under Article 11(2) of CUCA can therefore be divided into technical and organisational information.

The first category includes technological information, confidential (technical) know-how, recipes, rationalisation projects, and technical solutions, even if they do not meet the inventive step requirement under the Industrial Property Law (Kępiński, Szwaja, 2024). Production, construction or design processes should be classified as such. The category of organisational information of an enterprise that can be classified as trade secrets in the literature includes methods of quality control of goods and services, marketing methods, or methods of work organisation (Kępiński, Szwaja, 2024), as well as the rules of cooperation between individual departments of the enterprise (Nowińska, Szczepanowska-Kozłowska, 2022). As such, some elements of the business model, such as product distribution methods or customer relations, can be classified as trade secrets.

For information to be covered by the concept of trade secrets, it must be confidential and subject to measures taken by the entrepreneur to maintain that confidentiality, as well as having economic value (Kępiński, Szwaja, 2024; Nowińska, Szczepanowska-Kozłowska, 2022). For this reason, it may be difficult to protect product distribution methods or customer relations as trade secrets due to their external, public nature. It is not necessary for such information to be applicable in another enterprise (Kępiński, Szwaja, 2024), i.e. a given method of product distribution or customer relations may not be possible to use in other enterprises due to its specific nature.

It is also possible to protect a business model from being used by another entrepreneur on the basis of the general clause of unfair competition (Article 3(1) of CUCA) as a so-called non-standardised act of unfair competition. The general clause may be the basis for protection against imitation of solutions, including those of an organisational nature (Kępiński, Szwaja, 2024), or ideas or concepts (Szwaja, 2006; Jasińska, 2010), including the conduct of business activity. An action consisting in the use of a business model of enterprise by a competing entrepreneur may be classified – at least *prima facie* – as contrary to good practice and, moreover, as threatening or infringing the interests of the entrepreneur who was the first to use such a business model. On the other hand, however, it should be remembered that classifying the use of another company's business plan as unfair competition cannot lead to a restriction of freedom of economic activity by granting protection to intangible assets that are not subject to exclusive rights. Therefore, the assessment of an act consisting in modelling one's business plan on another entrepreneur's business model will be made taking into account the circumstances of the case.

5. Claims for the abuse of business model as an act of unfair competition

The inability to protect a business model based on a system of exclusive rights, while at the same time being able to protect business models based on regulations combating unfair competition, raises the question of what claims an entrepreneur affected by such an act can pursue. The basic catalogue of claims available to an eligible entrepreneur in the event of an act of unfair competition includes, first and foremost, a claim for cessation of unlawful activities (Article 18(1)(1) of CUCA) and the removal of the effects of unlawful activities (Article 18(1)(2) of CUCA). In addition, an entrepreneur who has suffered damage as a result of an act of unfair competition may demand the surrender of unjust enrichment (Article 18(1)(5) of CUCA), provided that the surrender of unjust enrichment should take place on general terms, i.e. the terms specified in the Act of 23 April 1964 Civil Code (consolidated text, Journal of Laws of 2025, item 1071; hereinafter referred to as the CC), as well as compensation for damage caused to the injured party by an act of unfair competition on the general principles specified in the CC (Article 18(1)(4) of CUCA). Furthermore, an entrepreneur affected by an act of unfair competition, in a situation where the act of unfair competition was committed culpably, may demand that an appropriate sum of money be awarded for a specific social purpose related to the promotion of Polish culture or the protection of national heritage (Article 18(1)(6) of CUCA) a so-called penalty payment. Irrespective of the above claims, an entrepreneur affected by an act of unfair competition may demand a single or multiple publication of a statement with appropriate content and form (Article 18(1)(3) of CUCA). This request includes the possibility of demanding that the statement be disseminated not only in the press, but also in any other

way, including the press and the Internet. Finally, pursuant to Article 18(2) of CUCA, the court may, at the request of the entitled party, also rule on products, their packaging, advertising materials and other items directly related to the act of unfair competition. In particular, the court may order their destruction or inclusion in the compensation.

Irrespective of the above claims, the provisions of CUCA provide for specific legislative solutions addressed to situations of unfair competition involving the violation of trade secrets. Firstly, due to the difficulty in determining the causal link between the act of unfair competition and the damage, as well as the amount of the damage itself, an entrepreneur affected by an act of unfair competition in the form of a breach of trade secrets may, as an alternative to compensation on general terms (Article 18(1)(4) of CUCA), claim compensation in the form of a lump sum. 1(4) of CUCA) compensation in the form of a lump sum. This takes the form of a payment of a sum of money corresponding to the remuneration which, at the time of the claim, would be due for the consent of the entitled party to the use of information constituting a trade secret (Article 18(5) of CUCA).

Secondly, an entrepreneur affected by an act of unfair competition consisting in a breach of trade secrets may demand that the defendant be obliged to make public information about the judgment or the content of the judgment, in a specified manner and to a specified extent, if this is justified by the circumstances of the act of unfair competition, in particular the manner in which the act was committed, the value of the information to which the act related, the effect of the act and the likelihood of unfair competition being committed in the future, and if the defendant is a natural person, if this is not opposed by the defendant's legitimate interest, in particular the protection of his or her personal rights. However, the manner and scope of making the information about the judgment or the content of the judgment public must not lead to the disclosure of trade secrets (Article 18(3) of CUCA), and therefore, in the case in question, the methods of distribution or customer acquisition used in a given enterprise.

Thirdly, in the event of an act of unfair competition consisting in a breach of trade secrets, the court, instead of granting a request for cessation or removal of the effects of the unlawful acts, or ruling on the products, their packaging, advertising materials and other items directly related to the act of unfair competition, it may, at the request of the defendant, oblige the defendant to pay the claimant appropriate compensation, in an amount not exceeding the compensation that would be due at the time of the claim for the right holder's consent to use the information, for a period not longer than until the state of secrecy ceases, if three conditions are met, i.e. at the time of using or disclosing information constituting a trade secret, the defendant did not know and, even with due diligence, could not have known that the information was obtained from a person who used or disclosed it in the circumstances specified in Article 11(1) 4 of CUCA, granting the request for cessation would cause disproportionate damage to the defendant, and the obligation to pay remuneration does not infringe the legitimate interests of the claimant. (Article 18(4) of CUCA)

6. Pursuing claims for the abuse of business model

Claims for unfair competition are pursued in separate intellectual property proceedings before courts specialising in such matters. On 1 July 2020, intellectual property divisions were established within the district courts in Gdańsk, Katowice, Lublin, Poznań and Warsaw. Thanks to this measure and the entrusting of appeals against the rulings of these district courts to the Courts of Appeal in Poznań and Warsaw, a structure of specialised courts (hereinafter referred to as intellectual property courts) dealing with intellectual property cases was created (Kurosz, 2021).

The concept of intellectual property matters is defined in Article 479⁸⁹ of the Act of 17 November 1964 – Code of Civil Procedure (consolidated text, Journal of Laws of 2024, item 1568, as amended; hereinafter referred to as the CPC). In light of Article 479⁸⁹ § 2(1) of CPC, intellectual property cases also include cases concerning the suppression of unfair competition. Therefore, in a situation where elements of a specific business model are classified as a trade secret, claims for infringement of that secret, i.e. committing an act of unfair competition as defined in Article 11(1) of CUCA, will be heard before an intellectual property court. The situation will be similar if the use of someone else's business model is classified as an untypical act of unfair competition.

Classifying the above cases as intellectual property cases not only subjects them to the jurisdiction of intellectual property courts, but more importantly, means that they will be heard in separate proceedings in intellectual property cases covered by the provisions of Article 479⁸⁹-479¹²⁹ of CPC. Thanks to this, an entrepreneur who has suffered damage as a result of an act of unfair competition will be able to take advantage of a special legal institution applicable only to proceedings in intellectual property cases, facilitating the pursuit of claims, in particular for damages and the surrender of unjust enrichment, which is the securing of evidence (Article 479⁹⁶-479¹⁰⁵ of CPC) (Kurosz, 2025). The entrepreneur may make this request both before bringing an action and in the course of proceedings (Article 479⁹⁷ § 1 of CPC).

However, such an entrepreneur will not be able to take advantage of the two other specific procedural measures provided for in the rules of procedure in intellectual property cases, i.e. disclosure or surrender of evidence (Articles 479¹⁰⁶-479¹¹¹ of CPC) and a request for information (Articles 479¹¹²-479¹²¹ of CPC). In the case of a request for disclosure or surrender of evidence and a request for information, the application of these institutions is limited, as follows from Articles 479¹⁰⁶ *in principio* of CPC and Article 479¹¹³ § 1 of CPC – only to cases concerning the infringement of exclusive rights referred to in Article 479⁸⁹ § 1 of CPC, and therefore it is not possible in cases of unfair competition (as stated by the Court of Appeal in Warsaw in its decisions of 20 November 2020, ref. no. VII AGz 497/20, unpublished, of 15 December 2021, ref. no. VII AGz 498/21, unpublished, of 28 January 2022, ref. no. VII AGz 613/21, unpublished, and of 6 September 2024, ref. no. VII AGz 483/24; contrary to the

Court of Appeal in Poznań in its decisions of 5 April 2022, I AGz 5/22, unpublished; of 2 August 2023, I AGz 54/23, LEX No. 3622487; of 18 March 2024, I AGz 240/23, unpublished, of 5 December 2024, I AGz 20/23, unpublished, and of 9 June 2025, I AGz 251/24, unpublished; Antoniuk, 2026; Pinkalski, 2025).

Furthermore, it should be noted that an entrepreneur who has been harmed by an act of unfair competition may use the institution of securing a claim (Articles 730-757 of CPC), which allows them, in particular, to stop a market competitor from exploiting their business model. This procedural institution in intellectual property cases is characterised by certain specific features relating to the securing of non-monetary claims (Gołaszewska, 2023). This is reflected in the departure from the rule of *ex parte* proceedings in such cases in favour of a hybrid model with predominantly adversarial proceedings and exceptions in favour of *ex parte* proceedings (Antoniuk, 2023).

7. Concluding remarks

The above considerations lead to several important conclusions. Firstly, it is not possible to protect a business model under copyright law as such, but only its description, which may be classified as a work within the meaning of the CUCA. This follows from the provisions of Article 1(2¹) of CRRA, which explicitly excludes ideas and methods, among other things, from copyright protection. The inability to protect a company's business model under copyright law does not preclude the protection of a customer database used by a specific entrepreneur in activities based on a given business model under copyright law or the PDA.

Secondly, the possibility of protecting a business model as a technical solution subject to industrial property rights, i.e. an invention or utility model, should also be excluded. The exclusion of business models from industrial property protection, due to their non-technical but organisational nature, is a consequence of the explicit mention in the list contained in Article 28(1)(3) of IPL of schemes (rules and methods) of conducting business activity as not qualifying as inventions. However, it is possible to classify it as a rationalisation project, provided that such a model is recognised as a rationalisation project by the entrepreneur in his or her adopted rationalisation regulations.

Thirdly, the elements of the business model used by a given entrepreneur may be protected as a trade secret, provided that these elements meet the requirements for classification as a trade secret. Regardless of this, the use of someone else's business model may be classified as an atypical act of unfair competition. In such a situation, an entrepreneur affected by an act of unfair competition will be entitled to a wide range of claims provided for in the CUCA. These claims will be pursued in separate intellectual property proceedings before specialised

intellectual property courts. As part of these proceedings, the entrepreneur will be able to take advantage of a special procedural measure supporting the pursuit of their claims, namely the institution of securing evidence.

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BUILDING THE EMPLOYER'S IMAGE IN DIVERSITY MANAGEMENT PROCESSES

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Purpose: This article presents the ways in which organizations from the *Best Employers ranking* communicate and implement diversity, equity, and inclusion (DEI) activities in the context of building a credible employer image. The aim of the article is to identify practices that strengthen the attractiveness of offers and the trust of employees and candidates.

Design/methodology/approach: Qualitative desk research was used, including the analysis of the content available in the online sources of ten organizations from the ranking of the best employers. Corporate and career websites, annual reports, press releases, interviews, and social media content were analyzed.

Findings: Top-rated employers build credibility in diversity and equity management activities through clearly defined goals, dedicated programs, and regular reporting. In this way, they achieve lasting effects both within the organization and in the candidate experience.

Research limitations/implications: The conclusions are based on the analysis of publicly available materials, which limits access to the full internal data of the surveyed organizations.

Practical implications: Based on the analysis of leaders' practices, a set of recommendations for companies was developed regarding effective communication and implementation of DEI measures, supporting the credibility of the employer brand.

Social implications: Consistent action for diversity, equity, and inclusion reduces barriers to entry for underrepresented groups, improves the availability of products and services, and strengthens public trust in companies.

Originality/value: This article outlines how businesses strengthen their image and reputational advantage through consistent and measurable DEI practices.

Keywords: Diversity, equity and inclusion; employer branding; inclusive leadership; accessibility.

Category of the paper: Research paper; General review.

1. Introduction

The employer brand image is shaped not only by the amount of remuneration or the range of benefits offered, but above all by the credibility and authenticity of the organization in terms of its values (Kopeć, 2016). Diversity, equity, inclusion (DEI) has become one of the key values of the modern world of work. In recent years, empirical and review research has confirmed that consistent implementation of the DEI strategy strengthens the employer's image, increases the attractiveness of recruitment offers, employee satisfaction and loyalty to the organization (Wiśniewska, 2015). This phenomenon is particularly evident in younger generations, especially among Generation Y and Z, who see inclusivity as one of the main criteria for choosing a workplace (Vieira et al., 2024).

In the era of digital recruitment, the role of DEI communication in building an employer's brand is particularly important. Job websites, social media, and videos enable the presentation of an inclusive organizational culture in an engaging and diverse way (Hanu et al., 2021). At the same time, the discrepancy between the declarations and the actual practices of employers can be exposed and publicized by the online community. In response, more and more organizations are moving away from purely declarative statements, replacing them with evidence: the publication of numbers, employee accounts or reports on the implementation of the DEI strategy. Such actions significantly increase the credibility of the brand and strengthen its authenticity (Subbarao et al., 2022).

The aim of the article is to present communicating diversity management in the process of building an employer's image and to identify good practices of companies included in the Forbes "Best Employers in Poland 2025" ranking.

2. Literature review

Diversity, Equity and Inclusion (DEI) management is now one of the key elements of organizational strategies, both in the social and business dimensions (Taneta, 2024). Diversity refers to demographic, cultural, cognitive, and organizational diversity in the workplace, encompassing characteristics such as age, gender, ethnicity, work experience, and thinking style (Ferdman, Deane, 2014). Equity focuses on providing equitable opportunities for development and promotion for all employees by eliminating systemic and structural barriers (Shore et al., 2011). Inclusion has to do with creating an environment where diversity is not only accepted, but actively exploited, and employees feel fully engaged and valued (Roberson, 2006).

Initially, the approach to diversity in organizations was mainly limited to activities in accordance with the requirements of anti-discrimination law. Currently, diversity management is treated as a strategic organizational resource that can contribute to competitive advantage (Barney, 1991). Research indicates that organizations that successfully implement DEI policies achieve higher financial results, better innovation, and higher employee satisfaction (Hunt, Layton, Prince, 2015).

Employer branding is defined as a set of characteristics that make an organization perceived as an attractive place to work (Backhaus, Tikoo, 2004). The term "image" refers to the way in which a person or object is perceived and presented (PWN, 2015, p. 1148).

Shaping a positive employer brand image includes both internal initiatives – aimed at current employees, and external initiatives – aimed at attracting candidates (Matuszewska-Kubicz, 2020). Activities for creating the employer's internal image are primarily aimed at retaining key employees by providing development opportunities, a friendly working atmosphere and building commitment to achieving the organization's goals. On the other hand, external activities focus on encouraging qualified and talented people to apply for a job in the company (Wiśniewska, 2015).

Having a consistent and positive employer image, both inside and outside the organization, brings numerous benefits (Grzesiuk, 2023). The most important include:

- attracting and retaining talented employees,
- shortening the time needed to fill vacant positions,
- reduction of costs related to recruitment and selection,
- strengthening the identification of employees with the company's mission and vision,
- increasing employee engagement and motivation,
- increasing job satisfaction,
- improving relations with customers and business partners,
- strengthening the company's brand and the products and services it offers (Socha, Magońska, 2020).

The process of building the employer's image is comprehensive and includes a wide range of activities related to both the company's organizational strategy and its personnel policy (Minchington, 2007, p. 15). It refers to the values represented by the organization and to the practices that aim to attract, engage and retain both current and future employees (Conference Board, 2001).

According to F. Lievens, employer image involves the conscious of a company's identity by creating its image as a desirable workplace – both inside the organization and outside (Lievens, Van Hove, Anseel, 2007, p. 48). It is perceived as a way in which the company functions in the minds of employees and stakeholders, emphasizing its uniqueness and attractiveness (Minchington, 2006; Ambler, Barrow, 1996).

In a broader sense, the image of the employer can be treated as a dynamic process, integrating the organization's strategy with its brand, human resources management and corporate social responsibility activities (Aggerholm, Andersen, Thomsen, 2011). It consists of a set of features and attributes that employees and potential candidates assign to a given company. It includes both measurable elements – such as the level of remuneration, bonus system or benefits – and non-measurable aspects, e.g. organizational culture, management style, professional development opportunities or prestige of the organization.

The modern approach to building an employer's brand assumes that the authenticity and consistency of organizational values with business practices are key to building a credible image. DEI management is an important element in this context, as it allows organizations to present themselves as inclusive and open to diversity (Gadomska-Lila, 2013).

Research indicates that consistent implementation of diversity and equity management strategies increases the attractiveness of recruitment offers, improves employee satisfaction and loyalty, as well as builds trust among candidates, especially representatives of Generations Y and Z, for whom inclusivity is one of the key criteria for choosing a workplace (Glassdoor, 2020; Deloitte, 2021).

Effective diversity management requires proper communication that allows employees, candidates, and the outside community to see the real actions of the organization. In the context of DEI, this means that an organization should not only declare inclusive values, but also present specific activities to support diversity, such as training, mentoring, data reporting, or development programs for underrepresented groups (Wiejak, 2021).

Career websites, social media, videos and employee storytelling are now key communication channels about the approach to diversity and equality. Authenticity and transparency in the message are key to building trust; lack of consistency between declarations and practices leads to the so-called diversity washing, which can negatively affect the image of the organization (Roberson, 2006; Ferdman, Deane, 2014).

The literature on the subject indicates practices that are recognized as effective in managing DEI. These include:

- Creating employee networks and support groups (Employee Resource Groups),
- Mentoring and development programs for underrepresented groups,
- Transparent reporting of diversity data,
- Inclusive communication in recruitment and marketing content,
- Involvement in social and pro-social initiatives (Deloitte, 2021; McKinsey, 2020).

In the context of building the employer brand image in Poland, it is worth referring to the practices of the best employers who present their DEI activities in a systematic and transparent manner. These activities are an example that diversity management is not only an HR function, but an integral element of organizational strategy and corporate culture.

3. Research method

This article reviews the literature on 10 organizations recognized as the best employers in Poland in 2025 according to the Forbes ranking. The analysis was carried out on publicly available materials published by these organizations on the Internet - in particular:

- websites and "Career" tabs,
- press releases and annual reports,
- social media profiles (LinkedIn, Facebook),
- interviews and employee reports published online.

The analysis was qualitative and based on the desk research method. To ensure the reliability and comparability of the data, the following verification procedures were applied:

Assessment of source credibility - sources were evaluated in terms of the authority and formality of the publication. Documents originating directly from the organizations were preferred. Additionally, it was verified whether the information was confirmed by at least two independent sources.

Verification of data consistency across companies - to ensure comparability, the analysis was conducted according to a uniform DEI category framework (e.g., gender equality, disability, ethnic diversity, LGBTQIA+, age). For each company, data were collected in the same areas and assessed according to the same criteria. In cases of missing information or differences in data presentation, the principle of data triangulation was applied – information from various materials was compared and supplemented with additional sources. If it was not possible to verify a particular piece of information, it was treated as missing data rather than as confirmation of an action.

The aim of the article is to present the importance of Diversity, Equality and Inclusion (DEI) management in the process of building an employer's image and to identify good practices in this area on the example of organizations recognized as the best employers in Poland in 2025 according to the Forbes ranking.

Table 1.
10 companies from the Best Employers ranking

Place in the ranking	Company name	Industry
1	Adidas	Clothing, accessories, sports equipment (production and trade)
2	Intel	Electronics, electrical engineering, computer hardware
3	Hilton	Gastronomy, tourism, sports and leisure services
4	Microsoft	IT, Internet, Software, Computer Games and Computer Service
5	Google	IT, Internet, Software, Computer Games and Computer Service
6	Decathlon	Clothing, accessories, sports equipment (production and trade)
7	Deichmann	Clothing, accessories, sports equipment (production and trade)
8	Nike	Clothing, accessories, sports equipment (production and trade)
9	Samsung	Electronics, electrical engineering, computer hardware
10	CD PROJECT	IT, Internet, Software, Computer Games and Computer Service

Source: <https://www.forbes.pl/najlepsi-pracodawcy/2025>

The Forbes Poland's Best Employers ranking is an annual, nationwide survey of employees' opinions about employers, which the editors prepare in cooperation with the research company Statista, known for creating lists and analyses of the labor market. The ranking is based on anonymous online surveys filled in by employees of large companies active in Poland. Organizations with at least 250 employees, representing approximately 25 industries, are eligible, and the final list includes the top 300 entities nationally.

The ranking methodology is based on a two-component recommendation measure, combining the assessment of one's own employer with opinions about other entities in the industry. The direct indicator measures the readiness to recommend your own organization (on a scale of 0-10), which is a measure of employee trust and loyalty. The indirect indicator includes ratings of competing companies, which allows to take into account the market context and balances the internal perspective. Each organisation is given a score on a scale of 0-100 points, after verifying the consistency of the surveys and the eligibility of the entities.

4. Research results

More and more companies around the world are treating diversity, equality and inclusion as an important part of their strategy, not just in the area of personnel management. These practices are becoming a key component of organizational culture and the way of building the image of a responsible employer. By referring to examples of companies that consistently and transparently implement DEI activities, it allows us to understand how diversity can support innovation, employee engagement and sustainable development of the organization.

To identify ways of informing the public and defining good practices for managing diversity and equality, it was decided to analyse in detail the information of the first 10 companies indicated in the ranking.

Adidas

Adidas operates more than 30 Employee Resource Groups around the world. These are voluntary initiatives created by employees themselves that help build a sense of belonging and community within the company. These groups cover different areas such as ethnicity, gender, sexual orientation (LGBTQIA+), generational differences, religion, disability or mental health. Any employee can join them, regardless of their position.

The company also invests in diversity and inclusion (DEI) education and training. Employees receive materials for self-education, and managers undergo mandatory training in counteracting discrimination and harassment. As a result, the organization strengthens the culture of respect and understanding in the workplace. An important element of these activities

is the "Leadership with Inclusiveness" program, addressed to the management staff. It consists of three stages – self-assessment, coaching and mutual learning, and the aim is to help leaders develop competencies in managing diverse teams and promote equality in practice.

As part of its efforts to promote gender equality, the company assumes that by 2033, women will occupy half of management positions. In 2023, they already accounted for 40% of executives globally, 48% at middle and lower management levels, and 52% among those starting their careers in the company. To achieve full balance, the company runs mentoring and development programs that help women advance to higher positions.

The company is also committed to fighting racism and promoting racial equality. The company runs programs that help increase the representation of underrepresented workers, especially in the U.S. In 2020, the "United Against Racism" initiative was launched, which aims to support social justice and diversity. As part of the program, Adidas has pledged to invest \$120 million in anti-racism efforts and to award 55 scholarships annually to Black and Hispanic students, and to have at least 30% of new positions in the U.S. include people from these communities.

The presented DEI strategy shows that the company treats diversity as the foundation of organizational culture and the key to creating a work environment in which everyone can feel respected, supported and have equal opportunities for development.

Intel

Intel's equality and diversity policy is systemic and transparent. The company publishes measurable goals, representation data, and a description of programs to support underrepresented groups as part of the global Inclusion at Intel initiative, which is based on gender equality, accessibility, and an extensive network of Employee Resource Groups (ERG) to support the inclusion and development of talent from diverse backgrounds. The "Inclusion at Intel" website showcases more than 250 employee groups, such as ERG Pride, Women at Intel Network, Disability & Accessibility Network, and NextGen, which enable the exchange of experiences, mentoring and community building. Intel reaffirms its commitment to diversity by joining the Diversity Charter, pledging to combat discrimination and foster a culture of equality in the workplace.

The company consistently develops a strategy for the inclusion of people with disabilities, creating a work environment based on accessibility, equality and respect. Her work is regularly recognized by industry organizations e.g. the American Association of People with Disabilities (AAPD) and Disability:IN, which give Intel top marks for implementing accessibility and inclusivity standards. In 2025, the company achieved the maximum score of 100 points in the Disability Equality Index for the ninth time in a row, receiving the title of one of the best workplaces for people with disabilities. The company has set a goal for 10% of its total workforce to be employees who self-identify as having disabilities, using this metric as a key

measure of the effectiveness of DEI efforts. Intel combines an inclusive approach with technological innovation, developing solutions that increase digital accessibility, including products and tools to support people with functional limitations, and making its own processes, training, and workspaces accessible.

The company's organizational culture is based on the belief that diverse employee perspectives and experiences are a source of innovation and competitive advantage. By supporting the development of ERGs and promoting the principles of equal treatment, Intel is building an environment where every employee can fully participate in the life of the company, contributing to the creation of technologies that benefit all users – without barriers or exclusions.

Hilton

Hilton considers diversity, equity and inclusion as an integral part of its business strategy and human resource management. The company regularly sets representative goals for gender and ethnicity diversity, linking their implementation to the leaders' compensation system. This solution incorporates DEI accountability into the management structure, creating a cycle that includes declarations, actions, measurement of indicators and adjustments, which strengthens the credibility of the employer brand and the operational efficiency of hotels on a global scale. Progress on commitments is published as part of the Travel with Purpose strategy, which includes annual reports and data on progress on equality and inclusion.

An important part of Hilton's organizational culture is Team Member Resource Groups, which support building a community of employees with diverse identities, experiences, and perspectives. These groups create a space for mentoring, exchange of experiences and development of leadership competencies, and their activities are supported by senior leaders, which is conducive to shaping a culture of openness and cooperation.

An important area of DEI Hilton's activities is the employment of people with disabilities, implemented through a long-term partnership with the Project SEARCH program. The initiative combines vocational training, on-the-job support and sustainable employment, providing an example of the effective integration of people with disabilities in the hospitality industry. The effectiveness of its efforts in this area is confirmed by Hilton's achievement of a maximum score of 100/100 in the Disability Equality Index in subsequent years, which strengthens the company's reputation and facilitates the implementation of uniform accessibility standards in different regions of the world.

Hilton brings global DEI standards to local markets through research on employment barriers and awareness campaigns on diversity and accessibility. This approach confirms that the successful implementation of the DEI strategy in an industry with a high degree of multiculturalism requires flexibility and adaptation to the cultural and legal context of individual countries. External accolades, such as high rankings in DiversityInc rankings and

a place in the Hall of Fame, are independent confirmation of the effectiveness of Hilton's diversity and equity management strategy. The company has consistently strengthened its position among global leaders in sustainable leadership, combining DEI goals with business development, innovation, and social responsibility.

Microsoft

Microsoft has consistently developed a culture of diversity, equity, and inclusion for more than a decade, making it a key component of its leadership, innovation, and social responsibility strategy. The company publishes the Global Diversity & Inclusion Report every year, in which it presents detailed data on the representation of women and minority groups, employment levels and turnover, and pay equity. Transparent reporting allows you to track progress and account for goals in an open and reliable way. Over the years, Microsoft has steadily increased the representation of women and people from underrepresented groups, especially at the leadership and partner levels. Such transparency underscores a responsible approach to managing technological transformation, considering DEI aspects.

Microsoft's organizational culture is based on nine global employee groups that support the growth and belonging of employees with different identities. These include Women at Microsoft, GLEAM (LGBTQIA+ community), BAM (Black & African American), HOLA (Hispanic/Latinx), Indigenous, Disability, Military, Asians and Families. These groups operate on a global and local level, organising mentoring, workshops, educational and advisory initiatives. They also co-create human resources management policies and career development programs, which strengthens the coherence and inclusiveness of internal processes.

One of the most important pillars of Microsoft's DEI activities is the concept of Inclusive Design – designing products and technologies so that they are accessible and intuitive to the widest possible range of users. To this end, the company has created an internal platform with design guidelines, components and courses such as Introduction to Inclusive Design & Accessibility, which help design teams implement accessibility principles from the product concept stage.

The report released by the company for 2024 confirms that gender pay equality is maintained and the median wage gap is further narrowing. These actions demonstrate that Microsoft combines an ethos of equality with a practical, systemic approach to managing human capital and designing innovation in a truly inclusive way.

Google

Google operates an extensive diversity, equity, and inclusion management system, based on its Diversity Annual Report and the "Belonging" platform. The platform organizes the company's activities in three areas: the workplace, technology, and social partnerships, with all initiatives focusing on belonging and designing products with all users in mind. The 2024 report

shows continued investment in inclusive teams, the development of accessibility features in products, and educational and social programs that support underrepresented and excluded groups.

In the area of organizational culture, Google is working to increase the participation of leaders from underrepresented groups, including the African or African American community. To support the development of these leaders, the company has established special teams and people responsible for talent development. The reports document the actions taken, implementation tools and effects in the development of inclusive leadership.

Google advances accessibility technologies by combining research and development with user education. Examples include the Accessibility Discovery Centres in London, Dublin, Zurich and Dubai, where designers, engineers and communities of people with disabilities collaborate on new solutions.

Another area of activity is diversity in the supply chain. Google plans to increase spending at companies belonging to underrepresented groups to \$2.5 billion and expand the program outside the US. At the same time, the company publishes the principles of supplier responsibility and reports on the results of these activities, which shows its social and economic impact.

Decathlon

Decathlon combines diversity, equality and inclusion (DEI) with its mission "Move people through the wonders of sport". This means that the company strives to make sport and work at Decathlon accessible to everyone – regardless of age, gender, background or ability. In 2024, a global DEI strategy was introduced, based on four main goals:

1. create teams that reflect the diversity of society,
2. ensure equal opportunities in professional development,
3. build a work culture based on respect and openness,
4. design products and services that are accessible to all users.

The actions taken are part of a public sustainability report, so you can verify how the company is achieving its goals. In its 2024 documents, Decathlon shows that values such as caring and inclusion are embedded in everyday work culture. As many as 89-92% of employees declare pride in working in the company, which shows that they feel good and appreciated in it.

Decathlon also develops several initiatives to support different groups of employees. These include the Women in Tech program – supporting women in the tech industry, Cross-Culturalism – language and intercultural training, and Smart Working – a program teaching effective remote work. Through these initiatives, teams learn to collaborate, trust each other, and be open to different perspectives.

The company has earned the international EDGE (Equity, Diversity & Gender Equality) certificate, which confirms that it cares about equal pay, promotions and leadership development. The audit covered as many as 80% of the world's employees and helped determine where further improvements could be made. In addition, the Global Maturity Index DEI was created – a tool for comparing progress between countries. Its idea refers to sports competition – it is to motivate teams to further improve.

Decathlon has also been supporting people with disabilities for years. The company cooperates with sports clubs for people with disabilities, introduces workplace facilities (e.g. ergonomic workstations, assistants, sign language interpreters) and signs contracts at the national level that help in employing such people. An important element is also educational campaigns, e.g. "Live My Life" (role swap for one day) or sports tournaments on wheelchairs – thanks to which employees better understand the needs of others and learn empathy.

Deichmann

Deichmann pursues the "DEICHMANN for all" strategy. This means that the company strives to ensure that everyone – regardless of age, background, fitness or social background – feels treated with respect and has equal opportunities. These values are combined with the company's mission "the company must serve people" and with ads that show a variety of characters so that more people can identify with them.

Within the organization, Deichmann regularly surveys employee feedback (so-called pulse survey) and conducts training for managers on how to better manage diverse teams. The company supports women in technical industries through initiatives such as "Bündnis für Frauen in MINT-Berufen" and the internal "empower" network, which help develop leadership and equal career opportunities. The "Chancengeber" program gives employment opportunities to people with an unusual career path, e.g. after a break from work or a change of industry, which helps them start their career in sales.

Inclusivity can also be seen in advertising campaigns – Deichmann deliberately shows people of different ages, backgrounds and levels of fitness, so that everyone can find themselves in them. The company strongly opposes hate speech against customers and employees.

Deichmann is also involved in charity work. The Deichmann Foundation supports around 200 projects per year – e.g. in Germany, Tanzania and Madagascar – focusing on education and social inclusion. This is part of a broader approach of the company, which puts people at the center of its operations and reputation as a responsible employer.

Nike

Nike publishes data on its activities as part of the Impact Resources platform and annual Impact Reports. There you can find information about the number of workers from different groups, about pay equality between women and men around the world, and between white

people and minorities in the US. In 2021, the company confirmed full gender pay equality and an increase in the number of women and minority people in management positions.

The company has Employee Resource Groups – support groups that help build a sense of belonging and support professional development. Nike also partners with external organizations, such as TAAF (The Asian American Foundation), and organizes events aimed at educating future leaders in supporting a culture of diversity.

The company also develops products that are accessible to everyone. One of the developed product lines allows you to put on shoes hands-free. The company promoted such a solution during the Disability:IN conference, where it was awarded for inclusive marketing in 2025. The Enabling Accessibility program supports the creation of accessible and ergonomic workplaces for people with disabilities.

Reports released by the company for 2023 indicate that Nike exceeded targets for racial and ethnic diversity among American employees, including in executive positions. However, the low number of women on the boards of partner companies remains a challenge – the organization is responding to this by introducing gender equality analysis tools and women's development programs.

The company also invests in communities, with \$140 million in funding for the Black Community Commitment program since 2020 and additionally supports Historically Black Colleges and Universities and Hispanic-Serving Institutions, allocating \$10 million over five years to educational and athletic projects. In this way, Nike combines DEI activities with community and education development.

Samsung

Samsung has a diversity, equity, and inclusion strategy that aims to create a work environment based on equal opportunities, mutual respect, and a sense of belonging. The company emphasizes that diverse teams are a source of innovation. As part of this strategy, it is developing the Women at Samsung program, activities supporting people with disabilities and intergenerational initiatives.

Between 2023 and 2024, Samsung established the DEI Council and developed the ERG network around the world. Currently, there are 43 groups that bring together about 6600 employees. These groups organize mentoring, volunteering, and training, helping employees grow professionally and build relationships.

As part of inclusive employment, Samsung runs the "Stellar Forest" program, which creates jobs for people with intellectual disabilities. At the end of 2024, it employed 301 people and expanded its operations. The company also runs an internship program for graduates from this group.

Samsung is also developing technologies that are accessible to everyone. As part of the "Samsung Inclusive Essentials" philosophy, awarded IDEA Gold 2025, it designs devices and interfaces to be easy to use – through various forms of information: touch, color, sound and shape. One UI 8 features to support people with hearing problems, such real-time call captions, keyboard translations, and a mode developed in collaboration with users with hearing loss.

Samsung's entire DEI strategy is based on three main pillars:

1. Governance and Data – DEI Council, policies and goals to 2030.
2. Inclusive employment – Stellar forest program and ERG networks.
3. Inclusive products – UI development and device design for all.

This approach allows Samsung to measure the effects of its actions, show their impact and build an image of a company that truly cares about equality, diversity and accessibility – both for employees and users of its products.

CD PROJEKT

CD PROJEKT has been pursuing a diversity policy since 2018 and has signed the Diversity Charter under the auspices of the European Commission. The company is committed to prohibiting discrimination, promoting equal treatment, and engaging both employees and partners in diversity and inclusion efforts. In its reports, the company emphasizes that diversity and an inclusive work culture support creativity and innovation, which are key in game development.

In practice, CD PROJEKT introduces solutions that combine employee well-being with equal opportunities. One example is paid menstrual leave, for which the company received a distinction from 30% Club Poland. CD PROJEKT also runs programs to support the development of women in the gaming industry, such as "Girls in the Game!" – workshops and mentoring for girls who want to start a career in gamedev. Since 2020, more than 3.5 thousand people have applied for the program, and many participants continue their professional development in projects and studios, which helps build a new generation of talent in the industry.

The company is also one of the first Polish entities to apply the principle of double materiality, i.e. the analysis of the impact of its activities on society and the environment and the impact of these factors on the company.

In 2024, there were critical opinions in the media about DEI's activities in the gaming industry, but CD PROJEKT publicly defended its practices, emphasizing that diversity and inclusion are crucial for the quality of the games created and the development of talent.

CD PROJEKT has consistently combined its approach to DEI with its mission to "create revolutionary games for gamers around the world". The company shows that diverse teams and a safe, supportive work environment are not only social values, but also the foundation of creative and business success.

Comparative analysis

The analyzed descriptions of the companies allowed to identify key directions of action in the field of diversity, equality and inclusion. To systematize this information, the following comparison table has been prepared, which compares the approach of individual companies to selected areas of DEI policy.

Table 2 presents a comparison of Diversity, equity and inclusion activities in ten global companies across different industries. The comparison covers seven key DEI policy areas:

1. Gender equality – initiatives related to the representation of women in management, equal pay and mentoring programs.
2. Disability approach – employment programs, accessibility of products and jobs, and mental health activities.
3. Racial and ethnic diversity – initiatives to support minorities, counteract discrimination and invest in communities.
4. LGBTQIA+ and sexual orientation – equality policies, employee groups and actions for the acceptance of diverse identities.
5. Generational/age diversity – activities supporting cooperation between generations and the development of employees of different ages.

Table 2.
10 companies from the Best Employers ranking

Company	Equality between women and men	Approach to disability	Racial and ethnic diversity	LGBTQIA+ and sexual orientation	Generational / Age Diversity
Adidas	50% of women in management by 2033; mentoring programs.	Disability and mental health support groups.	The "United Against Racism" program, \$120 million in investments, scholarships.	LGBTQIA+ groups in ERG.	ERG covering generational differences.
Intel	Gender representation goals; transparent reporting.	100/100 in the Disability Equality Index; target of 10% of employees with disabilities.	Counteracting discrimination; Diversity Charter.	ERG comes along; support for the LGBTQ+ community.	ERG NextGen – generational diversity.
Hilton	Gender goals related to leaders' salary.	Project SEARCH – integration of people with disabilities; 100/100 DEI Index.	Global and local actions on ethnic diversity.	Not disclosed	Not disclosed
Microsoft	Equal pay; increase in the participation of women in management.	Disability ERG Group; accessibility technologies.	Communities BAM, HOLA, Indigenous.	GLEAM – the global LGBTQIA+ community.	ERG Military and Families covering different generations.

Cont. table 2.

Google	Goals to increase the participation of women in management.	Accessibility Discovery Centres; development of accessibility features.	Development of leaders from African American and Hispanic groups.	Not disclosed	Not disclosed
Decathlon	EDGE Certificate; "Women in Tech" program.	Facilities, sign interpreters, cooperation with sports for people with disabilities.	Cross-Culturalism – intercultural training.	Not disclosed	Programs supporting different generations; Smart Working.
Deichmann	"empower" network; initiatives for women.	"Chancengeber" program; inclusive workplaces.	Campaigns with people of different cultures and backgrounds.	Not disclosed	Not disclosed
Nike	Equal pay for women and men; development of women in management.	"Enabling Accessibility" program; hands-free products.	Black Community Commitment	ERGs supporting LGBTQ+; inclusive marketing.	Not disclosed
Samsung	"Women at Samsung" program; An equal promotion.	"Stellar Forest" – employing people with intellectual disabilities.	Cultural diversity; global activities.	Not disclosed	Intergenerational initiatives in ERG.
CD PROJECT	"Girls in the Game!"; menstrual leave.	Wellbeing support; safe working environment.	Anti-discrimination policy; Diversity Charter.	Not disclosed	Not disclosed

Source: Own study.

An analysis of activities in ten international companies shows approach to diversity, equity and inclusion. All analyzed organizations include at least some of the DEI areas in their strategies, but they differ in the scope of implementations, priorities and the way progress is reported.

The most common element of DEI policy is gender equality – each of the companies conducts initiatives to promote gender balance in organizational structures, including through mentoring programs, training or setting representative goals. In the area of disability, there is clear efforts to create more accessible jobs, develop technological solutions that support accessibility and work with external organizations.

Racial and ethnic diversity and support for the LGBTQIA+ community are strongly emphasized in companies with a global reach, especially in technology companies and corporations with an international workforce. In European companies, especially in the trade and manufacturing sectors, these activities often focus on cultural and social inclusion and the promotion of equal access to professional development.

The area of generational diversity and age management is relatively less developed – it appears mainly in the context of mentoring programs or flexible forms of work.

5. Literature discussion and summary

Diversity, equity, and inclusion (DEI) is becoming a key element of organizational strategies and building an employer's image. Companies that present specific actions and measurable effects – such as data, reports, development programs or employee opinions – gain in attractiveness, loyalty and employee satisfaction. The visibility of DEI initiatives on social media is conducive to attracting talent, but the lack of consistency between message and practice generates reputational risk, so the consistency of communication with real activities is crucial.

The conducted original research confirms the conclusions presented in the literature, according to which diversity, equity, and inclusion are becoming an important element of contemporary organizational strategies, although the scope and degree of implementation of specific DEI areas remain diversified (Shore et al., 2011; Roberson, 2006). All analyzed companies take into account at least selected elements of DEI, which is consistent with previous studies indicating growing institutional, social, and market pressure in this area (Cox, 1993).

The most developed area of DEI policies in the examined companies is gender equality. This result confirms the findings of Eagly and Carli (2007), who indicate that initiatives aimed at gender balance are most often the first and most systematically implemented element of diversity strategies. In the studied organizations, activities such as mentoring programs, training, or setting representation targets were most frequently observed, which aligns with the recommendations of human resource management literature emphasizing the importance of formal mechanisms supporting the advancement of women within organizational structures (Kossek et al., 2006). At the same time, it is increasingly emphasized that excessive reliance on such instruments may be insufficient, as development programs alone do not automatically lead to lasting structural change or to the elimination of barriers to women's advancement (Kossek et al., 2006). Therefore, although initiatives such as mentoring or representation targets are common, they require support through deeper, systemic changes in the organization in order to effectively translate into gender balance at all levels of the structure.

In the area of disability, the companies studied mainly focus on increasing workplace accessibility, implementing technological solutions, and cooperating with external organizations. This direction of action is consistent with the results of Schur, Kruse, and Blanck (2005), who indicate that organizational culture and infrastructural and technological accessibility are key factors facilitating the employment of people with disabilities.

At the same time, Santuzzi et al. (2014) emphasize that these activities are often fragmented. Although the literature points to the necessity of a comprehensive approach, including both infrastructure accessibility and changes in managerial attitudes, the companies examined in practice focus primarily on technical solutions and formal policies. As a result, the inclusion of people with disabilities is often reactive rather than strategic, which is confirmed by previous

studies indicating the persistence of so-called “hidden barriers” in the workplace environment (Gąciarz, Bartkowski, 2014).

Racial and ethnic diversity, as well as support for LGBTQIA+ communities, are more prominently emphasized in globally operating companies, especially in the technology sector. These results are consistent with the research of Badgett et al. (2013), which indicates that international corporations more often implement comprehensive anti-discrimination policies and support programs for LGBTQIA+ employees, perceiving them as an element of building competitive advantage and employer attractiveness. Ragins (2008) also emphasizes that the existence of formal equality policies contributes to the creation of a safe organizational climate, which is reflected in the practices analyzed.

The least developed area of DEI policies in the examined companies remains age diversity and generational management. Actions in this area are mainly limited to mentoring programs and flexible forms of work. This result is consistent with the findings of Kunze, Boehm, and Bruch (2011), who indicate that age management rarely has a strategic character and most often functions as a complementary element to other HR initiatives. Similar conclusions are drawn by Truxillo et al. (2015), emphasizing that an approach based on the employee life-cycle perspective is still not widely implemented in organizations.

Organizations that combine DEI strategy with business goals, integrate it into management processes and transparently report on progress, build a more durable and credible image. The analysis of companies included in the *Forbes Best Employers Poland 2025 ranking* made it possible to identify common patterns of effective practices. Most often, these include:

1. Governance and accountability – setting goals, creating policies, regular reporting and external audits to monitor progress.
2. Communities and employee development – creating support groups and mentoring networks to foster development and exchange of experiences.
3. DEI in products and ecosystem – embedding accessibility and inclusivity in designs, products, and supply chains, and fostering supplier diversity.
4. Consistency of communication – every public message should be supported by data, reports or examples of actions, which avoids the phenomenon of "diversity washing".

The identified practices are in line with global employer branding trends and confirm that diversity management is a key factor in building organizational reputation. All surveyed organizations implement elements of DEI policy, but the degree of their development and formalization varies depending on the industry, region and size of the company. Gender equality is the most developed area in the organization's publications, while the least is generational diversity and LGBTQIA+ orientation.

Increasingly, companies perceive DEI not only as an image element, but as a factor influencing organizational culture, employee retention, and innovation. In the longer term, we can expect to deepen activities in areas that have so far been less exposed – especially in the field of age diversity, inclusive design and cross-sectoral cooperation.

A limitation of the study is that the analysis is based on public data, which does not allow for a full assessment of the maturity of DEI practices – especially in terms of internal HR processes, recruitment and employee performance. In the future, it is worth the analysis with internal data and monitoring the evolution of DEI indicators in terms of industry and locality.

Although the own research results confirm many aspects presented in the literature, the analysis also reveals inconsistencies that indicate the limited maturity of DEI strategies in the organizations studied. The literature emphasizes that the effectiveness of DEI policies depends not only on their formal existence but primarily on the degree of integration with key management processes and on systematic evaluation of results (Roberson, 2006; Shore et al., 2011). Meanwhile, in the companies examined, these actions may be declarative and fragmented, and progress reporting focuses mainly on selected quantitative indicators.

In conclusion, effectively building an employer's image through DEI requires consistency, courage and authenticity. Organizations that see diversity as an integral part of their identity and strategy not only attract talent but also strengthen their reputation and social impact. In the age of digital communication, the most valuable value is credibility based on facts – programs, training, partnerships and progress indicators. DEI, understood in this way, is becoming one of the pillars of the long-term success of modern employers.

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SELF-INTEREST AS AN ETHICAL DILEMMA FOR POLISH STATUTORY AUDITORS OPERATING AS PRIVATE ENTREPRENEURS

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Purpose: The article poses the question of whether self-interest constitutes a chance or a threat for Polish statutory auditors, who simultaneously operate as private entrepreneurs. The main objective of the study is to explore the ethical dilemmas arising from the conflict between professional independence and auditors' own economic interests.

Design/methodology/approach: The study employs a case study methodology and presents three situations in auditor practice where statutory auditors must choose between preserving ethical standards and prioritizing their own or their firm's business interests. Case study based on an unstructured interview with a statutory auditor. The examples of real situations were compared with legal and professional ethics standards.

Findings: The analysis shows that self-interest is an inherent element of auditors' professional practice. The findings suggest that the decisive factor is not the presence of self-interest per se, but the auditors' ability to balance it against ethical requirements and institutional safeguards. The study concludes that strengthening professional awareness of ethical conflicts reduce threats to independence are crucial for transforming self-interest from a potential risk into a constructive driver of auditors' work.

Research limitations/implications: The main limitation is the use of a case study method, which limits the generalizability of the conclusions. Provided cases concern only Polish certified auditors and do not include accountants. The investigation should be extended to include cases related to other principles of auditors' professional ethics.

Practical implications: The presented analysis offers valuable insights for practitioners who need to adjust their decision-making processes during ethical dilemmas and manage their audit companies. It highlights the need for continuous reflection on the dual role of statutory auditors as independent professionals and private entrepreneurs.

Originality/value: The paper compares theoretical and practical approaches. The analysis provides conclusions regarding auditors' consideration of ethical dilemmas and their cautious approach to interpreting regulations.

Keywords: self-interest, statutory auditor, entrepreneur, ethics.

Category of the paper: Qualitative, scientific research.

1. Introduction

A statutory auditor in Poland holds a profession of public trust, but must also navigate the realities of a free-market economy. Changing circumstances prompt Polish entrepreneurs to pursue income-generating opportunities in which self-interest plays a significant role. Statutory auditors, constrained by strict regulations, operate in commercial enterprises where self-interest is regarded as a significant ethical risk.

Statutory auditors in Poland operate under a unique model. They are independent experts, yet they also function as entrepreneurs, managing their own businesses or audit firms under domestic law. This creates a specific contradiction. On one side, there is a need for independence and adherence to professional ethics. On the other hand, economic pressures and the need to remain competitive in the audit market influence their actions. The literature extensively discusses self-interest, conflicts of interest, and auditor independence (Johari et al., 2017; Hoseininasab et al., 2020), but these topics are generally examined in the context of large international audit firms and global markets. In these studies, self-interest is mainly seen as a threat to audit quality and auditor independence, as well as an influence on ethical decision-making (Johari et al., 2017; Surya et al., 2021). Additionally, Hussay (1999) already highlighted that familiarity threats exist in both private and public companies. Meanwhile, the perspective of auditors operating within the entrepreneurial model, typical of the Polish market, remains largely overlooked. Dwekat (2023) noted that most existing research focuses on individual factors, whereas organizational factors receive less attention. Moreover, as the business environment evolves, research on ethics needs to become more practical.

The research gap is in the limited understanding of how self-interest influences auditors' decisions when acting as entrepreneurs in Poland. First, the specific situations in which economic self-interest may conflict with professional ethics under local conditions remain unexplored. Second, the literature usually views self-interest solely as a threat, overlooking its potential to drive improvements in service quality, innovation, and the building of a long-term reputation. Third, most research on this topic has been quantitative, with few qualitative studies that reveal the core ethical dilemmas auditors face in practice.

The article addresses this gap by employing a case study to examine situations in which Polish auditors must choose between self-interest and adherence to ethical principles. This practical approach helps identify both the risks and opportunities associated with self-interest in the auditing profession, thereby addressing a research gap.

Regarding the aim, research poses the following three questions:

RQ1: In what type of situations does self-interest influence the decisions of statutory auditors?

RQ2: To what extent can self-interest coexist with compliance with ethical and professional standards?

RQ3: Does the entrepreneurial role of auditors create more opportunities or threats for maintaining professional integrity?

To address the research questions, a literature review, a case study based on semi-structured interviews, and an analysis of legal standards of professional ethics have been employed.

The paper is structured as follows. The first section introduces, while Section 2 presents the methodology. Section 3 describes the theoretical background and research findings of the case study. Section 4 discusses the findings, and Section 5 provides a conclusion, indicates future potential research directions, and presents limitations.

2. Methods

Previous studies have proved that literature on auditors' ethical issues was examined using different research methods, namely a systematic literature review (Renik, 2023), unstructured interviews (Chauhan, 2019; Mulcahy, 2021), or a qualitative approach combining a literature review and semi-structured interviews (Wijaya et al., 2021).

This article uses a case study approach to explore specific situations faced by Polish auditors who must choose between maintaining professional ethics and pursuing self-interest or the interests of the audit firm. This study is extended to include a review of the literature and an analysis of Polish legal acts. In this regard, the study employed the case study method to provide a real-world context for ethical standards and domain law, enabling detailed analysis of complex phenomena in their natural environment. Combining those methods offers a clearer and deeper understanding of auditors' decisions in real-world settings and shows when and how self-interest influences their choices.

The case study based on unstructured interviews with a co-author, a statutory auditor. The interview was conducted online via Google Meet on August 4, 2025.

The interview primarily focused on the situations the co-author experienced during his work as a statutory auditor. It was not scripted to ensure an objective assessment of the interviewee's condition and to prevent the auditor from influencing the interviewee's responses, thereby allowing the auditor to interpret them independently. The results were presented as a descriptive summary of a statutory auditor's experiences in Section 3.3.

For these reasons, this article employs a case study approach, including unstructured interviews, a scoping literature review, and an analysis of legal standards, to offer a broader perspective. This method can assist auditors in ethical decision-making, which is essential for managing a business such as an audit firm.

3. Theoretical background and findings

3.1. Critical literature review

For many years, the literature on economics and auditing has emphasized that an auditor's financial interest can influence audit quality and the independence of the audit opinion (Simunic, 1984). It may create ethical conflicts for auditors and reduce their willingness to remain, given the pressures and dilemmas they entail.

In previous research, Wijaya et al. (2021) used a qualitative approach combining a literature review and semi-structured interviews to examine auditors' perceptions of ethical responsibility. They focused on four dimensions: ethical behavior, organizational factors, professional standards, and regulatory frameworks. However, Chauhan (2019) highlights the benefits of unstructured interviews, including greater face validity, positive reactions from both interviewees and interviewers, comparable validity levels, and increased practicality in various real organizational settings and situations. Some of these advantages are not available through a structured method. Additionally, Mulcahy (2021) states that the unstructured interview, which emphasizes the interviewee's narratives and flexibility, is well-suited to exploring elusive or under-researched concepts. This empirical research investigates auditors' ethical conflicts and discusses their personal values (Tormo-Carbó, 2024). Additionally, another study found that threats such as self-interest, self-review, advocacy, familiarity/intimacy, and intimidation can erode both the auditor's independence of thought and appearance (Nawaiseh, Alnawaiseh, 2015).

However, empirical research offers mixed evidence regarding the impact of self-interest. On the one hand, experiments and behavioral studies suggest that perceived threats to self-interest can influence auditors' judgments (e.g., stock valuations). However, the results do not always support the "amoral, profit-maximizing" auditor model. Instead, much depends on the context, a strong professional identity, and the organization's ethical culture (Chung et al., 2015). On the other hand, research indicates that moral intensity mediates the relationship between auditors' ethical orientation and the threat of self-interest in their ethical decision-making (Johari et al., 2017).

Currently, the situation for Polish statutory auditors may vary. The literature review highlights the dominance of research on large audit firms that employs quantitative methods. At the same time, there is a need for qualitative research to understand the subtleties of decisions made in practice. In the national context, specific conditions are important. Most auditors are solo practitioners or small firms (PANA Report, 2025), operating in a regulatory and market environment shaped by professional self-governance, national regulations, and market practices. Despite numerous legal regulations, they must manage their firms and adhere to professional ethics simultaneously (Ustawa o biegłych rewidentach).

Statutory auditors need to consider practical issues that can help an audit firm manage its operations, including matters of business ethics (Treviño, Nelson, 2013). This is a key step in Treviño's interactionist model (Treviño, 1986), which provides a structured approach to handling difficult situations by considering both the auditor's traits (e.g., experience) and situational factors (e.g., ethical standards and market practices). To understand the factors that influence auditors' behavior within an organization, it is important to analyze corporate culture and auditing practices (Sonjaya, 2024). The findings indicate that auditors working in organizations with strong ethical cultures show higher levels of ethical sensitivity, professionalism, and compliance with standards. Conversely, those in environments with weaker cultures may face pressures that threaten their independence and integrity. Therefore, promoting, sustaining, and managing an ethical corporate culture is essential.

3.2. Analysis of legal standards of professional ethics

The International Ethical Standards (IFAC by IESBA) define five categories of threats to the auditor's core ethical principles, including the self-interest threat, and specify mechanisms and safeguards to minimize these threats. These guidelines form the basis for ethical regulations and practices worldwide, with updates, such as to fee and client relationship rules, highlighting the growing emphasis on assessing threats to self-interest (IFAC, 2018).

Additionally, national legal standards specify a wide range of obligations that auditors must adhere to (Ustawa o biegłych rewidentach). To better understand the ethical conflicts auditors face, several ethical principles should be introduced and examined.

For example, art. 80. 1. states that remuneration for performing research and certifying the reporting of results obtained by an audit firm, statutory auditors, and subcontractors cannot be:

- based on all conditions, including research results or certifying development reports,
- determined or shaped based on the available resources of the entity, or for certification of reporting that covers the development of entities or entities from which non-audit services result, or certification of reporting included in the development by the audit firm or an affiliated entity within the network.

Furthermore, art 80. 2. indicating that compensation for conducting research and certifying the reporting of developed results shall not be based on labor intensity, work complexity, or required installations (Ustawa o biegłych rewidentach, art. 80, Ust. 1-2).

Moreover, the audit firm and the key statutory auditor shall not perform an audit if there is a risk of self-review, self-interest, promotion of the interests of the audited entity, familiarity, or intimidation resulting from a financial, personal, business, employment, or other relationship between the audited entity and the key statutory auditor, the audit firm, a member of the network to which the audit firm belongs, or a natural person who could influence the audit outcome. This is the case when such relationships could lead a reasonable, informed third party to believe that the independence of the key statutory auditor or the audit firm is compromised, even after

applying safeguards designed to eliminate or reduce the threat to an acceptable level (Ustawa o biegłych rewidentach, art. 69, Ust. 6).

Additionally, the key statutory auditor, the audit firm, its employees involved in the audit, and any individual directly participating in the audit activities whose services are used or supervised by the key statutory auditor or the audit firm, as well as individuals closely associated with them, are prohibited from requesting or accepting any financial or personal benefits from the audited entity or its related parties unless an objective, rational, and informed third party would consider their value to be insignificant or immaterial (Ustawa o biegłych rewidentach, art. 71).

Offering or accepting inducements may threaten compliance with fundamental principles, particularly integrity, objectivity, and professional behavior (International Code of Ethics for Professional Accountants, par. 250.2).

An inherent characteristic of every auditor's profession (internal and external) is strict adherence to ethical principles. Ethics is the study of right and wrong, grounded in principles of proper conduct and rules to be followed (Gasparski, 2012).

A wide range of facts and circumstances could pose threats to compliance with the fundamental principles. The following are examples of facts and circumstances within the category of self-interest threat that might create risks for a professional accountant or auditor when performing a professional service (International Code of Ethics for Professional Accountants, par. 300.6.A):

- a professional accountant and auditor with a direct financial interest in a client,
- a professional accountant [and auditor] quoting a very low fee to secure a new engagement, and the fee is so low that it may be challenging to perform the professional service according to applicable technical and professional standards at that price,
- a professional accountant and auditor with a close business relationship with a client,
- a professional accountant [and auditor] with access to confidential information that could be used for personal gain,
- a professional accountant [and auditor] discovering a significant error while reviewing the results of a previous professional service performed by a member of the accountant's firm.

Safeguards depend on the facts and circumstances. Examples of actions that, in specific situations, might serve as safeguards to address threats include, among others, disclosing to clients any referral fees or commissions. Arrangements received to recommend services or products that could pose a conflict-of-interest threat (International Code of Ethics for Professional Accountants, par. 300.8)

Generally, holding any financial interest in an audit client (evident when auditing firms sell their services to clients in the free market) may create a conflict of interest. Factors relevant in evaluating the level of a self-interest threat created by holding a financial interest in an audit client include (International Code of Ethics for Professional Accountants 510.3):

- the role of the individual holding the financial interest,
- whether the financial interest is direct or indirect,
- the materiality of the financial interest.

In summary, the analysis above indicates that each client presents a threat. The danger of that threat depends on specific factors. Some are addressed in the Code of Ethics, while others require a statutory auditor to conduct a detailed analysis in the course of their work. Isn't it a paradox that auditing firms need to find their place in the competitive landscape of a free-market economy? The authors emphasize that turnover among auditing firms stems from client demand for their services.

3.3. Case studies

Case studies examine incidents that occurred between 2016 and 2024 within Polish SME entities in the field of auditing. Coauthor was an applicant and later CEO of three small auditing firms (Kancelaria Biegłych Rewidentów KLB Sp. z o.o., KLB Audyt Sp. z o.o., Euroconsult Sp. z o.o.) as well as an advisor to other auditing companies. The following case studies occurred, and due to the threat of breaching the code of ethics, the auditing firms did not sign agreements to provide any auditing services. Perhaps it was an overreaction to potential risk. However, these companies' policies were aimed at avoiding controversial issues that could raise real or perceived suspicions.

Case Study No. 1.

Self-interest was practical: wine, an exclusive breakfast or brunch, and an intangible promise to other business contacts from the current CEO's friends, as well as future agreements with his business partners. The company's CEO aimed to build relationships with contractors.

The statutory auditor who entered the company had the opportunity to join the business network and, in this way, could become a contractor for several upcoming companies.

Case study No. 2

Cross-selling through auditing involved two strategies: requesting audits of companies that provided advisory services and offering advisory services in conjunction with auditing. The aim was to simultaneously engage approximately 30 entities for an audit, focusing on a specific area of expertise. This approach would close the deal by showing the owner that an auditor is helpful, capable of finding solutions, and trustworthy.

Self-interest was substantial from the perspective of a small auditing firm: 30 auditing contracts were signed simultaneously with related companies that shared similar core businesses and a single owner.

The statutory auditor, during their first conversation with the owner, presented the solution they would propose to address the issue under discussion. After the advisory service has been completed, they cannot conduct an audit because of the autocontrol that would occur in each company where the solution would be implemented. In this way, the statutory auditor lost a contract for 30 new companies and provided a solution to a large company free of charge.

Case study No. 3

The third situation concerned conducting an audit at three friendly or well-paying companies. Three parties were interested in a deal in which one specific auditor and one specific company would audit the other specific company.

The first party was the accounting office. The office's owners were known to an auditor. One accounting office employee had previously worked at the auditing firm, and the separation between the former employer and the employee was amicable. Additionally, this accounting office wanted to expand its auditing services and was seeking a „friendly auditor” to collaborate with.

The Second Party was an advisor who also owned another company that needed an audit. His goal was to secure a preferential price for his company's audit in exchange for recommending the first company.

The Third Party was the owner and CEO of a company that needed an audit. His goal was to find a well-educated partner for his businesses and to have his company audited quickly and smoothly. He was willing to pay whatever was necessary, offering prices 20 times the market rate for the company's auditing services. Self-interest was multifaceted, including additional services from the accounting office, advisory services, and remuneration for a specific audit.

4. Discussion

The Code of Ethics and the AOB set out general principles. However, each situation must be handled on a case-by-case basis. There is no single rule or definitive answer, the decision depends on the auditor's professional judgment.

The case study shows that the auditor often prefers to avoid the risk of bias and loss of independence by declining to accept the audit.

To begin, the CEO of each company is responsible for developing the company's growth strategy and identifying business opportunities. All three case studies clearly presented opportunities for an auditing firm from a business perspective. On the other hand, the International Code of Ethics for Professional Accountants (part 340.2) emphasizes that, „...offering or accepting inducements might create a self-interest, familiarity, or intimidation threat to compliance with the fundamental principles, particularly the principles of integrity,

objectivity, and professional behavior”. This means that inducements can lead to breaches of the core principles of the external auditor’s profession.

Furthermore, even hospitality, which might be seen as inappropriate, must be regarded as a potential threat to the external auditor (International Code of Ethics for Professional Accountants, par. 250.11 A3). The authors contend that there are no clear, unquestionable rules for deciding which hospitality is appropriate and which is not. It is one of many paradoxes that hospitality, an act of goodwill intended to promote fruitful business cooperation, can be perceived by the service recipient as a threat.

Moreover, this is not the end of the story, as there is concern that a kind gesture could be perceived as problematic. Even if an auditor considers hospitality appropriate, they should remember that others might not view it as a sign of goodwill. The International Code of Ethics for Professional Accountants (par. 340, par. 11 A3) emphasizes that “[...] Examples of circumstances where offering or accepting such an inducement might create threats even if the professional accountant has concluded there is no actual or perceived intent to influence behavior improperly include:

- “self-interest threats when a professional accountant [and auditor] is offered hospitality from the prospective acquirer of a client while providing corporate finance services to the client,
- familiarity threats when a professional accountant [and auditor] regularly takes an existing or prospective client to sporting events,
- intimidation threats when a professional accountant [and auditor] accepts hospitality from a client, the nature of which could be perceived to be inappropriate were it to be publicly disclosed”.

Negotiation processes involve managing a business in a market economy without subsidies, reimbursements, or help in securing orders. However, there is a requirement to pay fees to the professional self-governing body, which compels auditing firms to generate income and negotiate terms that allow the economic entity to remain viable.

The International Code of Ethics for Professional Accountants (par. 330.2) states that „[...] the level and nature of fee and other remuneration arrangements might create a self-interest threat to compliance with one or more of the fundamental principles”. Furthermore, negotiation should not be regarded as a standard or routine procedure (par. 410.4 A). „When fees are negotiated with and paid by an audit client, this creates a self-interest threat and might create an intimidation threat to independence”.

Fees are among the most important incentives, clearly influencing behavior that might otherwise seem confusing or call into question the auditor’s trustworthiness. On the other hand, service fees are usually the company’s only source of income. They impact not only the maintenance but also the growth and development of the auditing firm.

According to the code of ethics, audit firms exist not to generate profit but to ensure the accuracy of companies' accounting practices in accordance with applicable business laws. Audit firms are required to serve as corporate oversight bodies, employing certified auditors as individuals of public trust while providing services based on market-economy principles. This clearly does not constitute an argument for auditing firms to generate revenue. However, it causes significant disruption to the potential flow of funds into the company, of which the authors highlight three dimensions.

First, potential referral fees or commissions that violate the code of ethics are unethical. On the other hand, in the expertise market, they are considered compensation for the absence of a sales department. Examples of unacceptable remuneration are the following (International Code of Ethics for Professional Accountants, 330.5.A1):

- a fee paid to another professional accountant to obtain new client work when the client continues as a client of the existing accountant but requires specialist services not offered by that accountant,
- a fee received for referring a continuing client to another professional accountant or other expert where the existing accountant does not provide the specific professional service required by the client,
- a commission received from a third party (for example, a software vendor) in connection with the sale of goods or services to a client.

Secondly, the next hindrance is earning too much from a single client or a network of associated clients, which may influence the behavior of the auditing firm and the auditor, who may feel they are not independent and objective and strive for positive results regardless of the actual situation. „The level of the self-interest threat might be impacted when a large proportion of fees charged by the firm or network firms to an audit client is generated by providing services other than audit to the client, due to concerns about the potential loss of either the audit engagement or other services. Such circumstances might also create an intimidation threat...” (International Code of Ethics for Professional Accountants, par. 410.11 A1; 410.14 A1). In business, building a network linked to good service performance is a natural result. Otherwise, service providers must constantly seek new clients. The code of ethics does not assist auditors. Instead, it requires them to conduct audits to the highest standards while simultaneously limiting opportunities for cooperation, which is essential for business growth.

Lastly, other types of remuneration could be considered additional fees, thus posing a threat to the auditing firm. The question arises: could positive word-of-mouth within the business network, or a simple lunch, be considered additional compensation? How should an unintentional recommendation to another entrepreneur be evaluated? It might be more valuable than any marketing campaign for another company.

From a business perspective, the consequences of this attitude are the loss of opportunities that depend on luck. It means missing opportunities to grow, earn significant income, and expand a professional network. The Code of Ethics not only identifies threats such as intimidation, self-interest, and family pressures but also addresses various forms of remuneration (International Code of Ethics for Professional Accountants, par. 905.2; par. 906.2).

In summary, higher earnings for auditors can be achieved only by acquiring more clients and offering more services, which may compromise the due diligence required for audit duties. This issue should be addressed promptly through legal amendments, code updates to reflect current market conditions, or the establishment of a price range for auditors' services. Such measures ensure rates are neither undervalued nor overvalued, thus eliminating bias or self-interest.

5. Conclusions

The growing disconnect between regulations that demand very cautious practices and auditors' need to operate freely in the market creates the paradoxes discussed in the article. The authors highlight that maintaining the current situation will further distort the market. Auditors might form large entities that offer a sense of security, thereby creating an oligopoly, or they may continue to exit the profession. From a scientific perspective, this situation should be monitored and analyzed to identify its root causes and develop solutions that promote effective market regulation.

The case study method also has a practical side. The analysis results can be applied directly in auditing work and professional training. The situations described help foster ethical thinking, improve professional skills, and raise awareness of threats to auditor independence in a business setting. The case study examined three ethical conflicts related to a threat to independence. The analyzed cases, when compared with ethical principles and legal standards, confirmed auditors' cautious approach to ethical dilemmas, leading them to refuse to provide an audit to the client. This decision aligned with the principles. However, it did not result in company growth or client acquisition. None of the situations is clear-cut, and each owner, with their own management style, might make a different decision, which could affect service quality, reputation, or profits. This is an important lesson for statutory auditors who manage an audit firm as private entrepreneurs. The authors believe this research will help researchers by suggesting future study directions, assist practitioners by offering insights and potential solutions, and benefit students by presenting practical examples.

In the age of new technologies, further research should explore different aspects of independence and professional judgment, as well as other principles less common in the literature, such as professional secrecy and relevant skills. Auditors need practical guidance on ethical dilemmas. Additionally, future studies could be strengthened by using quantitative methods, such as surveys. Researchers should also consider comparing the two perspectives on the ethical aspects of current technological changes between small audit companies and the Big Four.

A limitation of the study is its qualitative nature and the small number of cases, which prevent generalization to the entire population of auditors. It also presents only situations related to statutory auditors' self-interest in Poland with respect to the principles of independence. However, an in-depth description of real professional situations offers a better understanding of the mechanisms of ethical decision-making in the Polish audit market and suggests directions for further quantitative research.

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READINESS OF POLISH COMPANIES TO IMPLEMENT AI

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Purpose: The aim of this study is to identify the extent to which Polish enterprises are ready to implement artificial intelligence (AI) technologies and to examine whether this readiness is related to the firms' ability to unlearn outdated routines, beliefs, and practices. The study also investigates the mediating role of inter-organizational cooperation in the relationship between organizational unlearning and AI readiness.

Design/methodology/approach: Based on empirical data collected from 371 companies operating in Poland, we conducted quantitative analyses of the relationships between organizational unlearning, inter-organizational cooperation, and AI readiness. To determine the strength and direction of the analyzed relationships, we employed correlation analyses, exploratory factor analysis (EFA), multiple regression analysis, variance inflation factor (VIF) diagnostics, and structural equation modeling (SEM).

Findings: Organizational unlearning has a significant positive impact on AI readiness, which is positively correlated with interorganizational collaboration. The ability to unlearn at the organizational level fosters the development of interorganizational cooperation. The research model indicates a synergistic effect.

Research limitations/implications: Rapid technological change may limit the long-term validity of findings. Future longitudinal and mixed-method studies are recommended to capture the evolving dynamics of AI readiness.

Practical implications: The study provides insights for managers seeking to enhance their organization's readiness for AI implementation. It emphasizes the importance of fostering an organizational culture that supports unlearning, collaboration, and experimentation. Encouraging cross-organizational partnerships and promoting reflective practices can accelerate the effective integration of AI solutions into business operations.

Originality/value: This study expands research on AI adoption by linking organizational unlearning and inter-organizational collaboration with AI readiness. It offers empirical evidence from Polish enterprises, highlighting how these capabilities strengthen organizations' ability to implement AI effectively.

Keywords: Artificial intelligence, organizational unlearning, inter-organizational cooperation, AI readiness.

Category of the paper: Research paper.

1. Introduction

In November 2022, ChatGPT was made available for public use, and since then there has been a surge of interest in artificial intelligence. Within three years, many companies have developed their own AI models. With the development of technology, artificial intelligence has been redefined (Masley et al., 2025). The definition of an artificial intelligence system, updated in 2023 by the OECD, emphasizes that it is a machine-based system that infers (for explicit or implicit purposes) how to generate results based on the input data it receives. The results are predictions, content, recommendations or decisions that can affect virtual or physical environments. AI systems differ in their levels of autonomy, input data sources and adaptability after implementation (OECD, 2024). The use of artificial intelligence in an organization's activities is becoming one of the key conditions for organizational development, as well as for building and maintaining competitive advantage. Artificial intelligence can support decision-making processes, increase operational efficiency, and enable the creation of new business models (Dwivedi et al., 2021). AI and universal access to it are transformative in nature – its capabilities allow for increased productivity and efficiency, enable the optimization of resource management, including environmental and social resources, and improve the quality of services in sectors such as healthcare and education (Turyasingura et al., 2024). However, it is worth emphasizing that simply possessing the technology does not guarantee success, and the prerequisite for effectively exploiting the potential of AI is organizational readiness, understood as the ability of an organization to adapt the technology, integrate it with existing processes, and develop the competencies necessary to use the technology effectively (Alsheibani et al., 2018; Kumar et al., 2024; Rasul et al., 2025).

To summarize the above considerations, contemporary organizations are increasingly faced with the need to redefine their structures and processes in the face of the dynamic development of artificial intelligence technology. Although there is a wealth of literature on digital transformation and innovation, relatively little research focuses on the internal management mechanisms that determine organizational readiness to implement AI. In particular, the impact of organizational unlearning and inter-organizational cooperation on the ability of enterprises to adapt artificial intelligence technology remains insufficiently recognized, which constitutes a significant research gap (Fitjar, Rodríguez-Pose, 2013; Lee, Choi, 2003; Zhang, Lyu, Zhu, 2022).

The aim of this article is therefore to examine how organizational unlearning and inter-organizational cooperation influence the readiness of Polish enterprises to implement artificial intelligence (AI) technologies. The study assumes that inter-organizational cooperation acts as a mediator in the relationship between unlearning processes and organizational readiness. Based on empirical data collected in 2024 from companies operating in Poland, an analysis of the relationship between three key constructs was conducted: organizational unlearning, inter-

organizational cooperation and readiness to implement AI. The structure of the article consists of three main parts. The first part presents the latest state of knowledge on artificial intelligence, with particular emphasis on the readiness of Polish companies to implement it, and discusses the theoretical foundations of the three constructs analyzed: organizational unlearning, inter-organizational cooperation and readiness to implement AI. The second part presents the empirical research methodology, including the characteristics of the research sample, the measurement tools used, and the analytical procedures. The third part presents the results of statistical analyses along with their discussion. The article concludes with a discussion of the theoretical and practical implications, the limitations of the study, and suggestions for further research.

2. Organizational unlearning and interorganizational collaboration as determinants of AI readiness

The implementation of artificial intelligence reveals that the barrier to change is not always a lack of knowledge, but rather an excess of outdated knowledge deeply rooted in organizational routines and structures (Pardo del Val, Martinez Fuentes, 2003). The response to this challenge is organizational unlearning, most often understood as the process of consciously rejecting outdated beliefs, practices and cognitive patterns that limit an organization's ability to adapt in a changing environment (Becker, 2019; Hislop et al., 2014; Klammer et al., 2025). Classic definitions of this construct emphasize the aspect of deliberately "getting rid of" knowledge, i.e. Hedberg (1981, p. 18) defines unlearning as "the process by which learners reject knowledge", while Nystrom and Starbuck (1984, p. 53) point out that it consists in "discovering inadequacies and rejecting existing ideas". The common denominator is therefore the treatment of unlearning as a process of consciously rejecting knowledge or cognitive patterns that have lost their usefulness.

This phenomenon is associated with creating space within an organization to generate new knowledge and skills (Klammer et al., 2025). Researchers unanimously emphasize that effective unlearning is intentional and process-oriented (Tsang, Zahra, 2008; Hislop et al., 2014; Klammer et al., 2025). This means that simply discontinuing ineffective procedures is not enough but it is necessary to create conditions for critical reflection on existing ways of operating and replacing them with new solutions. In particular, in situations of profound change, such as the rejection of fundamental organizational assumptions, this process requires questioning the existing logic of action, which is a prerequisite for the assimilation of new practices and knowledge patterns (Klammer, Gueldenberg, 2019).

It is particularly important to link the process of unlearning with learning. The relationship between these two concepts is dynamic and synergistic, and unlearning is often a prerequisite for effective, transformative learning (Odor, 2018). It enables the abandonment of outdated cognitive and operational models, which in turn strengthens the organization's ability to acquire new knowledge and develop competencies (Fiol, Lyles, 1985). In this sense, unlearning is the foundation of organizational learning in dynamically changing environments where existing patterns of behavior are becoming obsolete (Tsang, Zahra, 2008).

Companies implementing new technologies, including artificial intelligence, are forced to make changes to their structures, processes and management methods. These changes also extend to the areas of communication and interpersonal relations, requiring organizations to eliminate outdated practices in order to effectively implement innovations and adapt to new conditions (Akgün et al., 2003). Empirical research confirms that companies that are able to systematically review and update their procedures implement technological innovations faster (Kim, Chung, 2017) and respond more effectively to environmental uncertainty (Klammer et al., 2025). The ability to abandon outdated decision-making models, communication structures and operational practices therefore promotes readiness to implement artificial intelligence, as it reduces mental and organizational barriers to new technologies (Klammer et al., 2025).

Flexible adaptation of processes and organizational culture enables companies to implement new technologies more quickly (Nonaka, Takeuchi, 1995). Organizational unlearning, on the other hand, potentially facilitates the implementation of product and process innovations, increasing the ability of companies to assimilate modern technological solutions (Zhang et al., 2021). In this sense, unlearning is one of the key elements of dynamic capabilities (Teece, 2007) that enable organizations to adapt effectively to disruptive technologies such as artificial intelligence.

During the unlearning process, organizations should also consider the value of potential knowledge loss by assessing whether the knowledge in question may still be useful in the future (Becker, 2019). However, it should be emphasized that unlearning does not necessarily mean permanent loss – more often it involves consciously abandoning or giving up certain patterns of behavior that have lost their usefulness (Akgün et al., 2006). In this context, it is crucial to involve employees in the decision-making process, as the need to unlearn often meets with resistance due to habitual practices (Collina, 2025).

Effective unlearning creates conditions conducive to organizational openness, which is essential for cooperation with external partners (Klammer, Gueldenberg, 2019). In this context, inter-organizational cooperation can be a natural extension of learning and unlearning processes, enabling the exchange of knowledge, resources and experience needed to implement artificial intelligence technologies. Inter-organizational cooperation refers to relationships and interactions between different organizations aimed at achieving mutual benefits, such as the exchange of knowledge and resources or the pursuit of common and convergent goals (Fitjar,

Rodriguez-Pose, 2013). Inter-organizational cooperation can take many forms and be classified according to the perspective adopted, e.g. strategy, structure, number of partners or nature of links (Pietruszka-Ortyl, 2017). Partnerships can be formal, such as OpenAI and Microsoft, outsourcing, cooperation with universities, but also informal, such as industry forums or open-source.

Organizations that engage in cooperation with technology companies, universities or research institutes have the opportunity to acquire the necessary competences and tools for effective technological development and successful implementation of artificial intelligence (Zhang, Lyu, Zhu, 2022). Companies that collaborate with research units or technology partners implement new technologies more effectively (Cheserbrough, 2003). This enables organizations to acquire key knowledge resources, thereby reducing implementation costs and errors, and increasing operational flexibility in a rapidly changing environment (Bettiol et al., 2023).

Inter-organizational cooperation in AI projects can also contribute to solving problems with technology integration, adapting to new regulations and data management (Cepa, Schildt, 2019). However, organizational culture, lack of trust, or difficulty in dividing responsibilities may prove to be limitations to cooperation (Campion et al., 2022). Organizations undertaking cooperation must have common goals, which increases their willingness to cooperate. In a rapidly changing environment, organizational cooperation can be crucial in AI implementations.

Organizational unlearning creates an environment conducive to openness to collaboration, as it enables organizations to question their own assumptions and practices and to adopt new perspectives from outside. Research confirms that unlearning increases an organization's ability to collaborate effectively with other organizations (Zhang, Lyu, Zhu, 2022; Cepeda-Carrión et al., 2015). Organizations that are willing to revise their strategies and methods of operation integrate better with their partners, which promotes long-term partnerships and mutual learning. In this context, inter-organizational cooperation plays a key role in building organizational readiness to implement AI. It provides access to expert knowledge, reduces the risks and costs of implementation, and promotes the creation of innovative solutions (Lee, Yang, 2014; Taherdoost, Madanchian, 2023). At the same time, it acts as an intermediary mechanism between unlearning processes and organizational readiness, as openness to cooperation allows for more effective use of acquired knowledge and its transformation into practical applications.

3. Artificial intelligence market and organizational readiness for AI implementation

Since ChatGPT entered widespread use, the artificial intelligence market has been growing rapidly and attracting considerable interest from individual users and the business sector. An analysis of Google trends for 'AI' in Poland shows a clear increase from November 2022 to the present. These clear increases are related to new functionalities of artificial intelligence models, e.g. in April 2023, GPT-3.5 released new versions of the model equipped with the ability to browse the Internet. Looking at global searches, the situation is more stable, characterized by steady growth without any clear peaks (www1). Market growth forecasts are also promising for artificial intelligence. It is estimated that the AI market in the transmission sector will reach \$34.18 billion in 2025 and as much as \$155.05 billion in 2030, giving a CAGR of 35.3% (MarketsandMarkets, 2025). Currently, the most popular AI models include Google Gemini, OpenAI – ChatGPT, Anthropic – Claude, Meta – Llama, Cohere, Mistral, Mistral AI, Huawei, and Baidu. In 2024, as much as 90% of significant artificial intelligence models came from the industrial sector, which is a significant difference compared to 60% in 2023. Most models are created in the United States, ahead of China and Europe. China, in turn, is the leader in scientific publications on artificial intelligence (HAI, 2025).

Recent data from the Digital Economy and Society Index (DESI 2025) indicate substantial cross-country differences in the adoption of artificial intelligence by small and medium-sized enterprises across Europe. While countries such as Denmark, Sweden, and Belgium report AI adoption rates exceeding 20%, the level of AI use among Polish SMEs remains significantly lower, at below 5%. This positioning places Poland among the lowest-ranked EU countries in terms of AI diffusion, highlighting the presence of structural, organizational, and cognitive barriers to AI implementation.

The data presented may indicate doubts about the future of artificial intelligence and controversies related to the rapid and unregulated development of artificial intelligence. The AI Now Institute think tank has published a report highlighting lobbying efforts to limit legal regulations that could be argued to restrict innovation. It points to the negative social consequences of the rapid development of artificial intelligence, such as the exclusion of smaller companies in favour of Big Tech, which has the computing power and capital to dominate the market, potential overinvestment, the development of efficiency at the expense of society, and support for a bipolar world policy (2025). Rapid development also necessitates the creation of a legal framework for data processing and inference, as well as responsible and ethical inference based on knowledge available to artificial intelligence models (MC, 2023). However, this does not change the fact that companies currently leading the way in implementing artificial intelligence in their operations will outperform their competitors by 15%. Thanks to the rapid development of AI, the difference in revenue generation between

leaders and companies skeptical about artificial intelligence in 2026 may be more than double (WEF, 2025). The MIT report counters the data presented, pointing out that 95% of AI pilot projects in companies have failed (ROI equal to or less than 0), indicating a learning gap (MIT, 2025).

However, contemporary research on digital transformation emphasizes that the mere presence of technology is not a sufficient condition for effectively exploiting its potential (Dąbrowska et al., 2022; Hanelt et al., 2021; Holmström, 2022). A key factor enabling organizations to effectively implement AI-based solutions is organizational readiness to implement AI, understood as the complex ability of a company to adapt, integrate and operationally utilize technology within existing structures and processes (Rasul et al., 2025; Kumar et al., 2024). As noted by Alsheibani et al. (2018), this readiness also means the ability of an organization to implement and benefit from broadly understood AI solutions. This readiness encompasses both technical aspects, such as IT infrastructure, data quality and system security, as well as organizational factors, including the digital skills of employees, the flexibility of structures, openness to change and the strategic alignment of technology with the organization's goals and processes (Hradecky et al., 2022; Lai et al., 2025).

The implementation of AI involves many changes in internal and external structures and processes in terms of technology and organization (Liu et al., 2020). The level of an organization's readiness to implement AI is determined by its internal potential, such as resources, competencies and openness to innovation (Jöhnk et al., 2021), but the attitude of external audiences – customer expectations and readiness – is no less important. A PwC report (as of October 2024) shows that over 75% of the companies surveyed have started investing in AI at an early stage, and 55% of customers said they were ready to take advantage of AI support. 83% of individual respondents expect procedures in the public sector to be improved through the use of artificial intelligence, which is a higher value than the support seen by consumers in business. Entrepreneurs point to the greatest added value in process automation and improved prediction quality (PwC, 2024). The TOE (Technology-Organization-Environment) framework emphasizes that human, technological and organizational resources play a key role in the process of adapting artificial intelligence, and that their proper preparation significantly increases the success of implementation (Alsheibani et al., 2018). The use of artificial intelligence for advanced processes requires a range of new skills among employees, as well as unlearning old patterns of behavior (Morandini et al., 2023). The basic competences of the future are considered to be skills from the group of cognitive (cognitive) competences, technical (including digital) competences, competences in the use of information and knowledge, as well as social competences (Santana, Díaz-Fernández, 2023). In connection with the development of the European Green Deal, so-called green competences are also recognized (PPP, 2022). As indicated in the PFR and Google report, universal competences related to the use of artificial intelligence include legal and ethical competences and AI security, critical thinking and the ability to interpret AI results, basic knowledge of artificial intelligence, and change management and leadership (2025).

The development of AI is also changing the structure of employment in companies. Globally, there is a shortage of 4.7 million qualified cybersecurity specialists, who are essential in view of the rapid development of technology (CP, 2025). The situation is similar on the Polish market – readiness for technological change is unsatisfactory, with more than half of the employees surveyed having not undergone any training in cybersecurity in the last 5 years (ESET, 2025). Due to staff shortages and rapid technological change in the field of cybersecurity and artificial intelligence, acquiring knowledge seems to be an elite pursuit. Companies not only report staff shortages, but also skills gaps, noting that these are a bigger problem than the lack of employees (ISC2, 2023). The noticeable shortage of workers and skills may be a barrier to the sector's continued growth (OECD, 2023). Google Gemini is currently testing a business model based on providing technology and skilled personnel to customers by introducing a training cycle for interested parties, where upon completion it not only issues a certificate but also connects employers with its graduates (www2). Faced with a growing shortage of specialists in the field of artificial intelligence, companies are increasingly looking for ways to develop internal skills and build partnerships that support the adaptation of technology. Examples of such activities include initiatives by technology companies, such as Google's training programmers, which not only promote AI-related skills, but also create a network of cooperation between companies and experts. This indicates that successful AI implementations require not only technological infrastructure, but also investment in knowledge, skills and inter-organizational relationships (Butler et al., 2021).

The rapid pace of technological development indicates that access to AI solutions alone is not sufficient for successful implementation. The effectiveness of adaptation is determined not only by technological resources, but above all by an organization's ability to learn and respond flexibly to change. However, despite the growing interest in artificial intelligence, relatively little research focuses on the internal organizational mechanisms that determine the effective implementation of this technology (Wamba-Taguimdje et al., 2020; Dwivedi et al., 2021). Previous work has focused primarily on technological aspects such as IT infrastructure, data quality and employees' digital skills, largely ignoring the importance of organizational factors such as learning, unlearning and collaboration processes (Holmström, 2022). However, it is precisely these factors that may be key determinants of organizational readiness to implement AI, influencing the way in which companies adapt and integrate new technologies into their structures. Among the internal factors conducive to organizational readiness to implement artificial intelligence, particular importance is attached to cognitive and relational processes – the organization's ability to unlearn and inter-organizational cooperation. These determine the extent to which companies are able to reject outdated patterns of behavior and, at the same time, build relationships that enable them to acquire new knowledge.

Despite the rapidly growing body of research on AI implementation, existing studies mostly focus on technological and resource-based determinants of organizational readiness, such as IT infrastructure, data quality, and employees' digital skills. Considerably less attention has

been paid to internal cognitive and relational mechanisms that enable organizations to adapt effectively to new and/or disruptive technologies. In particular, organizational unlearning remains underexplored in the context of AI adoption. Although unlearning is increasingly recognized as a core element of dynamic capabilities, empirical evidence explaining its role in shaping organizational readiness for artificial intelligence implementation is still limited.

At the same time, inter-organizational collaboration is typically examined as an independent driver of innovation, with insufficient consideration of its links to internal learning and unlearning processes. Consequently, little is known about how organizational unlearning fosters openness to inter-organizational collaboration and whether such collaboration acts as a mediating mechanism between unlearning and organizational readiness for AI implementation. Addressing this gap, the study integrates organizational unlearning and inter-organizational collaboration within a theoretical framework, examining their direct and indirect effects on a firm's readiness to implement AI-based solutions.

Based on the literature review and theoretical considerations presented above, the following research hypotheses were formulated:

- H1: There is a positive relationship between organizational unlearning and a company's readiness to implement artificial intelligence-based solutions.
- H2: There is a positive relationship between organizational unlearning and the level of inter-organizational cooperation.
- H3: There is a positive relationship between inter-organizational cooperation and a company's readiness to implement AI solutions.
- H4: Inter-organizational cooperation mediates the relationship between organizational unlearning and a company's readiness to implement AI solutions.

4. Methods

4.1. Sample selection

In order to empirically verify the hypotheses, a quantitative study was conducted using the online survey technique. The data collection process was carried out in the second half of 2024 and was organized by the Research and Development Centre of the University of Economics in Katowice. The research sample was drawn from a database of over 10,000 records containing contact details of domestic and foreign enterprises operating in Polish. 6201 invitations to participate in the survey were sent to randomly selected entities, sending them to representatives of enterprises by electronic and telephone means. After obtaining consent to participate in the study, respondents received an individual link to an online questionnaire. In the end, 371 completely completed surveys were collected, which corresponds to a return rate of about 6%. The respondents were managers of the surveyed companies or persons appointed by them with knowledge of the functioning of the organization.

The survey included companies with a diverse profile of activity and market coverage. The largest group were companies operating on the domestic market (178 units) and entities of a manufacturing nature (162). The structure of the sample also varied in terms of employment size – from micro-enterprises with 3 employees to large organizations employing more than 5000 people. The age of the analyzed companies ranged from 3 to 90 years, which allowed the study to include both young and mature organizations. The average number of employees in the surveyed enterprises was 194, while the average age of the companies was 22.8 years. Detailed characteristics of the sample are presented in Table 1.

Table 1.
Characteristics of the surveyed enterprises

Scope of activity		Business profile	
Local	49	Trade	38
Regional	55	Service	82
National	178	Production	162
International	82	Mixed	89
Global	7	No response	0
Together	371	Together	371
Characteristics by size and age of the company		Size of the surveyed companies (number of employees)	Age of the subjects studied (years)
Average		194	22.8
Standard deviation		548	13.3
Median		50	22
Minimum		3	3
Maximum		5034	90

Source: own elaboration.

4.2. Characteristics of the studied variables

The questionnaire used in the survey was constructed on the basis of measurement tools recognized in the literature and covered three main areas of analysis: organizational unlearning, readiness to implement artificial intelligence (AI) and the level of interorganizational cooperation. These variables are directly related to the research model and allow for empirical verification of the accepted hypotheses.

With regard to organizational unlearning, a six-item scale developed by Lyu, Yang, Zhang, Teo, and Guo (2020) was used. This scale refers to an organization's ability to abandon outdated practices, beliefs, and procedures that hinder adaptation to technological and organizational changes. The obtained Cronbach alpha reliability coefficient ($\alpha = 0.890$) confirms the high internal consistency of the scale. The results of exploratory factor analysis ($KMO = 0.889$; $\chi^2 = 1138.8$; $df = 15$; $p < 0.001$) indicate an unambiguous one-factor structure, explaining 64.9% of the variance.

The measurement of AI readiness was based on the eight-item scale proposed by Holmström (2022). This tool takes into account both the technological aspect (the current use of AI solutions) and the strategic aspect (the existence of an AI policy or plan in the enterprise). Cronbach's high alpha coefficient ($\alpha = 0.981$) and KMO test results = 0.948 ($\chi^2 = 4696.7$;

$df = 28$; $p < 0.001$) confirm the internal consistency and validity of the construct, which explains 88.2% of the total variance.

To assess the level of inter-organizational cooperation, a five-item scale developed by Lee and Yang (2014) was used. This scale refers to a company's relationship with its key stakeholders – customers, suppliers, competitors and research institutions – and includes areas of interaction in marketing, technology and innovation. The obtained Cronbach alpha coefficient ($\alpha = 0.857$) and KMO values = 0.803 ($\chi^2 = 914.5$; $df = 10$; $p < 0.001$) confirm the homogeneity of the construct and a high level of reliability.

All the scales used were evaluated in terms of reliability and statistical accuracy. The values of Cronbach's alpha coefficients exceed the recommended threshold of 0.7, which indicates their high internal consistency. Univariate solutions in exploratory analyses (EFAs) prove that each of the variables under study refers to a homogeneous theoretical concept, which justifies the creation of synthetic indicators in further analyses. The high values of the Kaiser-Meyer-Olkin measure and the important results of the Bartlett sphericity test confirm the correctness of the adopted measurement model and the accuracy of factor analyses. Taking into account the possibility of collinearity between the analysed variables, the variance inflation coefficient (VIF) was verified. For this purpose, a regression model was built, in which the dependent variable was the readiness to implement AI, and the explanatory variables were organizational unlearning and interorganizational cooperation. Metavariables created by averaging the values assigned to each of the statements included in each of the measurement scales were used for the analysis. This allowed to obtain synthetic indicators for each theoretical construct. The results of the regression and the collinearity analysis are summarized in Table 2.

Table 2.
Results of regression analysis and collinearity test

Model fit measures								
					General Model Test			
Model	R	R ²	Corrected R ²	Standard error of estimation	F	df1	df2	p
1	0.634	0.402	0.396	0.893	61.6	4	366	<,001
a. Predictors: (constant), Organizational unlearning, Interorganizational cooperation, LOGAGE, LOGSIZE.								
Model		Non-standardized coefficients		Standardized coefficients	t	Sig.	Collinearity statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	Constant	-1.7483	0.4793		-3.647	<,001		
	Organizational unlearning	0.5204	0.0824	0.30132	6.317	<,001	0.718	1.39
	Interorganizational cooperation	0.3557	0.0512	0.34615	6.953	<,001	0.659	1.52
	Lifetime Log 10	-0.0391	0.2987	-0.00636	-0.131	0.896	0.694	1.39
	Log 10 of the number of employees	0.4618	0.1163	0.18861	3.969	<,001	0.723	1.44
Dependent variable: AI readiness								

Source: own elaboration.

The multiple regression analysis showed that the adopted model satisfactorily explains the variability of enterprises to implement AI-based solutions ($R^2 = 0.402$; adjusted $R^2 = 0.396$). This means that about 40% of the variance of this variable can be attributed to the influence of factors included in the model. Organizational unlearning, interorganisational cooperation and enterprise size were statistically significant predictors, while the age of the organisation did not show a significant impact. The obtained values of coefficients of colinearity (VIF in the range of 1.39-1.52) and tolerance (0.65-0.72) confirm that there is no risk of interdependence between variables (Thompson et al., 2017). These results are the basis for further analysis of the relationships between theoretical constructions and verification of the research hypotheses. Based on the results obtained, it was decided to move to the stage of modeling structural equations (SEM), in order to analyze the relationships between the studied constructs in depth.

5. Results

Before modeling the structural equations, a correlation analysis was carried out, the aim of which was to initially assess the direction and strength of the relationship between the variables studied. In preparation for this analysis, arithmetic means and standard deviations for metavariables were calculated, constituting the averaged values of the positions included in individual constructs. The obtained indicators were then used to determine Pearson correlation coefficients, enabling the identification of potential relationships relevant from the point of view of further modeling.

Table 3.

Descriptive statistics and correlations between the studied variables

Correlation matrix						
		1	2	3	4	5
1. Organizational unlearning	r (Pearson's correlation)	—				
	p	—				
2. AI Readiness	r (Pearson's correlation)	0.512***	—			
	p	<,001	—			
3. Interorganizational cooperation	r (Pearson's correlation)	0.530***	0.550***	—		
	p	<,001	<,001	—		
4. Log 10 of organizational age	r (Pearson's correlation)	0.145**	0.243***	0.314***	—	
	p	0.005	<,001	<,001	—	
5. Log 10 number of employees	r (Pearson's correlation)	0.147**	0.315***	0.245***	0.518***	—
	p	0.004	<,001	<,001	<,001	—
Mean	5.59	4.44	7.20	1.28	1.65	5.59
Standard deviation	0.998	1.72	1.68	0.280	0.704	0.998
Note: * $p < .05$, ** $p < .01$, *** $p < .001$.						

Source: own elaboration.

The correlation analysis presented in Table 3 indicates that most of the variables studied are moderately or strongly related to each other, with all relationships being statistically significant. The strongest correlations were recorded between organizational unlearning and interorganizational cooperation ($r = 0.530$; $p < 0.001$) and between readiness to implement AI and interorganizational cooperation ($r = 0.550$; $p < 0.001$). There is also a strong positive correlation between readiness to implement AI and organizational unlearning ($r = 0.512$; $p < 0.001$), which confirms that learning and collaboration processes significantly support the preparation of organizations for the implementation of AI technologies. The control variables in the model were the size of the organization and the period of its existence. Both showed positive, albeit weaker, correlations with AI readiness ($r = 0.315$ and $r = 0.243$; $p < 0.001$), suggesting that older and larger enterprises are slightly better equipped to adopt AI technology. As expected, there is also a significant and relatively strong relationship between the number of employees and the lifetime of the company ($r = 0.518$; $p < 0.001$), which confirms the typical relationship between size and age.

In the next step, an analysis was carried out using structural equation modeling (SEM) in the Jamovi program with the SEMLj extension. In the first step, a measurement model was estimated, consistent with the assumptions of the adopted theoretical model. For each latent variable, convergent relevance indicators such as composite reliability (CR) and average variance extracted (AVE) were calculated. The calculations were made using a prepared spreadsheet in Excel, according to the formulas proposed by Hair et al. (2019). The values of the AVE and CR coefficients for all tested constructs exceeded the recommended thresholds (0.50 for AVE and 0.70 for CR, respectively), which confirms the convergent accuracy and reliability of the measurement. These results form the basis for further analysis of the structural model, aimed at verifying the relationships between variables.

Table 4.
AVE and CR coefficients for the analyzed constructs

Variable	Coefficient	Value
Unlearning	AVE	0,57939567
	CR	0,89193902
AI Readiness	AVE	0,86802688
	CR	0,98134754
Interorganizational cooperation	AVE	0,5386444
	CR	0,84932881

Source: own elaboration.

Due to the moderate sample size ($N = 371$), the estimation process uses the bootstrap procedure, which allows multiple randomization of subsamples from the original data set. The analysis used 5000 replications, which increased the stability and reliability of the obtained estimates. The three main variables - organizational unlearning, interorganizational collaboration, and AI readiness - were treated as latent constructs to better reflect their complex nature and the interconnectedness between them. The control variables, i.e. the age and size of

the company, were transformed logarithmically ($\log_{10}$), which improved their distribution and statistical properties, as well as enabled a more precise interpretation of the effects in the structural model. In order to synthetically represent the relationships, tabular analysis (Table 5) was used – for each hypothesis and the relationship described in it, a model parameter (parameter and value of the p statistic) was indicated.

Table 5.
Hypothesis testing results

Relation (hypothesis)	Estymata (b)	The p-value	Hypothesis verification
Organizational unlearning → AI readiness (H1)	0,552	$p < 0,001$	Confirmed
Interorganizational collaboration → AI readiness (H2)	0,434	$p < 0,001$	Confirmed
Organizational unlearning → Interorganizational cooperation (H3)	0,586	$p < 0,001$	Confirmed
Organizational unlearning → Interorganizational collaboration → AI readiness (Mediation) (H4)	0,457	$p < 0,001$	Partially confirmed

Source: own elaboration.

Based on the results presented in Table 5, the following conclusions can be drawn. Hypothesis H1, assuming a positive relationship between organizational unlearning and readiness to implement artificial intelligence technologies, was confirmed ($b = 0.552$; $p < 0.001$). Hypothesis H2, advancing a positive effect of interorganizational cooperation on readiness to implement AI, was confirmed ($b = 0.434$; $p < 0.001$). Hypothesis H3, assuming a positive relationship between organizational unlearning and interorganizational cooperation, was confirmed ($b = 0.586$; $p < 0.001$). The conducted analysis also confirmed the significance of the indirect effect of interorganizational cooperation in the relationship between organizational unlearning and readiness to implement artificial intelligence technologies. According to the approach proposed by Baron and Kenny (1986) and further developed by Hayes (2017), the significance of both the indirect and direct effects indicates the presence of partial mediation. In this model, the estimated value for the indirect path ($b = 0.457$; $p < 0.001$) confirms that inter-organizational cooperation acts as a mediating factor that strengthens the influence of unlearning processes on organizational readiness. At the same time, the direct effect remains statistically significant ($b = 0.552$; $p < 0.001$), indicating that organizational unlearning affects the readiness to implement AI both directly and indirectly - through increased interorganizational cooperation. Following the typology proposed by Zhao, Lynch, and Chen (2010), this configuration corresponds to complementary mediation, as both the direct and indirect effects are significant and point in the same positive direction. Importantly, the authors emphasize that no minimum difference between coefficients is required for mediation to be established; what matters is the statistical significance and consistency of the effects.

6. Discussion and directions for further research

In light of the results obtained, the implementation of artificial intelligence appears to be a multidimensional process, involving not only the development of technological infrastructure, but also cognitive, social and organizational adaptation. The confirmation of a positive relationship between organizational unlearning and readiness to implement AI indicates that the ability to reflectively abandon established patterns of behavior is a key condition for strategic technological adaptation. This result is consistent with the findings of Zhao and Yan (2023), Maccioni and Ghiringhelli (2022), and Yin and Hoang (2025), who emphasize that unlearning processes foster innovation by reducing cognitive organizational baggage and increasing knowledge absorptiveness. In the context of AI implementations, unlearning enables not only the acquisition of new tools, but also the redefinition of how technology is thought about – from the perspective of a threat to a strategic resource. However, it should be noted that excessive cognitive and structural change can lead to organizational overload and increased anxiety among employees, which, as Besio et al. (2024) point out, can limit the effectiveness of digital transformation.

The relationship between unlearning and inter-organizational cooperation confirms that a willingness to question existing internal practices increases an organization's openness to exchanging knowledge and experience with external partners. This result is consistent with the findings of Zhang, Lyu and Zhu (2022), who showed that unlearning processes are a prerequisite for effective inter-organizational learning, enabling the transfer and integration of knowledge within cooperation networks. Interpreting this in the light of Chesbrough's (2003) concept of open innovation, it can be concluded that unlearning promotes the crossing of organizational boundaries and the creation of space for experimentation and co-creation of solutions (Antonacopoulou, 2009). This means that companies that systematically review their procedures and cognitive models are more likely to engage in technology partnerships, research consortia or innovation networks (Rossoni et al., 2024). This type of cooperation is not only a channel for knowledge transfer, but also a mechanism for building trust and adaptive capacities that increase an organization's resilience to environmental turbulence (Kupers, Mullie, 2014).

The role of inter-organizational cooperation as a mediator in the relationship between unlearning and readiness to implement artificial intelligence emphasizes the importance of social relations in the process of technological adaptation. The results suggest that the ability to abandon outdated cognitive patterns is not sufficient on its own – only when combined with the active exchange of knowledge and resources between organizations does it lead to a real increase in technological readiness. This result builds on the findings of Lee and Yang (2014), indicating that cooperation networks are not only a source of knowledge, but also a mechanism supporting the absorption and implementation of AI solutions. In this sense, collaboration acts

as a catalyst for unlearning processes, enabling the testing of new concepts in a low-risk environment, strengthening the ability to experiment, and accelerating learning through observation of partners' practices (Kim, Park, 2022). From a strategic management perspective, this means that building inter-organizational networks of trust and learning can be a key condition for the effective digital transformation of enterprises.

From a management theory perspective, the results confirm that readiness to implement artificial intelligence can be interpreted as a manifestation of dynamic organizational capabilities – the ability to learn, unlearn and reconfigure resources in conditions of uncertainty (Holmström, 2022; Teece, 2070). Organizations that actively engage in unlearning and collaboration develop greater cognitive and structural flexibility, enabling them to respond more quickly to technological change and transform knowledge into operational advantage more effectively. In this view, readiness to implement AI is not only a result of technological resources, but also the effect of consciously shaping mechanisms of learning, reflection and adaptation. This means that an organization's ability to derive lasting benefits from AI depends not only on investment in technology, but above all on the ability to combine the cognitive (unlearning) and relational (collaboration) dimensions into a coherent development strategy (Uren, Edwards, 2023).

From a managerial perspective, the findings suggest that strengthening AI readiness requires not only technological investment but also organizational transformation. Managers should focus on fostering a culture of unlearning, for example encouraging employees to question outdated practices, reflect critically, and embrace experimentation. At the same time, establishing interorganizational partnerships with technology firms, research institutions, and industry associations can accelerate knowledge transfer and reduce the risks associated with AI implementation. In the Polish business context, building soft competencies such as openness, adaptability, and collaborative leadership appears crucial for aligning technological and organizational readiness. These actions jointly enhance firms' ability to absorb AI-driven innovations and translate them into sustained competitive advantage.

Summary

Artificial intelligence remains an evolving technology whose long-term societal and economic impact will only become fully evident over time. The findings of this study highlight that the diffusion of AI requires not only technological advancement but also social learning processes within and between organizations. Building readiness for AI adoption involves developing new competencies while intentionally unlearning outdated routines and mental models. These changes have a broader social dimension, as they foster more inclusive and

knowledge-based ecosystems of collaboration. Strengthening interorganizational cooperation contributes to reducing skill gaps and promoting responsible, human-centered AI adoption

At the same time, it is worth to notice that the conducted research has certain limitations, such as: the cross-sectional research design and the reliance on quantitative data, which restrict the ability to capture the dynamic and processual nature of organizational unlearning and collaboration. In addition, the findings reflect the specific institutional and cultural context of organizations operating in Poland, which should be considered when assessing their applicability in other settings. Despite these limitations, this study contributes new knowledge by demonstrating that organizational unlearning and interorganizational cooperation jointly shape readiness for AI implementation, thereby extending existing research that has predominantly emphasized technological and infrastructural factors.

The insights generated by this study can be used by managers and policymakers to design AI implementation strategies that explicitly combine internal unlearning mechanisms with external collaboration initiatives, as well as by researchers to develop more integrative models of organizational readiness for emerging technologies, including AI.

The results of this study open several promising avenues for further exploration. First, the relationship between organizational unlearning and AI readiness may unfold over time, suggesting the need for longitudinal studies capturing the dynamic nature of learning and adaptation processes. Second, future research could incorporate qualitative approaches to better understand the cognitive, cultural, and structural barriers that shape organizations' readiness for AI. Another valuable direction would involve examining moderating factors such as leadership style and organizational culture, which may strengthen or weaken the links between unlearning, collaboration, and technological readiness. Finally, inspired by recent findings on the reciprocal influence between AI adoption and unlearning (Yin, Hoang, 2025), it would be worthwhile to investigate whether the implementation of AI itself stimulates new cycles of organizational unlearning and knowledge renewal.

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THE PRACTICE OF STRATEGIC ALLIANCES: PROCESSES, PEOPLE, AND PERFORMANCE FEEDBACK

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Purpose: This paper analyses strategic alliance management practices in small and medium-sized enterprises (SMEs) in Poland, focusing on organisational roles, monitoring tools, stages of cooperation development, and mechanisms used to align partners' goals and strategies in resource-constrained environments.

Design/methodology/approach: The study adopts a qualitative research design based on semi-structured interviews conducted in 2024 with representatives of ten Polish SMEs involved in strategic alliances within an international Erasmus+ project. This approach enables an in-depth examination of alliance management processes, organisational arrangements, and competence development practices, grounded in the literature on alliance management and inter-organisational cooperation.

Findings: The results show that 90% of the surveyed SMEs do not employ a dedicated Alliance Manager, with alliance coordination handled on an ad hoc basis by owners or senior managers. Competence development related to alliance management is largely reactive, while monitoring relies mainly on informal assessments rather than structured tools. Most alliances remain at the stage of formalising cooperation frameworks and do not progress to joint investments. Goal alignment between partners is partial and usually limited to selected initiatives rather than fully integrated strategic alignment. Based on these findings, the paper proposes recommendations including the professionalisation of alliance management roles, more systematic competence development, standardisation of monitoring practices, deeper formalisation of cooperation, and the introduction of structured knowledge management mechanisms.

Research limitations/implications: The qualitative nature of the study and the small sample size limit the generalisability of the findings. Future research could expand the analysis to larger and more diverse samples of SMEs.

Practical implications: The findings highlight key organisational gaps in alliance management and suggest that even in resource-constrained SMEs, introducing formal coordination roles, monitoring mechanisms, and knowledge management practices may enhance alliance effectiveness.

Originality/value: The paper provides original empirical evidence on alliance management practices in Polish SMEs, revealing the gap between theoretical models and everyday managerial practice.

Keywords: strategic alliances; small and medium-sized enterprises; Alliance Manager; cooperation monitoring; knowledge management; Poland.

Category of the paper: Research paper.

1. Introduction

In today's network economy, strategic alliances play a key role as a flexible and effective mechanism for achieving synergies between organisations (Gulati, 1998). In fact, Michael Porter and Fuller (1986) already recognised their potential in strengthening competitive advantage through cooperation rather than competition. Emanuela Todeva and David Knoke (2005) define strategic alliances as formalised, inter-organisational structures based on cooperation that enable goals to be achieved more effectively than through independent action (Todeva, Knoke, 2005). In this context, the article analyses the key components of effective alliance management, focusing on three areas:

1. People and roles – who are the creators and implementers of alliances, what organisational structures support their activities, and whether there are specialised resources (Alliance Managers).
2. Processes and phases of cooperation – how the stages of creating and maintaining alliances proceed, what tools and technologies support the monitoring of their effectiveness, and how information and feedback are exchanged after the cooperation ends.
3. Results and communication – what internal communication and knowledge management mechanisms contribute to the sustainability and effectiveness of partnerships, and how companies adapt their activities in a dynamic business environment.

The analysis of these processes and practices provides a basis for formulating recommendations for practitioners, showing that effective communication, monitoring of cooperation results and an adaptive approach to alliance management play a key role in building long-lasting, trust-based and effective business relationships.

To deepen the knowledge on how strategic alliances are managed in Polish small and medium-sized enterprises, an analysis of key aspects related to strategic alliance management was conducted. The study focuses on defining the roles and responsibilities of those involved in the alliance management process, identifying the tools used to monitor the effectiveness of cooperation, and learning about methods for aligning goals and strategies between partners. This objective is achieved by seeking answers to the following research questions:

1. Who in the organisation is responsible for initiating and implementing strategic alliances?
2. Does the organisation provide training and activities to improve the qualifications of alliance managers?
3. At what stage of the process is the strategic alliance created by the organisation?
4. How do companies approach the alignment of goals and strategies within the alliance?
5. What tools and technologies support the process of evaluating and monitoring strategic alliances?

The answers to the research questions were obtained on the basis of research conducted in 2024 in small and medium-sized enterprises in Poland, Spain, Romania, Italy and Lithuania, using the method of personal interviews. Due to the extensive empirical material, this article presents only the results concerning enterprises operating in Poland. The study is part of a broader project entitled "Sustainable Alliance Manager: Educational Experience Towards Cooperation Skills with Environmental Awareness", implemented with the support of the European Union under the Erasmus+ programme (Grant Agreement for the Erasmus+ Programme 2023-1-ES01-KA220-HED-000157968).

2. Literature review

In literature, alliances are seen as interorganisational relationships that go through a recognisable life cycle: initiation and formation, design and contracting, implementation and post-formation management, and evaluation, followed by possible recombination or termination (Das, Teng, 2000; Spekman, Isabella, MacAvoy, 2000). In a classic process approach, Ring and Van de Vena (1994) describe repetitive loops of negotiation–commitment–performance, in which partners adjust both formal agreements and informal rules of interaction, gradually building trust and reducing uncertainty.

Doz (1996) showed that the effectiveness of alliances depends on multidimensional learning – about the environment, the task, the processes, the competencies and the goals – which modifies the initial assumptions and coordination mechanisms in the course of cooperation. Synthesis reviews emphasise that the choice of governance form (e.g. joint venture vs. contracts), the division of decision-making rights and control mechanisms should be consistent with the level of uncertainty, the risk of opportunism and the degree of resource complementarity (Gulati, 1998; Todeva, Knoke, 2005). More recent approaches focus on the post-formation phase, where coordination routines, performance measurement systems and trust-building practices are crucial, as they determine the actual transfer of value and the durability of the relationship (Kale, Dyer, Singh, 2002).

The approach is complemented by an evolutionary perspective, in which alliances can be treated as dynamic strategic games based on adaptation and selection of strategies over time. Evolutionary game theory models, used, among others, by Wajzer and Cukier-Syguła (2019), provide a paradigm that deepens the understanding of cooperation mechanisms. The authors analyse two 2×2 models: single-population and two-population, based on structures such as Stag Hunt (a game involving deer) and Chicken (a game involving roosters), using replicator dynamics and phase diagrams. Their findings show that the stability of cooperation depends on the initial distribution of strategies and the "fields of attraction" between cooperation and defection – similarly to strategic alliances, where it depends on whether partners decide to act together in the long term, even at the expense of short-term unilateral gains.

From this perspective, strategic choices made during the alliance formation phase – including decisions on formalisation and governance structure – determine the partners' subsequent ability to learn, adapt and strengthen their relationship. The evolutionary approach emphasises that cooperation can be sustained but is vulnerable to disruption if trust-enhancing mechanisms are lacking. In this context, the Alliance Manager emerges as a situational strategist responsible for building a "cooperative ecosystem" and ensuring that cooperation is maintained in a stable cooperation zone. As in evolutionary game models, communication tools, formalisation of goals and systematic monitoring can shift the alliance towards sustainable cooperation strategies, even under pressure to pursue individual interests.

As relationships evolve, the importance of the specialised role of the Alliance Manager, acting as a boundary spanner between organisations, grows. The key tasks of this role include: (1) translating strategic goals into operational mechanisms (governance, indicators, coordination rituals) (Kale, Singh, 2009), (2) managing risk and trust – including, among other things, escalating disputes and calibrating control and partnership (Dyer, Kale, Singh, 2001), (3) orchestrating knowledge exchange and embedding good practices in the form of organisational routines (Zollo, Reuer, Singh, 2002) and (4) monitoring results and initiating course corrections (Heimeriks, Duysters, 2007).

Research on alliance capability shows that organisations that accumulate experience from multiple alliances, build post-formation procedures and a dedicated alliance function achieve higher results thanks to better partner selection, more efficient coordination and faster learning (Heimeriks, Duysters, 2007). At the micro-process level, effectiveness is supported by inter-organisational routines such as shared KPIs, project reviews or knowledge forums, which stabilise cooperation and reduce transaction costs (Zollo, Reuer, Singh, 2002).

Finally, the relational view argues that advantages can arise across firm boundaries when the Alliance Manager actively develops relationship-specific assets, knowledge-sharing routines, and resource complementarity, with adequate governance and control (Dyer, Singh, 1998; Gulati, 1998). In practice, many organisations institutionalise this function by creating alliance departments or offices, which allows them to standardise processes, train staff and accumulate know-how (Dyer, Kale, Singh, 2001).

3. Methods

The aim of this article is to examine strategic alliance management practices in organisations, with particular emphasis on the roles and tasks of those responsible for creating and maintaining them, the tools and technologies used to monitor the effectiveness of cooperation, the phases of alliance development, and methods of aligning the goals and strategies of partners. The study also aims to analyse solutions supporting the development of alliance managers' competences and to identify internal communication mechanisms that influence the sustainability and effectiveness of partnerships in the long term.

The research questions analysed in the article focus on key areas determining the success of strategic alliances: from structural conditions in organisations (the role of managers, training processes, formalisation of cooperation phases) to technological tools supporting monitoring and evaluation, and mechanisms for aligning the goals and strategies of partners. The results of the study indicate that effective alliance management requires not only a specific organisational structure, but also effective communication and knowledge exchange processes, both during and after the partnership. An analysis of these aspects allows conclusions to be drawn about practical solutions that can increase the effectiveness of alliances and identify challenges related to their maintenance in a dynamic market environment.

The analysis for the project was conducted in five European countries: Poland, Spain, Romania, Italy and Lithuania.

The research material was based on personal interviews with managers responsible for alliances and company presidents who took on these responsibilities due to their strategic importance and, in some cases, due to limited human resources preventing the creation of dedicated positions. The interviews were semi-structured and were conducted between April and September 2024. The sample structure was as follows:

- 10 small and medium-sized enterprises from Poland,
- 10 from Spain,
- 10 from Romania,
- 10 from Italy,
- 10 from Lithuania.

Due to the extensive empirical material, this article presents only the results concerning Poland.

The sample was selected using *judgmental sampling* or *purposive sampling*, which means that participants were selected based on the researchers' knowledge, experience or recommendations. As emphasised by Frątczak and Mynarska (2007), in this type of research, individuals who best reflect the population under study are selected, and the sample includes entities with specific characteristics. In this case, SMEs that engage in strategic cooperation with other organisations and are involved in green transformation or conduct environmentally friendly activities were invited to participate in the study.

4. Results

One of the key elements of effective strategic alliance management is a clear definition of the roles and responsibilities of those involved in the process of creating and maintaining alliances. The organisational structure in this area has a direct impact on the effectiveness of cooperation, the speed of decision-making and the ability to build long-term relationships. An analysis of the results of a survey conducted among Polish SMEs allows us to assess how the alliance management function is currently performed in practice and whether it is reflected in formal positions within company structures.

As many as 90% of the companies surveyed admit that they do not have a separate Alliance Manager position in their structures (Table 1). Responsibilities related to initiating and conducting partnership cooperation are most often taken over by owners, CEOs or members of the management board. In many companies, these are additional tasks performed alongside daily duties such as logistics, sales or customer service. In small and medium-sized enterprises, this role is usually taken on by members of management, which is a result of limited human and financial resources. However, in larger companies, as in one of the cases analysed, this function is sometimes performed by a director in a more formalised manner. The way alliances are managed depends on the nature of the planned cooperation. For example, in smaller organisations, different departments are involved in the process depending on the needs, e.g. logistics in contacts with suppliers.

In most of the companies surveyed, alliance management is centralised and carried out by top management. Although this solution works well in small organisations, it may limit the possibilities of building more complex partnerships. The lack of a dedicated Alliance Manager position means that cooperation is conducted in a reactive and ad hoc manner, which hinders long-term planning and relationship development. Where the CEO or owners are responsible for alliances, the effectiveness of cooperation largely depends on their personal experience, negotiation skills and strategic vision. In smaller companies, the lack of resources to create such a position result in an informal division of responsibilities, and alliance management becomes less effective and dependent on the availability of those involved in the process.

Table 1.
Organisational structure – alliance manager

Question C1	Response frequency	
A person in the organisation who assumes, in an informal and unstructured way, some of the functions of the Alliance Manager, in addition to their own.	4	40
A person in the organisation dedicates half of their work time to carrying out their usual functions, and the other half assumes the functions of the Alliance Manager, especially the operational part.	5	50
There is a defined role for the Alliance Manager. One person in the organisation dedicates all of their time to carrying out the functions of Alliance Manager, but in managing Alliances, priority is always given to aligning the interests of the alliance parties rather than managing the alliance per se.	0	0

Cont. table 1.

The Alliance Manager role is strategic. The AM works in a more autonomous way focused on the management of the alliance (from an operational and corporate point of view). It also has recognition and trust from the members of the alliance and decision-making capacity. The company can even outsource the Alliance Manager function to an 'Expert'.	1	1
Catfish	1	10

Source: own study.

Another important area of analysis is the development of the competences of those responsible for managing strategic alliances. The effectiveness of inter-organisational cooperation largely depends on the knowledge and skills of the staff, but the way in which training activities are planned and implemented in the surveyed companies reveals significant differences in approaches. The results of the study provide an insight into how companies organise the process of improving qualifications, what mechanisms they use to identify training needs and to what extent these strategies fit into the long-term development goals of the organisation (Table 2).

As many as 67% of respondents admitted that training is mainly carried out in response to the current operational needs of alliances, rather than as part of pre-established development programmes. Employees' skills are developed primarily through professional experience and problem solving in their daily work. Many companies lack specialised training programmes and strategies for improving the qualifications of alliance managers, and training itself is sporadic or non-existent.

For 22% of the companies surveyed, training planning is based on a schedule and requests from employees. In such cases, there is a mechanism for gathering information from various organisational levels in order to match the training topics to project and operational needs. One of the survey participants indicated that his organisation provides training for both operational and corporate managers as part of the company's overall strategy. In many cases, competence development is based on daily practice, which limits access to modern alliance management tools and methods. Sometimes companies offer training in other areas, such as machine operation, software or first aid.

The survey results show that most companies do not have a consistent and long-term training policy for alliance managers, which makes it difficult to build key competencies in this role. Training that responds to immediate needs brings quick results, but a lack of long-term planning can lead to competency gaps. Companies that combine fixed schedules with ongoing responsiveness to needs reported from different levels of the organisation are more effective at developing their employees, including alliance managers. Many organisations fail to exploit the full potential of the training opportunities available on the market, which can undermine the effectiveness of management. In smaller companies, training decisions are usually made by the owner or management, which often results in a focus on strategic priorities at the expense of operational staff development.

Table 2.*Competence development*

Question C3	Response frequency	
People are trained and developed according to the needs that arise derived from the activity of the alliances.	6	6
There is a training and development plan to anticipate the needs that may arise derived from alliance activity.	2	2
The organisation's strategy includes the training of operational and corporate AM.	1	1
The operational and corporate AM takes responsibility (proactive in their learning and development) for their training and development, and ensures that the people in their organisation are sensitised and integrate the alliance perspective into their daily activity.	0	0
Catfish	9	100

Source: own study.

The lack of a well-thought-out training strategy in many companies affects not only the development of alliance managers' competencies, but also the way relationships with business partners are shaped. When skills development is based mainly on experience and ad hoc activities, it is more difficult to implement modern management tools or effectively secure interests in the long term. As a result, the importance of formal cooperation frameworks is growing – from clearly defining the principles of resource use, through precise assignment of responsibilities, to guaranteeing high quality standards. In this context, formalising agreements becomes not only a risk management tool, but also a natural complement to development activities, allowing for better protection of the company's strategic interests.

An important element of effective strategic alliance management is the way in which they are formalised, which affects both the security of cooperation and its long-term stability. An analysis of the research results allows us to understand the extent to which companies decide to create a formal legal framework for partnerships, what factors prompt them to sign agreements, and how the degree of formalisation of relations correlates with the level of resource and investment commitment. The study showed that entrepreneurs recognise the need to formally regulate strategic alliances to clearly define the rules for the use of resources, the distribution of profits and to ensure legal protection in the event of disputes (Table 3). The importance of a solid and transparent legal basis for this form of cooperation was emphasised. Although in some cases partnerships arise spontaneously, based on mutual trust and without written agreements, most respondents indicate that formalisation significantly strengthens the security of interests. Established agreements allow for more effective risk management, more precise definition of the scope of responsibilities of the parties and maintenance of high-quality standards.

Respondents pointed out that signing a formal agreement is particularly important when dealing with new business partners, especially in situations where customers have non-standard requirements.

Although companies value long-term relationships and informal cooperation based on trust, they see formalising contracts as a key tool for defining responsibilities and maintaining high quality of operations.

The data shows that 80% of respondents are in the process of establishing a formal framework for cooperation, without joint investments or costs (e.g. commercial customer-supplier, subcontracting or licensing agreements). Another 10% are in the process of formalisation, including individual investments or expenses coordinated between partners (e.g. co-production, co-promotion, distribution and sales agreements). The remaining 10% are in the formalisation phase with joint investments or costs, without the need to create a new legal entity (e.g. co-production, co-promotion, distribution and sales agreements).

Table 3.

A way to formalise a strategic alliance

Question B2.	Response frequency	
34. formalised collaboration framework, without joint investments or expenses (client-supplier commercial agreement, subcontracting agreement, licence agreement...)	8	80
35. formalised collaboration framework, with individual investments or expenses, coordinated between the participants (co-production agreement, co-promotion agreement, distribution and sales agreement, ...)	1	10
36. formalised collaboration framework that involves joint investments or expenses, without the need to generate a new entity with legal personality (co-production agreement, co-promotion agreement, distribution and sales agreement, ...)	1	10
37. formalised collaboration framework with shared capital and new or updated legal status (shareholding, joint venture, absorption, etc.)	0	0
Catfish	10	10

Source: own study.

Another area of analysis is the alignment of objectives and strategies between partners participating in strategic alliances. Consistency of vision and priorities is the foundation of effective cooperation, but in practice, companies often combine activities aimed at mutual benefits with the pursuit of their own individual ambitions. The results of the study allow us to look at how companies balance the pursuit of synergy with the preservation of autonomy, and how these choices affect the durability and quality of partnerships (Table 4). The analysis of the survey results shows that companies participating in strategic alliances maintain their own priorities and individual goals, and the alliance itself mainly serves as a platform for the exchange of knowledge, experience and information. The effectiveness of such cooperation largely depends on agreeing on common goals and developing a unified vision for development. A consistent organisational culture based on values that promote cooperation, which can significantly increase the effectiveness of partners' activities, also plays an important role.

Although companies undertake joint initiatives to improve quality and increase profitability, their individual ambitions remain crucial. The success of an alliance often depends on the ability to support each other in achieving economic advantage and reducing costs.

Even in the absence of a formally defined alliance management system, a clear sense of common purpose can bring partners together. Converging interests and clearly defined priorities among both staff and business partners foster effective cooperation. Moreover,

practice shows that even without a formal goal-setting process, mutual understanding and support on key issues can lead to the development of lasting and successful partnerships.

Table 4.

Convergence of goals and strategies between partners

Question D1	Response frequency	
Each company has its own objectives and particular interests in relation to the alliance. There is no real intention to integrate objectives or strategies; clearly, they operate separately and the objectives are not shared nor are they expected to be so in the medium term.	4	40
There are certain initiatives that seek to integrate the strategy and objectives of the different companies involved in the alliance, but they are residual, and their implementation is complex.	3	3
There is a perceived cohesion and shared purpose among the managers of the different companies, and there are decisions that confirm this, such as the integration of some groups, shared indicators, etc.	2	2
There is a clear sense of shared purpose between the people of the different companies that make up the alliance, it is perceived that people pursue shared interests and objectives and there is a real interest in integrating groups, plans and even shared measurement indicators.	1	10
Catfish		0

Source: own study.

An important element of effective strategic alliance management is systematic monitoring of their progress and evaluation of the effects of cooperation. It is the control mechanisms, analysis of quality indicators and the use of appropriate tools that determine whether a partnership will be able to maintain its effectiveness in the long term. However, the results of the study show that in practice, many companies approach this issue in an ad hoc and informal manner, which may limit their ability to detect problems early and implement corrective measures (Table 5). Most of the companies surveyed admitted that they do not have clearly defined procedures or specialised tools for monitoring the progress of cooperation after the alliance has been established. The assessment of results is usually based on general outcomes, such as the level of order fulfilment, customer satisfaction or the quality of cooperation. If the results are unsatisfactory, the partnership is not continued.

Many respondents do not use dedicated monitoring systems, assuming that ongoing cooperation is beneficial for both parties. Some companies use simple communication tools, such as WhatsApp, to maintain contact with partners and efficiently exchange daily information. The downside of this approach is the inability to collect structured data that could feed into monitoring systems on a regular basis. However, one company pointed to the need to implement more advanced IT solutions that would support the decision-making process and enable ongoing monitoring of the degree to which objectives are being achieved. Such support could help assess the extent to which alliances contribute to economic growth and improve the company's image.

Respondents use a variety of methods to monitor service quality indicators, including response time, customer satisfaction and delivery timeliness. Some companies cooperate with research units, use technical documentation or advanced computer programmes for detailed process analysis.

However, it is worth noting that Polish companies still lack uniform standards for monitoring and evaluating alliances – an informal approach remains dominant.

Table 5.

Monitoring the course of the alliance and assessing the effects of cooperation

Question B3.	Response frequency	
38. not monitored	5	50
39. individual evaluation; KPIs: Result; Effects: liquidation, maintenance	4	40
40. individual and joint evaluation; KPIs: Result and process, Quality of the relationship, Type of alliance selected; Effects: liquidation, reconversion, maintenance	1	1
Catfish	10	100

Source: own study.

Representatives of the surveyed Polish companies unanimously emphasise that cooperation with business partners promotes the acquisition of new knowledge and the development of employee competences. The experience gained remains within the organisation, forming the foundation for subsequent projects and driving further development. Partnerships also enable the implementation of innovative materials and technologies, which translates into increased operational potential. Managers emphasise the importance of open communication with employees, both through formal and informal channels, so that they are fully aware of the company's strategy and directions of development (Table 6). Such transparency facilitates understanding of the organisational context, increasing team motivation and effectiveness. In practice, however, the approach to knowledge sharing varies – some companies use structured procedures to identify and transfer knowledge gained in projects to other teams or partners, while others base the learning process solely on everyday experience. It also happens that, despite formal processes, the objectives of knowledge sharing are not clearly defined. The lack of systematic analysis of the experience gained means that valuable information remains within a narrow group of project participants, and the entire organisation misses out on the opportunity to use it. In some companies, the effectiveness of cooperation is only evaluated after the project is completed, and the conclusions discussed within the team help to optimise future activities and strengthen relationships with partners. However, some companies limit themselves to sharing only general information, thus protecting strategic data and trade secrets. This approach highlights the challenge facing companies – finding a balance between openness in sharing knowledge and protecting key information and competitive advantage.

Table 6.

Feedback and knowledge acquisition

Question B4.	Response frequency	
Moment: No reflection on what has been learned; Who identifies it: Nobody reflects on what they have learned; Who it is shared with: What has been learned is not shared	1	1
Reflect on what was learned at the end of the collaborative project; The project leader identifies the learnings; Learning is shared within the collaborative project team	3	3

Cont. table 6.

Without defined objectives, we reflect on what was learned during and at the end of the collaborative project; The team participating in the collaborative project identifies the learning; Learning is shared with other teams within the organisation or with the collaborating organisation	5	5
Learning objectives are established before starting the collaboration project and reflection is carried out during and at the end of said process; The inter-organisational team participating in the project identifies the learning; Learning is shared with other teams within the organisation and with the collaborating organisation	1	10
Catfish	1	10

Source: own study.

The data presented in Table 6 confirm significant differences in approaches to reflection on acquired knowledge and its diffusion in the surveyed companies. Although most companies declare that they undertake activities related to the identification and dissemination of experience gained during cooperation, these practices are often informal and not linked to clearly defined learning objectives. Only a few companies implement systematic solutions that include planning knowledge objectives at the project initiation stage and regular reflection during its implementation. These results indicate that the potential of alliances as a source of organisational learning is in many cases only partially exploited, which limits the possibility of sustainable knowledge transfer and its institutionalisation within the organisation.

5. Discussion

The survey results confirm that strategic alliance management in Polish SMEs is largely based on ad hoc solutions, both in terms of roles and procedures. The lack of a dedicated alliance manager in 90% of the surveyed companies indicates that the model in which owners or management are responsible for initiating and coordinating cooperation, often combining these responsibilities with their day-to-day operational tasks, continues to dominate. These conclusions are consistent with the findings presented in the literature, which emphasises that in the SME sector, limited human and financial resources favour centralised management and a low level of specialisation (Das, Teng, 2000; Kale, Singh, 2009).

At the same time, recent research indicates that even in conditions of limited resources, developing Alliance Management Capability promotes the growth of innovation and internationalisation of SMEs, which emphasises the importance of a more formalised approach to roles and competencies in managing inter-organisational cooperation (Al-Tabbaa, Zahoor, 2024).

In the area of competence development for those responsible for alliances, a reactive approach prevails, consisting of organising training in response to current needs. While such activities may bring short-term benefits, they also limit the possibility of long-term and strategic organisational competence building (Gomes, Barnes, Mahmood, 2016). These results confirm the observations of Heimeriks and Duysters (2007), according to whom the lack of a systematic

approach to skills development in SMEs means that the effectiveness of cooperation depends primarily on the individual skills of managers rather than on sustainable organisational solutions.

An analysis of the phases of the alliance process indicates that most of the surveyed companies (80%) are at the stage of formalising a cooperation framework without joint investments. This may indicate a cautious approach to the commitment of financial resources, characteristic of SMEs, which prefer flexible and relatively low-cost forms of cooperation (Todeva, Knoke, 2005). At the same time, respondents emphasised that formalising agreements increases the security of the parties' interests and facilitates risk management, which is consistent with Gulati's (1995) view, pointing to the role of contracts in reducing uncertainty and potential conflicts.

Current empirical research also shows that strategic alliances are an important mechanism for building dynamic internationalisation capabilities and competitive advantage in SMEs, even if the cooperation is initially based on limited capital involvement (Peng, 2025).

In terms of aligning goals and strategies, the study found that while companies maintain their own strategic priorities, they also seek to identify areas for joint action and value creation. This confirms the thesis of Doza and Hamel (1998), according to which the sustainability of alliances is based not on full integration of objectives, but on strategic coherence and a shared vision of cooperation.

The lack of standardised tools for monitoring and evaluating cooperation remains a significant problem. Half of the companies surveyed do not regularly monitor the effects of alliances, which limits the possibility of organisational learning and improvement of subsequent projects (Inkpen, 2001). At the same time, the results indicate that companies using formal assessment tools are more likely to engage in systematic knowledge transfer practices, confirming the importance of knowledge management as a source of competitive advantage (Nonaka, Takeuchi, 1995).

Reviews of the latest literature indicate that alliance management capabilities, including formal monitoring routines, learning mechanisms, and linking collaboration to strategic objectives, are increasingly recognised as a key factor in the sustained effectiveness of inter-organisational alliances (Vurro et al., 2024).

6. Summary

The research conducted has allowed us to formulate a number of recommendations for improving the management of strategic alliances in small and medium-sized enterprises. In particular, the need to professionalise the role of alliance manager, a more systematic approach to competence development, formalisation of cooperation as a risk mitigation tool,

integration of partners' goals and strategies, and standardisation of monitoring and evaluation of cooperation outcomes were identified. An important role was also assigned to knowledge management, which can be a sustainable source of competitive advantage.

At the same time, the study has certain limitations that should be taken into account when interpreting the results. First, the analysis is based on respondents' declarations, which entails the risk of subjectivity in the assessments. Second, the research sample was limited to Polish SMEs, which makes it difficult to directly generalise the results to other institutional and cultural contexts. Thirdly, the cross-sectional nature of the study does not allow for a full assessment of the long-term effects of alliance management. These limitations indicate the need for further research, particularly of a comparative nature.

The novelty of the presented research lies in the empirical demonstration of the actual, largely informal nature of alliance management in Polish SMEs and the identification of the gap between the declared need for strategic cooperation and the level of its organisational embedding. The study also provides new insights into the importance of even partial formalisation of roles, procedures and assessment tools as a factor increasing the effectiveness of alliances in conditions of limited resources.

From the perspective of management and quality sciences, the presented results broaden the knowledge on the specifics of inter-organisational management in the SME sector, which remains relatively poorly recognised empirically. The study integrates the perspectives of strategic management, quality management and knowledge management, indicating that the effectiveness of alliances depends not only on strategic decisions, but also on the quality of organisational processes and learning mechanisms. Thus, the article makes both a cognitive and an applied contribution, providing a basis for further analysis and practical recommendations for SME managers.

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KEY SOCIAL SKILLS AS A GUARANTEE OF SUCCESS IN BUSINESS MANAGEMENT

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Purpose: The main objective of the article is to analyse the available literature on social competences, business competences and future competences and to find which of known competences are most needed.

Design/methodology/approach: The main methods used in the article are the analysis of data contained in reports on the employment and competences of employees and a review of the literature on competences and skills.

Findings: Social skills and competences are more important for employers than digital skills. The most important competences for employers are skills and experience related to the job position, followed by the ability to work in a team and customer service. Language competences as required skills appear less often in job offers than degree requirement or experience.

Social implications: The results of research and analysis of available literature on desirable social skills and competences can help to consider how to improve the quality of training for employees, including the development of social skills.

Originality/value: The article may be aimed at business managers in order to draw attention to the importance of social skills in company management. Determining which skills are most desirable according to reports can help in creating new training courses for employees, taking into account customer service quality and teamwork skills.

Keywords: competences, management, human resources.

Category of the paper: Literature review, viewpoint.

1. Introduction

In the modern era of often rapid economic changes, both individuals and businesses are forced to be flexible and adapt quickly to changing realities. The development of technology, information science and artificial intelligence allows companies to discover ever newer, previously unknown methods of solving problems, but also requires them to assimilate contemporary trends. Existing standards related to Quality Management Systems indicate directions for various types of activities so that a company can develop not only in its home

market, but also internationally, and among the activities aimed at improving the QMS of companies in various industries, those related to human resource management are extremely important.

The main objective of the article is to analyse the available literature on social competences, business competences and future competences, available reports from employer surveys on human resource management, and to consider which key competences are most useful in the era of Industry 4.0 and which competences are still in short supply.

2. Literature review

2.1. The definition of competencies

Quality management in companies involves not only process management, but also human resource management. Human capital is defined as ‘a resource of knowledge, skills, vital energy [...], which can be increased through investments, known as investments in people’ (Domański, 1993). In everyday life, the word ‘qualifications’ is often used interchangeably with the word ‘competences’. It should be noted that these words are not synonymous. Colloquially, “competences” are defined by the Longman Dictionary of Contemporary English as ‘the ability to do something; skill’. In turn, ability can be understood as something that is characteristic of an individual (of every human being) – as a mental or physical trait, and a competent person is one who is able to make appropriate use of their skills and knowledge in a changing reality (Dale, 1993). For a company to operate effectively, and thus generate income and be successful on the market, it is important to bear in mind that it is the work potential (employee potential) that directly influences the company's potential. In turn, work potential depends on the employee's health, working time and competences (Niedzielski, Walkowiak, 2004).

Competence can be understood in a behavioural context as the behaviour of a competent person, or in a task context as the skills used in the workplace (Armstrong, 2000). Qualifications, on the other hand, can be defined as a set of skills and mental and physical characteristics necessary to perform professional duties (Butkiewicz, 1995).

Although qualifications and competences are two different terms, there is a network of relationships between them, which are presented in Figure 1.

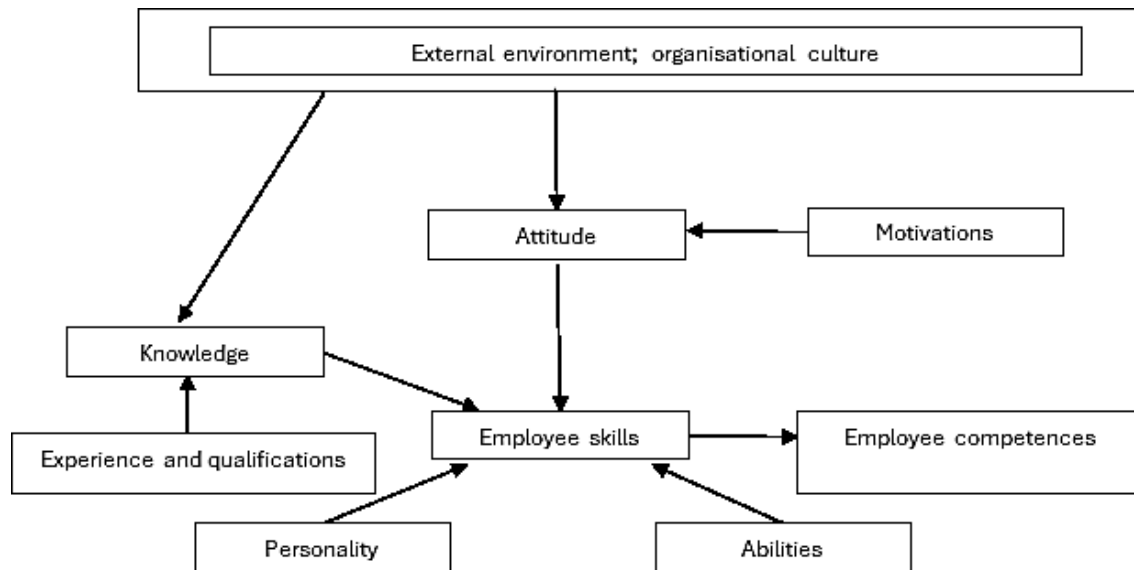


Figure 1. Relationship between skills, competencies and qualification.

Source: Rogozińska-Pawelczyk, 2006.

All elements are interrelated and must be taken into account in the area of incorporate organisational culture. Competences are always connected directly with skills. Employee skills consist of qualifications, experience and attitudes, while employee attitudes are driven by motivation.

2.2. Competences of the future

In today's world, employee competencies are a key aspect ensuring the possibility of improving quality management systems and, consequently, the functioning of the entire enterprise. An analysis of the available literature shows that the competencies of the future can be divided into four groups (Dębkowska et al., 2022):

- Social competences.
- Cognitive competences.
- Adaptive competences.
- Transformative competences.
- Digital and specialist competences.

Social competences include aspects such as emotional intelligence (the ability to recognise other people's emotions), negotiation skills (reaching compromises, reconciling different positions), human resource management (the ability to motivate, lead people and develop their abilities) and the ability to work in a team.

Cognitive competences are based on creativity, a broader view of the functioning of the company, critical thinking skills and so-called cognitive flexibility, which is the ability to analyse problems from different perspectives.

Adaptive competences refer to skills such as ‘the ability to find and interpret signs of change in the organisation's environment, the ability to identify signs of unlikely events that could significantly affect the company's situation, and the ability to act in situations of uncertainty’ (Dębkowska et al., 2022).

An important skill, which is also an indicator of moral and emotional maturity, is the ability to take responsibility (not only for oneself, but also for others). In complex situations, fraught with tension between people, it is also important to be able to pay attention to the values that guide other people. These skills belong to the transformative competences.

In addition to the above-mentioned competences, it should be borne in mind that those related to the human learning process are equally important. According to the European Council, the key competences in this area include:

- Digital competences.
- Personal, social and learning competences.
- Civic competences.
- Entrepreneurship competences.
- Multilingual competences.
- Reading and writing competences.

Each of these types of competences is necessary for a person to function in society and in the workplace (Gonzalez-Perez, 2022; Balcar et al., 2014). The divisions of competences are diverse, but it is important to understand that each competence consists of:

1. Attitudes – ways of perceiving and responding to situations, people and ideas (Lanzo, Olmo, 2010).
2. Knowledge.
3. Skills.

In view of the above, future skills can be defined as those skills that enable employees to perform their duties and take action in dynamically developing companies, dispersed geographically and operating in a market that requires rapid adaptation to technological changes, including the development of AI (Włoch, Śledziewska, 2019; Biggs, Lowenstein (2011)). In further part of article the author consider, using available data, which of skills are most required during the job and employee research.

3. Overview of social research available in reports

An analysis of publicly available statistical data provided by reliable companies was conducted. The weakness of the analysis is that it is based solely on data available to the average person. These studies were not conducted by the author. Reports available on the PARP website from 2025 were analysed: Job offers in Poland, Grant Thornton reports and ‘Every talent is

worth its weight in gold — inclusive employment’ — a report by the Union of Entrepreneurs and Employers for the current year.

According to a PARP report from July 2025, which is partly presented in Figure 2, the most important (most desirable) skills that a good employee should have are: customer service (35% of responses), strategic thinking (31% of responses) and team management (33% of responses).

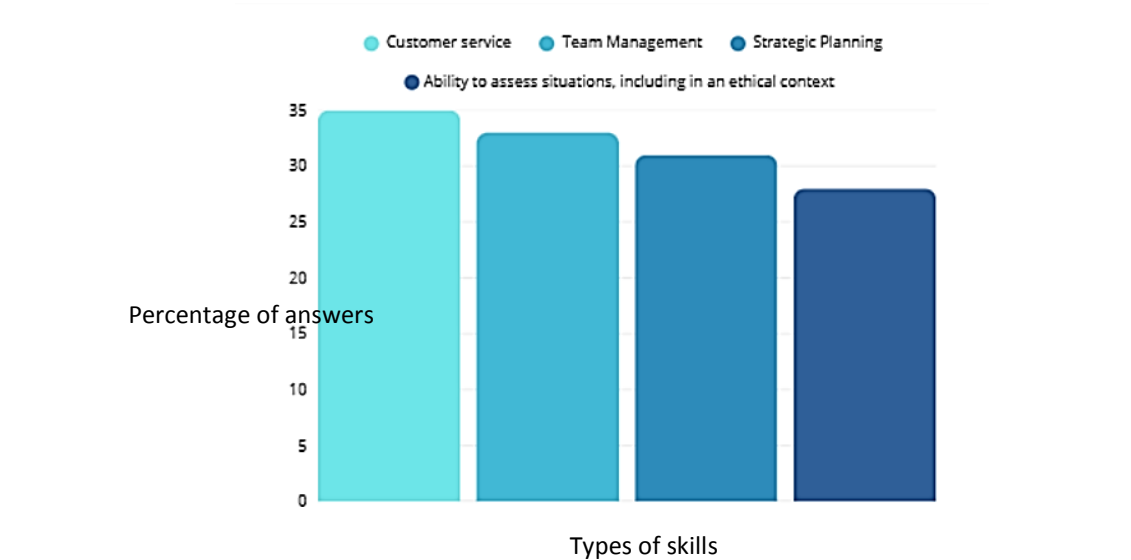


Figure 2. Most important skills according to the result of the study contained in the PARP report.

According to a report by PARP (Polish Agency for Enterprise Development) from July 2025, the most important competences for employers are skills and experience related to the job position, followed by the ability to work in a team, customer service, and, to a lesser extent, problem-solving, digital and management skills (Figure 3).



Figure 3. Most important competences for employers.

According to Grant Thornton's 2025 report on job vacancy research (as of June 2025), experience (technical, job-related) is the most important factor when hiring new employees. The highest percentage of job offers requiring experience was recorded in June 2023 (86%), and in the same month of subsequent years there was a decline – in June 2025 to approx. 57% (Figure 4).

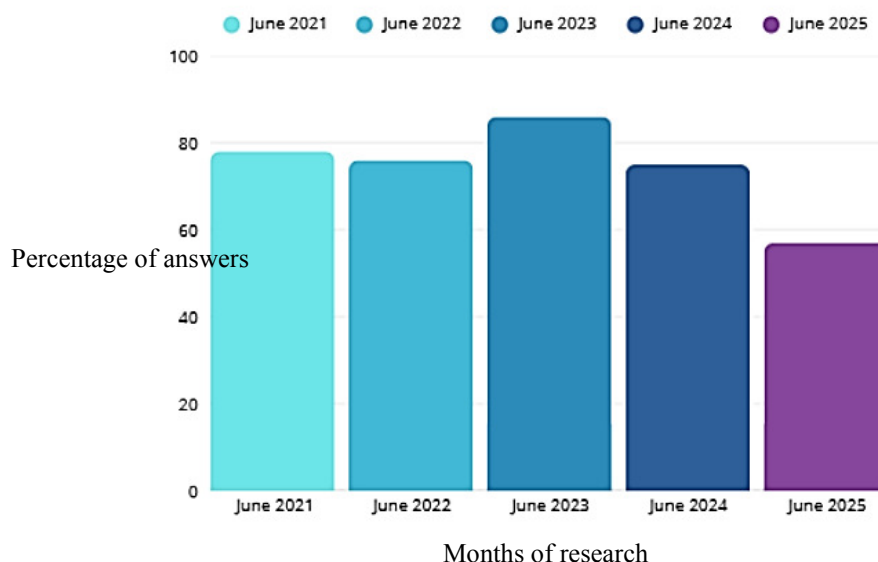


Figure 4. Quantity of job offers with experience required.

In 2021, approximately 48% of job offers in Poland required potential candidates to have a degree. In June 2025, this figure reached 42%, and in the meantime, there was a decrease in the number of offers requiring a degree, which is presented in Figure 5.

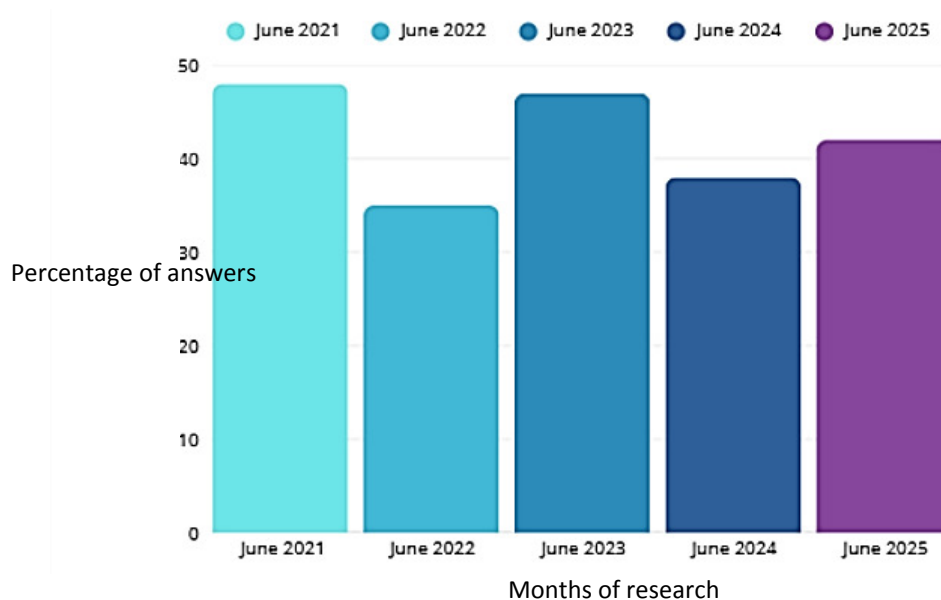


Figure 5. Quantity of job offers with degree required.

In June 2025, there was a decrease in the number of job offers requiring language skills (approx. 26%). For comparison, the highest percentage of job offers requiring language skills was recorded in June 2023 and amounted to 45%. (Figure 6).

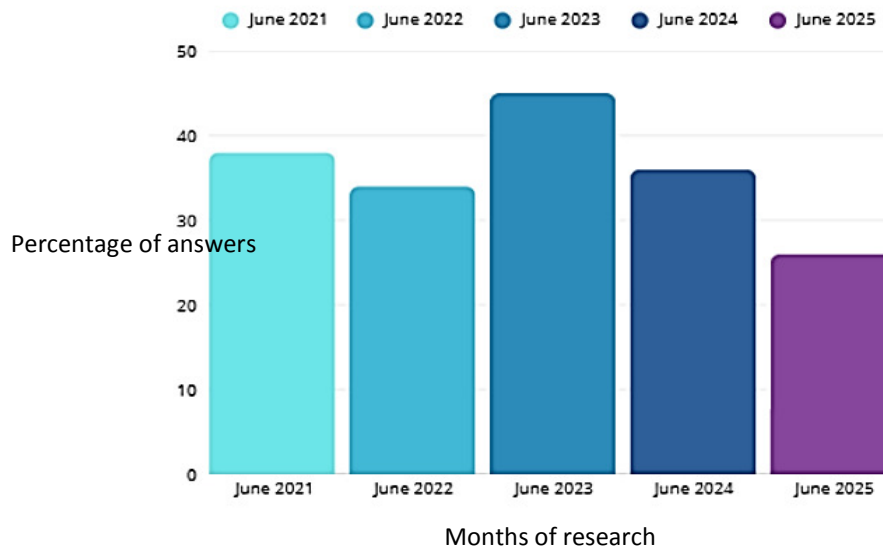


Figure 6. Quantity of job offers with language skills required.

4. Discussion

In today's world, experience is the most sought-after skill on the labour market. Interestingly, research shows that even experienced employees must constantly improve and update their qualifications in order to keep their jobs – in the EU market, almost 50% of adults are forced to supplement their professional qualifications (PARP, 2025). Despite the emergence of training centres, there are staff shortages, e.g. in the medical professions. An interesting trend can be observed in the case of language skills. According to a 2025 Grant Thornton report, since 2023, the number of job offers requiring language skills has fallen significantly (from 2023 to 2025, this decline amounts to almost 20 percentage points). Digital competences – both specialist and general – are not as desirable as, for example, the ability to work in a team (which is a social competence) or problem-solving skills. However, the most important factors are the skills and experience required for a specific job. Staff shortages in various professions raise questions about whether current training methods are insufficient, how to develop the skills of young people, and how to improve the skills of existing employees. According to what we have found in the literature, there are no studies that simultaneously refer to and describe how to identify an employee's weaknesses and develop social skills in order to manage the entire company effectively. Interestingly, available sources indicate that less qualified employees in professions where social skills are very important are more likely to leave their jobs (Aghion et al., 2023). Therefore, this is an area that needs to be addressed more often and quality management systems need to be improved to take this factor into account. There are general approaches to the subject of training, but the psychological differences between employees are problematic.

5. Summary

An employees should have the competence, skills and knowledge to be able to do their job effectively (Prien, 1981). Employers often find it difficult to find suitable candidates for jobs in their companies, regardless of the type of business. This is because the generation entering the labour market does not yet have the relevant experience in a specific field. The skills acquired after graduation are very important, but work experience is crucial during the recruitment process. Companies organise internships during which young employees can gain professional experience. However, social skills are second in terms of importance. The development of an employee's social skills within a company is a key aspect of quality management systems. The age of the employee, their abilities, and limitations (despite their professional experience) should be considered. The results of the research conducted can serve as a guideline for the development of employee training programmes, but also as a guide for job seekers on the extent to which they should further their education or develop their skills in order to increase their chances of finding employment.

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STRATEGIC SHAPERS OF INNOVATION ZONES: THE EVOLVING ROLE OF STPS IN ECOSYSTEM DEVELOPMENT

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Purpose: This study explores how science and technology parks (STPs) have evolved over the past decade, focusing on their transition from infrastructure-based facilitators of innovation to strategic shapers of innovation zones. It examines changes in governance, strategic priorities, and sustainability orientation, assessing their alignment with the Quintuple Helix framework.

Design/methodology/approach: A longitudinal comparative document analysis was conducted using data from the IASP Global Surveys (2015 and 2024). The study applies thematic coding to identify structural and functional transformations of STPs and interprets them within the ecosystem and Quintuple Helix perspectives.

Findings: The results show that STPs have shifted from publicly managed institutions to hybrid and professionalised governance models. They have diversified funding, expanded services, and integrated sustainability and ESG principles into their strategies. STPs now function as orchestrators of innovation ecosystems, actively shaping governance, sustainability, and spatial development.

Research limitations/implications: Based on secondary IASP data, the study offers global insights but limited regional granularity. Future research should include case studies for deeper contextual understanding. The reliance on secondary survey data limits direct observation of organisational practices; therefore, future research should combine longitudinal survey analysis with qualitative case studies to further validate the causal mechanisms identified in this study.

Practical implications: The findings highlight the need for policymakers and innovation managers to recognise STPs as strategic partners in regional and urban development. Strengthening hybrid governance, expanding ecosystem-oriented services, and embedding sustainability frameworks can enhance the long-term impact of STPs on competitiveness and innovation-led growth.

Social implications: The study highlights the social added value of STPs as institutions that connect science, industry, government, and society. By promoting sustainable innovation, civic engagement, and knowledge diffusion, STPs contribute to more inclusive, responsible, and participatory models of economic and social development.

Originality/value: The study provides rare longitudinal evidence of STP evolution and demonstrates their emerging role as strategic shapers of innovation zones.

Keywords: STPs, science and technology parks, Quintuple Helix, innovation systems, innovation areas.

Category of the paper: research paper.

1. Introduction

The geography of innovation has undergone a profound transformation in recent decades. Science and technology parks (STPs), once designed primarily as physical infrastructures supporting research commercialization and technology transfer, have evolved into strategic shapers of innovation zones. These entities now actively structure and govern how innovation ecosystems emerge, connect, and sustain themselves. Their function has expanded from hosting technology-oriented enterprises to curating dynamic, knowledge-intensive environments where academia, industry, government, and society interact in real time (Etzkowitz, Leydesdorff, 2000; Dąbrowska, 2024). This transformation reflects the growing importance of integrated spaces that orchestrate innovation across technological, social, and environmental domains.

Historically, STPs were conceived as regional policy instruments aimed at enabling technology transfer, stimulating entrepreneurship, and fostering economic diversification. Over time, however, globalisation, digitalisation, and the growing importance of sustainability have significantly altered their mission and governance. The traditional Triple Helix model of university–industry–government collaboration has gradually evolved into the more comprehensive Quintuple Helix model, which also incorporates civil society and the natural environment as active contributors to innovation (Carayannis, Campbell, 2010). Within this expanded framework, STPs no longer simply facilitate innovation processes but also shape their direction and inclusivity, aligning technological advancement with societal well-being and ecological responsibility (Carayannis, Grigoroudis, Campbell, 2022).

Recent scholarship confirms this shift in the conceptual and functional identity of STPs. Dąbrowska (2024) argues that their performance must now be analysed through a Quintuple Helix lens, recognising their strategic capacity to balance economic competitiveness with social and environmental objectives. Her findings demonstrate that STPs have transformed into complex, self-organising ecosystems that co-create innovation outcomes with diverse stakeholders. In this capacity, they have become institutional orchestrators that influence urban development, regional policy, and global knowledge networks.

Despite the dynamic evolution of STPs, longitudinal analyses capturing the full scope of these transformations remain limited. Many existing studies focus on single aspects such as governance or clustering, without considering their systemic interactions (Ratinho, Henriques, 2020). Using a longitudinal comparative document analysis of the IASP surveys from 2015 and 2024, this article aims to identify the structural, functional, and conceptual transformations that redefine the role of STPs within global innovation ecosystems. By interpreting these changes through the Quintuple Helix perspective, the study contributes to a deeper understanding of how STPs evolve into organised innovation spaces that integrate technological excellence with sustainability and social value. In doing so, the article positions STPs not merely as participants in innovation systems but as strategic actors shaping the development and governance of contemporary innovation zones.

2. Methodology

The purpose of this study was to explore and interpret the multidimensional evolution of STPs over a ten-year period, focusing on their strategic, organizational, and spatial transformations. The research investigates how the role of STPs has changed between 2015 and 2024 and to what extent these changes reflect a broader transition from technology infrastructure toward ecosystem-oriented innovation zones. The study also examines whether contemporary STPs align with the principles of the **Quintuple Helix Model**, which encompasses the interactions among academia, industry, government, civil society, and the natural environment.

The research questions guiding this study were formulated as follows:

- How have the ownership and governance models of STPs evolved over the past decade?
- How have the strategic priorities, functions, and services of STPs evolved, and what emerging trends define their current development trajectories?
- To what extent do contemporary STPs align with the Quintuple Helix framework and its emphasis on sustainable, multi-actor innovation ecosystems?

The primary research method employed in this study is qualitative document analysis (Bowen, 2009), supported by comparative and longitudinal analysis (Yin, 2014; Bryman, 2016) as the main analytical techniques. This approach enables a structured investigation of changes over time and allows both quantitative and qualitative data to be interpreted in their institutional and conceptual context. The empirical foundation of the study consists of two comprehensive reports published by the International Association of STPs and Areas of Innovation (IASP): the *IASP General Survey Report (2015)* and the *IASP Global Survey Report (2024)*. The IASP, founded in 1984 and headquartered in Málaga, Spain, unites nearly 400 member parks and innovation districts across 80 countries, providing a rich global dataset that captures the diversity and evolution of innovation environments worldwide.

Both reports were systematically reviewed and coded to identify key categories of change, including ownership and governance structures, relationships with universities and cities, diversification of services, integration of sustainability and ESG principles, and internationalisation trends. The thematic coding process followed an iterative abductive approach combining theory-driven and data-driven category development. An initial coding framework was derived from innovation ecosystem and Quintuple Helix literature and subsequently refined through open coding to capture themes emerging directly from the empirical material. Codes identified in both reports were compared across time periods to construct a longitudinal comparative coding matrix, enabling the identification of recurring themes, discursive shifts, and emerging patterns of transformation. Analytical reliability was strengthened through repeated cross-reading, temporal comparison, and theoretical triangulation, enhancing conceptual consistency, transparency, and replicability.

This methodological approach integrates descriptive comparison with interpretive synthesis, enabling the identification of both structural and conceptual evolution within the global network of STPs. By combining empirical analysis with theoretical reflection, the study provides a comprehensive understanding of how STPs have evolved into strategic orchestrators of innovation ecosystems between 2015 and 2024.

3. Results

The presentation of results is guided by the theoretical framework of innovation ecosystems and the Quintuple Helix model introduced in the previous sections. The identified empirical categories are interpreted not only as organisational changes but also as indicators of systemic transformation reflecting evolving interactions between academia, industry, government, society, and the natural environment. This perspective enables the findings to be analysed as empirical manifestations of broader theoretical shifts in the governance and spatial organisation of innovation.

The comparative analysis of the IASP Global Surveys from 2015 and 2024 reveals a significant and multidimensional transformation in the global landscape of STPs. The following results are presented in accordance with the analytical criteria outlined in the comparative table: identity and scope, role in the ecosystem, spatial distribution, governance, university relations, services, funding, scale, internationalisation, sectoral focus, sustainability, management, tenant profile, and strategic orientation.

Table 1.
Analysis of changes within STPs over a ten-year period

Category	2015 Findings	2024 Findings	Analytical Comment / Strategic Implication
Identity and Scope	Defined mainly as <i>Science & Technology Parks</i> focused on research commercialization and technology transfer.	Broader concept of <i>Organised Innovation Spaces (OIS)</i> including STPs, Innovation Districts, and Areas of Innovation.	Conceptual shift from “park-based” to “ecosystem-based” innovation environments.
Role in the Ecosystem	Functioned as intermediaries between universities, industry, and government (triple helix).	Act as orchestrators of innovation ecosystems integrating business, academia, community, and sustainability agendas.	Transition from knowledge transfer units to strategic innovation platforms.
Location Pattern	Mostly located on university campuses or city peripheries.	87.9% situated in urban areas; increasing integration with city fabric.	Urbanisation of innovation: parks evolve into <i>city-embedded ecosystems</i> .
Ownership and Governance	Predominantly public ownership (universities, local or national governments).	50.8% public, 31% mixed (PPP), 18.3% private.	Rise of public-private partnerships and professionalized management, hybrid governance models dominate.

Cont. table 1.

University Relations	Strong but traditional cooperation (research transfer, spin-offs).	80.2% formal partnerships; 75.4% within 5 km of a university; 47.6% host research groups.	Collaboration shifts from institutional to co-locational and co-creative forms.
Service Portfolio	Focused on incubation, R&D infrastructure, and basic business support.	93.7% run incubators, 81.7% accelerators, 75.4% cluster programs; broader community and social services.	Expansion from infrastructure provision to holistic, value-added ecosystem services.
Funding Structure	Largely dependent on public grants and subsidies.	Diversified revenue streams: public grants, rent, service fees, and private investment.	Greater financial autonomy and sustainability; parks as self-financing organizations.
Scale and Expansion	Mostly single-site operations.	37.4% operate multiple sites (2-5); 87.3% plan further expansion.	Regionalisation and networked models of innovation zones.
Internationalisation	Limited, mainly through IASP membership and events.	70.7% have formal international MoUs; growing cross-border cooperation.	From local clusters to globally networked innovation nodes.
Sectoral Specialisation	Dominated by ICT, biotech, electronics, materials.	Narrower focus (3-5 key sectors per park); AI, ICT, biotech most prevalent.	Shift toward thematic and high-value specialisation strategies.
Sustainability / ESG	Rarely mentioned; limited to energy efficiency.	Majority implement formal ESG or SDG frameworks; 65.8% dedicate >15% land to green areas.	Sustainability becomes a core strategic and identity component.
Management Teams	Small administrative teams (≤ 10 staff).	Typically 11-25 employees with expertise in innovation, ESG, and partnership management.	Professionalisation of park management and strategic competencies.
Resident Companies Profile	Mostly SMEs and university spin-offs.	SMEs still dominant but with rising presence of international firms.	Diversification and globalisation of tenant profiles.
Strategic Orientation	Focused on regional economic development and tech transfer.	Oriented toward global connectivity, sustainability, and talent attraction.	From regional development instruments to <i>global ecosystem enablers</i> .

Source: own work.

Identity and Scope

In 2015, the concept of the STPs was largely synonymous with infrastructure-based technology transfer. STPs were defined as physical facilities supporting collaboration between universities and industry, focusing on commercialization of research outcomes and enterprise incubation. By 2024, this narrow definition had evolved substantially. The term *Organised Innovation Spaces (OIS)* now encompasses STPs, innovation districts, and areas of innovation (IASP, 2024). This reflects a paradigmatic shift in understanding - from *parks as physical enablers of technology transfer* to *strategic orchestrators of innovation ecosystems*. Contemporary STPs function as platforms that integrate economic, social, and environmental objectives, aligning with the Quintuple Helix framework (Carayannis, Campbell, 2010; Dąbrowska, 2024).

Role in the Ecosystem

The traditional role of STPs as mediators of the Triple Helix model, linking academia, government, and business, has expanded into a multi-stakeholder paradigm that includes civil society and the natural environment. In 2015, STPs were considered *facilitators* of innovation; by 2024, they are *strategic actors* that actively shape innovation networks and regional policy agendas (Carayannis, Grigoroudis, Campbell, 2022). They serve as intermediaries between different layers of innovation governance, influencing knowledge exchange, sustainability initiatives, and entrepreneurial ecosystems. This role expansion underscores the transition of STPs from support institutions to ecosystem orchestrators (Dąbrowska, 2024).

Location and Urbanisation

The 2015 data showed that most STPs were located on the peripheries of cities, often near universities or in industrial zones. By contrast, the 2024 survey indicates that 87.9% of parks are now urban, integrated into city structures as part of innovation districts or mixed-use developments (Lecluyse et al., 2021). This spatial transformation demonstrates the process of *urbanisation of innovation*. STPs are no longer isolated technological enclaves; they are embedded within metropolitan ecosystems, linking research and entrepreneurship with cultural, residential, and civic functions (Davies, 2023). The integration with urban infrastructure enhances collaboration, visibility, and social engagement.

Ownership and Governance

In 2015, public ownership dominated the STP sector, with most parks operated by universities, municipalities, or regional governments. By 2024, ownership patterns have become much more diverse: 50.8% of parks remain public, 31% operate under public–private partnerships, and 18.3% are privately owned (IASP, 2024). This diversification indicates a growing trend toward professionalisation and hybrid governance. Public–private collaboration has introduced more agile decision-making processes and greater financial sustainability, reflecting the global trend toward entrepreneurial governance models. The growing share of private stakeholders suggests a strategic shift from publicly subsidized operations to self-sustaining, investment-driven organisations.

Relations with Universities

University collaboration remains central but has evolved significantly. In 2015, cooperation was often transactional, focusing on technology transfer or student entrepreneurship. By 2024, 80.2% of parks have formal agreements with universities, and 47.6% host research groups within their facilities. Moreover, 75.4% are located within a 5-kilometre radius of academic institutions (IASP, 2024). This indicates a deepening of co-creation mechanisms. STPs and universities now share not only infrastructure but also

research agendas and innovation programs. This shift represents a move from *proximity-based cooperation* to *co-locational integration*, where academic and entrepreneurial ecosystems merge (Dąbrowska, 2024).

Service Portfolio

In 2015, the typical service portfolio of a STP included incubation, research facilities, and technology transfer assistance. By 2024, this range has expanded dramatically: 93.7% of parks operate incubators, 81.7% offer acceleration programs, and 75.4% manage cluster initiatives (IASP, 2024). Additionally, new value-added services such as mentoring, networking, training, and internationalisation support have become widespread. Modern parks act as ecosystem integrators, providing business support alongside community-building and sustainability programs. This expansion indicates a transition from infrastructure provision to knowledge brokerage and systemic innovation support (Ratinho, Henriques, 2020).

Funding Structure

The funding models of STPs have evolved from reliance on public subsidies to diversified revenue streams. In 2015, most parks operated with government grants and limited rental income. In 2024, income sources include a combination of public funding, private investment, rental fees, service charges, and international project participation. This shift reflects a trend toward financial autonomy and economic sustainability, consistent with broader movements toward self-financing innovation ecosystems (IASP, 2024). The hybrid funding approach enhances resilience and reduces dependence on cyclical public budgets.

Scale and Expansion

While in 2015 most STPs consisted of single-site operations, by 2024, 37.4% manage multi-site campuses with two to five locations (IASP, 2024). This expansion signifies the rise of distributed innovation ecosystems, where parks form networks across metropolitan or regional areas. Such scaling supports cross-sector collaboration and resource optimisation, aligning with the global trend toward *polycentric innovation systems*. Moreover, 87.3% of parks plan further expansion, confirming their increasing spatial and organisational relevance.

Internationalisation

The global connectivity of STPs has increased significantly. In 2015, international engagement was limited mainly to conferences and IASP membership. By 2024, 70.7% of parks have signed formal international cooperation agreements (MoUs), and many operate as global hubs within transnational innovation networks (IASP, 2024). This growing connectivity enhances knowledge exchange, cross-border collaboration, and participation in international

R&D programs. STPs are thus evolving into global innovation intermediaries, enabling firms and research institutions to access international markets and expertise (Dąbrowska, 2024).

Sectoral Focus

The sectoral composition of STPs has become more specialised. In 2015, most parks hosted companies from broad technology fields such as ICT, biotechnology, and electronics. By 2024, parks increasingly focus on three to five priority sectors, with strong representation in AI, ICT, biotechnology, clean technologies, and life sciences (IASP, 2024). This thematic concentration aligns with regional smart specialisation strategies and fosters synergies between research and industrial strengths. It represents a strategic move from general-purpose technology zones to knowledge-intensive, sector-driven innovation clusters.

Sustainability and ESG Integration

Sustainability has emerged as a defining dimension of modern STPs. In 2015, environmental considerations were marginal. By 2024, a majority of parks implement formal environmental, social, and governance (ESG) frameworks and sustainability strategies. Approximately 65.8% dedicate more than 15% of their total area to green spaces, while 19% allocate more than half. Sustainability is now embedded in governance, infrastructure design, and stakeholder engagement. STPs align their missions with the UN Sustainable Development Goals (SDGs) and the European Green Deal, establishing themselves as laboratories of sustainable innovation.

Management Teams

Management structures have professionalised. In 2015, park management teams were small and administratively oriented, often fewer than ten staff. By 2024, the average team size ranges from 11 to 25 professionals, including experts in innovation management, ESG, and internationalisation. This professionalisation strengthens strategic planning and global competitiveness. It also reflects a broader transformation of STPs from *administrative bodies* into *strategically managed organisations*.

Resident Companies Profile

The resident base of STPs remains dominated by micro and small enterprises, yet its composition has become more diversified. By 2024, an increasing share of international firms and research-intensive startups coexists with university spin-offs. This diversity enhances knowledge exchange, accelerates innovation, and connects local ecosystems to global value chains (IASP, 2024).

Strategic Orientation

Finally, the strategic orientation of STPs has shifted from a focus on regional economic development and technology transfer in 2015 to a broader mission emphasising global connectivity, sustainability, and talent attraction in 2024. STPs now operate as strategic orchestrators of innovation zones, managing not only infrastructure but also the social, cultural, and environmental dimensions of innovation. Their evolution exemplifies the transition from technology-driven growth to ecosystemic, sustainable, and globally networked innovation governance.

4. Discussion

The results of the longitudinal analysis presented in this study provide comprehensive answers to the three research questions and confirm that STPs have undergone a profound institutional and functional transformation over the past decade. They have evolved from being support infrastructures facilitating technology transfer to becoming strategically managed organisations that orchestrate innovation ecosystems at multiple scales. This transformation encompasses changes in governance, operational priorities, and conceptual alignment with sustainable and inclusive models of innovation. In this respect, the empirical findings provide interpretive support for the theoretical transition from Triple Helix coordination mechanisms toward Quintuple Helix ecosystem governance, demonstrating how organisational transformations of STPs reflect broader systemic changes in innovation theory.

The first research question addressed the evolution of ownership and governance models in STPs. The comparative data reveal a clear transition from public dominance to a more hybrid and diversified landscape. In 2015, most parks were publicly owned and managed by universities or regional authorities, operating within rigid administrative frameworks. By 2024, nearly one third of all parks had adopted public–private partnership models, and almost one fifth were privately owned (IASP, 2024). This diversification marks a fundamental shift toward professionalised and performance-driven governance. The emergence of hybrid structures has enabled STPs to balance public accountability with the efficiency, flexibility, and innovation capacity typical of private sector management. Germain et al. (2021) observe that hybrid governance enhances strategic responsiveness by allowing STPs to adapt to technological change, attract private capital, and integrate entrepreneurial management practices. Sandoval Hamón et al. (2024) similarly emphasise that diversified governance structures strengthen institutional resilience by spreading financial and operational risks.

This evolution represents a move from administrative coordination to strategic orchestration. STPs are no longer managed as extensions of public policy but operate as independent institutions capable of shaping their own development trajectories. Dąbrowska (2024) argues that this new institutional maturity allows parks to act as orchestrators of innovation ecosystems, managing multiple networks and stakeholders rather than simply providing physical space for firms. The shift in governance thus reflects a deeper transformation in the identity of STPs, from policy tools to autonomous strategic actors in the innovation landscape.

The second research question examined how the strategic priorities, functions, and services of STPs have evolved and what emerging trends define their development trajectories. The findings indicate a marked expansion of functions and strategic goals. In 2015, the role of most parks was confined to technology transfer, business incubation, and research infrastructure provision. By 2024, their activities had broadened to include acceleration, mentoring, sustainability consulting, and internationalisation. The diversification of services demonstrates that STPs have adopted the role of ecosystem intermediaries that facilitate co-creation and collaboration between academia, industry, government, and society. Ratinho and Henriques (2020) note that such intermediary organisations are critical in enabling multi-actor innovation, as they design and coordinate the interactions that lead to knowledge exchange and collective learning.

Another striking change is the spatial reconfiguration of innovation spaces. Almost 88 % of parks now operate in urban or metropolitan areas, confirming the trend described by Lecluyse et al. (2021) as the urbanisation of innovation. The movement from peripheral university campuses to integrated city environments reflects a rethinking of innovation geography. Urban-based parks are not isolated technological enclaves but dynamic components of metropolitan innovation ecosystems, where scientific research, entrepreneurship, cultural activity, and civic life intersect. Davies (2023) points out that the integration of innovation infrastructure into cities generates new synergies between technological development and urban transformation. This spatial shift enhances the visibility of innovation and strengthens the social dimension of STPs by connecting them directly with local communities, creative industries, and municipal sustainability agendas.

Parallel to these organisational and spatial developments is the diversification of financial models. In 2015, most STPs relied heavily on public subsidies and project-based funding. By 2024, they had adopted more balanced revenue structures based on rental income, service fees, private investment, and international partnerships. This evolution illustrates a growing focus on financial sustainability and autonomy, reducing dependence on government programmes and allowing for long-term strategic planning. This trend reflects the increasing economic maturity of STPs as self-sustaining institutions capable of reinvesting in innovation infrastructure. The combined effect of governance diversification, urban integration, and financial independence shows that STPs are becoming complex, adaptive organisations operating as orchestrators rather than facilitators within innovation ecosystems.

The third research question explored the extent to which contemporary STPs align with the Quintuple Helix framework and its emphasis on sustainable, multi-actor innovation ecosystems. The analysis strongly supports the argument that the Quintuple Helix perspective now underpins both the strategic orientation and operational models of STPs. The 2024 data indicate that most parks have integrated ESG principles into their strategies and reporting mechanisms. Many have adopted the United Nations Sustainable Development Goals and the European Green Deal as reference frameworks, dedicating significant portions of their physical space to green areas and implementing energy-efficient technologies (IASP, 2024). Environmental responsibility and social inclusion are viewed as competitive advantages of STPs rather than regulatory obligations.

The incorporation of the Quintuple Helix model signifies a shift from purely economic or technological objectives to a more holistic vision of innovation that includes civil society and the natural environment. Carayannis and Campbell (2010) describe this framework as an evolution of the Triple Helix model, recognising that innovation is shaped not only by universities, industry, and government but also by societal and ecological systems. Buday (2025) confirms that this perspective is increasingly visible in global innovation policy, where sustainability and resilience are treated as integral to competitiveness. By embedding these principles into their missions, STPs have become laboratories of sustainable innovation, translating theoretical frameworks into practical strategies that link technological advancement with ethical responsibility.

Internationalisation further reinforces this alignment. More than seventy percent of parks now participate in global innovation networks and maintain formal international partnerships (IASP, 2024). This engagement enables them to exchange knowledge, attract investment, and participate in cross-border research initiatives. Germain et al. (2021) argue that such international linkages are essential for building resilient innovation ecosystems, as they allow local actors to access global markets and expertise. Thematic specialisation is another dimension of this global alignment. Many parks have concentrated on specific sectors such as artificial intelligence, biotechnology, clean technologies, and life sciences, contributing to global sustainability challenges while enhancing regional smart specialisation. This combination of sustainability, specialisation, and global connectivity shows that STPs are increasingly positioned as strategic mediators between local assets and global innovation flows.

Based on the finding it can be confirmed that STPs have matured into institutional orchestrators of innovation ecosystems. The evolution of governance demonstrates their growing autonomy and professionalisation. The expansion of functions and services, together with trends of urbanisation, financial independence, and global integration, illustrates their transition into multidimensional organisations that manage, connect, and sustain innovation. The adoption of the Quintuple Helix model anchors this transformation in a conceptual framework that unites technological, social, and environmental objectives.

While the findings indicate increasing alignment of STPs with the Quintuple Helix framework, this transformation should not be viewed as linear or universally successful. Expanding stakeholder involvement and sustainability agendas introduce governance complexity and coordination challenges, potentially creating tensions between economic efficiency and broader social and environmental objectives. Hybrid governance models may enhance flexibility but can also generate institutional ambiguity and conflicting stakeholder expectations, while sustainability integration may involve trade-offs between long-term societal value and short-term financial performance. Moreover, the growing strategic role of STPs may reinforce uneven regional development, as better-resourced ecosystems are more capable of benefiting from orchestration processes. These considerations suggest that the Quintuple Helix transition represents not only an opportunity but also a space of organisational experimentation and potential failure, highlighting the need for future research examining both successful and unsuccessful transformation pathways.

The implications of these findings extend beyond the institutional boundaries of STPs. Theoretically, they validate the ecosystemic understanding of innovation as a distributed process requiring coordination and collaboration among diverse actors. Practically, they suggest that governments and universities should recognise STPs not merely as infrastructure projects but as key policy partners in shaping sustainable innovation strategies. As the decade between 2015 and 2024 demonstrates, STPs have become strategic shapers of innovation zones, integrating governance, sustainability, and collaboration into a unified model of ecosystem development that defines the future of innovation.

5. Summary

This study demonstrates that STPs have evolved from traditional facilitators of research commercialisation into strategic actors shaping contemporary innovation zones. Over the past decade, STPs have transitioned from infrastructure-oriented entities into dynamic organisations that orchestrate complex innovation ecosystems. This transformation reflects fundamental changes in governance, strategic direction, and conceptual alignment with sustainable and collaborative models of innovation.

The evolution of governance from public control toward hybrid and professionalised management has enhanced the autonomy, flexibility, and strategic capacity of STPs. They now function as institutional anchors balancing public purpose with private efficiency and entrepreneurial leadership. This organisational maturity confirms their growing influence in shaping innovation policy and managing ecosystem development at both regional and global levels.

At the same time, STPs have broadened their functions and adopted new trajectories of development. Their integration into urban environments, diversification of services, and pursuit of financial self-sufficiency illustrate a transition from passive enablers to active orchestrators of innovation processes. Their increasing commitment to sustainability and alignment with the Quintuple Helix framework demonstrate that innovation is becoming inseparable from environmental and social responsibility.

Taken together, the findings demonstrate the emergence of STPs as institutional orchestrators that actively design, connect, and govern innovation ecosystems rather than merely hosting them. Their evolution confirms that the governance of innovation and the governance of sustainability are increasingly intertwined processes. In this sense, the study demonstrates a simultaneous structural, functional, and conceptual transformation of STPs, completing their transition from technology infrastructures to ecosystem-oriented innovation institutions. From a theoretical perspective, the study reinforces the ecosystemic understanding of innovation as a co-evolving and multi-level system requiring institutional coordination. From a policy perspective, the findings suggest that governments and universities should recognise STPs not merely as infrastructure projects but as strategic partners in shaping innovation-driven regional and urban development.

Based on the longitudinal analysis, several theoretical implications can be derived that extend the ecosystem perspective on STPs and provide directions for future empirical research. The findings indicate that the transition from predominantly public governance toward hybrid governance models increases the strategic autonomy of STPs and strengthens their capacity to orchestrate innovation ecosystems. The diversification of service portfolios mediates the shift from infrastructure-based innovation support toward ecosystem-based value creation and stakeholder coordination, while urban spatial embeddedness enhances ecosystem performance by increasing interaction density, knowledge exchange, and social engagement among stakeholders. Furthermore, the integration of sustainability and ESG principles transforms STPs from technology transfer intermediaries into institutions balancing economic, social, and environmental innovation objectives. Together, these insights contribute to theory development by conceptualising STPs as institutional orchestrators whose effectiveness depends on governance configuration, spatial integration, and sustainability alignment. Future research may empirically test these relationships through comparative case studies and mixed-method research designs.

The past decade has marked a turning point in the global landscape of innovation, as STPs have emerged as key institutional actors capable of integrating technological excellence with environmental and social responsibility. Their transformation encapsulates the central argument of this study: STPs have become strategic shapers of innovation zones, defining not only where innovation occurs but also how it is governed, sustained, and directed toward a more inclusive and sustainable future.

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APPLICATION OF AUTONOMOUS MOBILE ROBOTS (AMR) IN SMART MANUFACTURING

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Purpose: The aim of this work is to analyze global and domestic market trends regarding autonomous mobile robots (AMRs) and assess their potential impact on the development of smart manufacturing.

Design/methodology/approach: The study employed a desk research approach. The data sources included statistical data from public institutions, publicly available market reports, scientific publications, and industry materials. These data were used to assess the dynamics of the AMR market, its main application areas, development forecasts in the context of smart manufacturing, and the impact of AMR implementation on the employment structure in the manufacturing sector.

Findings: It has been established that the AMR market is growing rapidly, particularly in the logistics and manufacturing sectors, constituting a significant element of the industrial transformation towards Industry 4.0. Implementing AMR can significantly increase the flexibility, efficiency, and digitization of production processes.

Research limitations/implications: The lack of access to enterprise operational data makes it impossible to assess the actual impact of AMR implementations on production efficiency.

Practical implications: The dynamic growth in the value of the AMR market and the growing number of implementations across various industry sectors indicate that this technology is becoming a key element in the transformation of production towards Industry 4.0. The results of the analysis can provide companies with guidance on planning investments in autonomous mobile systems, taking into account local labor market conditions.

Social implications: The analysis can support public policies and educational strategies to prepare workers for increasing automation, ensuring that technological innovations are balanced with labor market needs.

Originality/value: An approach combining labor market analysis with an assessment of the adoption rate of autonomous mobile robots in the manufacturing sector allows us to identify countries and sectors with high potential for AMR implementation, especially in the context of smart manufacturing, where automation can significantly increase productivity and operational efficiency.

Keywords: autonomous mobile robots, automate guided vehicles, smart manufacturing, labor market.

Category of the paper: research paper.

1. Introduction

Modern manufacturing and logistics companies are under increasing pressure to increase efficiency, flexibility and speed of response to changing market conditions (Szeszák et al., 2025). A key area that impacts an organization's ability to achieve these goals is the internal supply chain - comprising all operations related to the transport of materials, components, and products within the enterprise. Traditional methods of organizing internal logistics, based on human labor, manual task planning, and rigid transport systems (e.g., conveyor belts or AGVs guided along fixed routes), often prove insufficient in the context of the growing complexity and variability of production processes. Low flexibility, error-proneness, and limited adaptability to changing operational conditions are becoming a significant barrier to achieving full automation and optimization of internal flows (Zhang et al., 2023).

In response to these challenges, autonomous mobile robots are gaining popularity, offering a new level of quality in intralogistics. AMRs are intelligent, autonomously moving transport units capable of autonomous navigation in dynamic environments, avoiding obstacles, optimizing routes, and communicating with other production systems in real time. Unlike automated guided vehicles (AGV) systems, which follow predefined paths, AMRs use data from cameras, lidar, and other sensors to make decisions based on the current environment (Fragapane et al., 2021; Kotlars, Skribans, 2024). However, implementing AMRs is not just about their physical presence in the enterprise. A key element in effectively utilizing their potential is integration with data collection and analysis systems, which enables the implementation of advanced optimization strategies. In this context, intelligent data-driven techniques such as machine learning, optimization algorithms, and digital twins are gaining increasing importance (Dobrzańska, Dobrzański, 2025).

As a result, combining mobile robotics with data analysis technologies opens up new possibilities for the automation, adaptability, and scalability of logistics processes within an enterprise. Optimizing the internal supply chain based on these technologies can lead to shorter transport times, reduced costs, increased reliability, and improved overall production efficiency. As a result, AMRs can become the foundation of modern, integrated, and intelligent intralogistics systems that support the implementation of Industry 4.0 strategies and the smart factory concept (Oztemel, Gursev, 2020; Hercik et al., 2022). In the concept of smart manufacturing, autonomous mobile robots play a key role in streamlining production and logistics processes. Thanks to their flexibility and independent decision-making, AMRs can effectively support the transport of components, semi-finished products, and finished goods between workstations, warehouses, and assembly lines. The use of such robots contributes to increased efficiency and reduced downtime resulting from manual material handling. Furthermore, the use of AMRs allows for better utilization of production space, improved employee safety, and reduced operating costs. Their integration with production management systems (MES, ERP) enables the creation of fully automated and self-regulating work environments. As a result, AMRs are becoming one of the pillars of the digital transformation

of industry, supporting the implementation of the Industry 4.0 concept and the construction of smart factories (Jacob et al., 2023; Lackner et al., 2024; Manuguerra et al., 2023; Niermann et al., 2023; Raamets et al., 2024; Unger et al., 2018).

The implementation of autonomous mobile robots in the manufacturing sector is becoming particularly important in the context of an aging population and growing labor shortages (Bazela, 2022; Gong et al., 2023). Automating repetitive and physically demanding tasks allows not only maintaining but often increasing productivity with a limited workforce. AMRs can relieve staff of monotonous duties, allowing workers to focus on more complex tasks, while simultaneously reducing the pressure associated with a shortage of skilled labor. However, the implementation of such solutions requires appropriate preparation of the organization – including training for employees in the operation and programming of robots – which shapes a new structure of employment and competences in manufacturing enterprises.

Given the growing importance of autonomous mobile robots in modern production facilities, it is crucial to understand their development directions and the impact they may have on manufacturing processes. Dynamic technological advances and the growing demand for flexible logistics solutions are driving the AMR market to grow rapidly, both globally and domestically. The aim of this paper is to analyze global and domestic market trends for autonomous mobile robots (AMRs) and assess their potential impact on the development of smart manufacturing, productivity, and employment structure in the manufacturing sector.

2. Methods

The conducted research used the desk research method and its aim was to identify key trends in the development of the AMR market on a global scale and to assess the level of advancement of implementation of this technology in Poland and the impact on the employment structure in the manufacturing sector

The study covers the years 2020–2025 and focuses on two levels of analysis: global and national. The study analyzed the most important development directions for the professional service robots market, including AMR, its sectoral structure and growth rate, the size of the working-age population, the unemployment rate, and the number of job vacancies.

The source material included statistical data from Eurostat databases, International Federation of Robotics (IFR) reports, market reports from analytical firms, scientific publications on mobile robotics and intelligent manufacturing systems. The national section utilized data from reports from the Central Statistical Office and studies on the implementation of Industry 4.0 solutions in Poland. Data analysis was descriptive and analytical in nature. A comparative analysis was also used, allowing for a comparison of the level of robotics and automation development in Poland with other European countries.

A limitation of the study is the lack of access to enterprise operational data, which prevents the assessment of the actual impact of AMR implementations on production efficiency. Nevertheless, the analysis allowed for the formulation of reliable conclusions regarding current market trends and the potential impact of AMR technology on the development of smart manufacturing in Poland and globally.

3. Results

This chapter presents the scale of service robot use, including AMRs, identifies market trends, and compares Poland's position in the European and global markets. The impact of AMR implementation on the employment structure in the manufacturing sector is also determined. The analysis was conducted according to the IFR robot classification. According to this classification, AMRs are professional service robots and constitute a key element of the smart factory, automating material transport and integrating with production systems. In the context of the smart factory, their role involves autonomous material transport, integration with production systems, and supporting process flexibility and optimization. Global sales of professional service robots increased by 9% in 2024. According to IFR, the number of professional service robots sold in 2024 reached 199,000 units. The five most popular application groups for professional service robots (excluding medical robots) in terms of unit sales in 2024 were transportation and logistics, hospitality, professional cleaning, agriculture, and search and rescue, security (IFR, 2025). Mobile robots, including AMRs, are well-known in the transport and logistics sector, which encompasses the use of mobile robots in internal transport and logistics processes within manufacturing enterprises (transporting raw materials, semi-finished products, and finished products between plant locations, warehousing, and picking in production halls). In 2024, 14% more units were sold in this sector compared to 2023 (Figure 1).

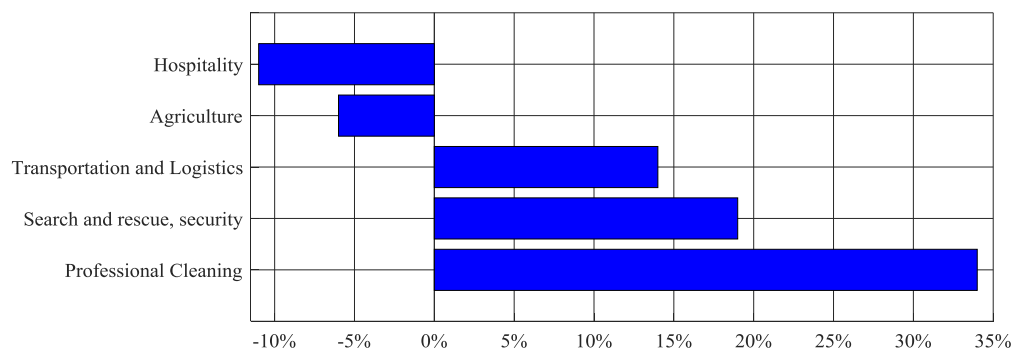


Figure 1. Growth rates of sales of professional service robots in 2024 compared to 2023, broken down by sector.

Source: International Federation of Robotics – 06.05.2025.

Robots designed for transportation and logistics applications accounted for the largest number of robots sold among professional service robots in 2024 (Figure 2). This is also reflected in the number of suppliers offering this application group. IFR provides information on 333 companies worldwide supplying various types of logistics robots.

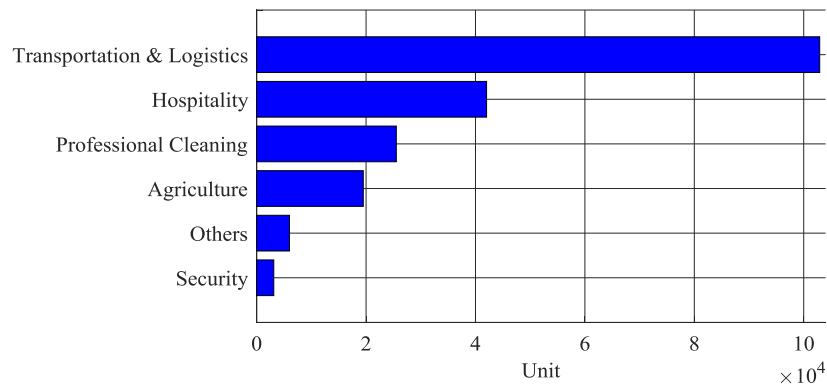


Figure 2. The number of professional service robots sold in each sector and their percentage share.

Source: International Federation of Robotics – 06.05.2025.

Eurostat data allows us to assess the degree of actual implementation of service robots, indicating the percentage of enterprises that use this type of technology in production and logistics processes, which is a practical reflection of trends related to the automation and digitalization of industry. The data presented in Figure 3 shows the percentage of enterprises (with more than 10 employees) using professional service robots.

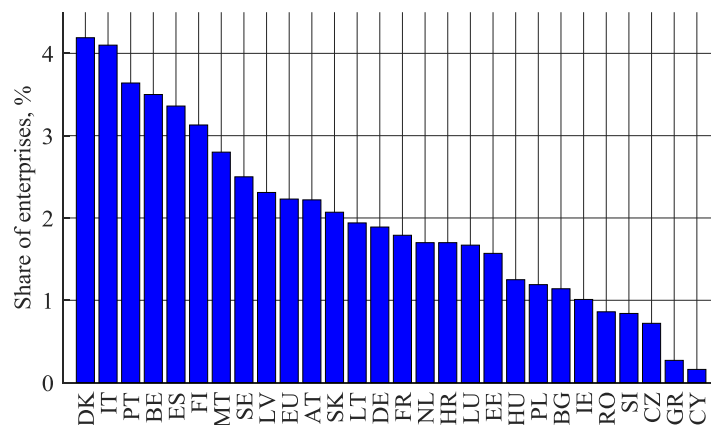


Figure 3. Share of enterprises using service robots in 2022 (enterprises ≥ 10 employees, excluding financial sector).

Source: own study based on data from the Eurostat database - 20.09.2025.

The prevalence of service robots is highest in Danish and Italian companies, at over 4%. Portuguese, Belgian, Spanish, and Finnish companies are second, with a level of over 3%. The EU average is 2.23%, with a maximum of 4.19% in Danish companies and a lowest of 0.16% in Cyprus. Polish companies using professional service robots accounted for 1.19% in 2022. Figure 4 presents the percentage of companies using professional service robots by employee number.

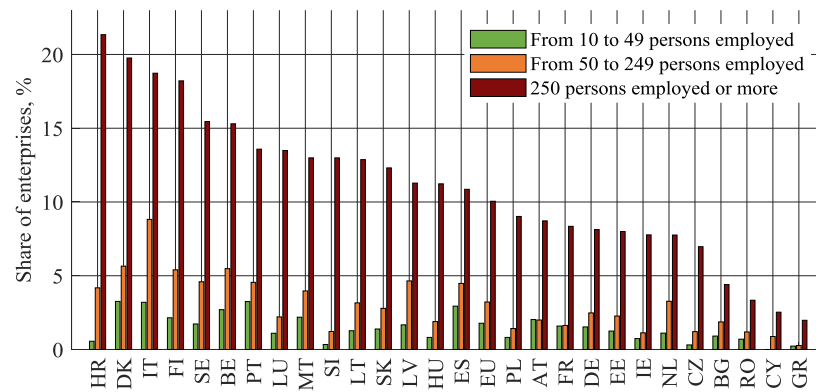


Figure 4. Share of enterprises using service robots by size of enterprises in 2022.

Source: own study based on data from the Eurostat database - 20.09.2025.

The graph shows that larger companies are more likely to use service robots in every country. Medium-sized and large enterprises are generally more likely to implement new technologies because they have easier access to investment capital and can utilize the necessary skills. In the EU, the average for small enterprises is 1.78%, for medium-sized enterprises 3.22%, and for large enterprises 10.05%.

Polish companies using professional service robots accounted for 1.19% of the total in 2022. This share was 0.8% for small companies, 1.4% for medium-sized companies, and 9% for large companies. Considering the type of business, professional service robots were most frequently used in businesses related to the repair and maintenance of computers and communications equipment (2.7%). Next in line are transportation and storage (1.6%) and manufacturing (1.6%). A detailed breakdown by business type is presented in Figure 5.

Differences in the adoption of service robots across companies of different sizes and industries can be explained by structural factors. The higher adoption of robots in large enterprises stems from greater technological potential and the availability of financial resources to invest in automation. In small companies, financial constraints and the scale of operations limit the ability to implement new technologies. However, variations across industries reflect the specific nature of processes – in sectors such as computer repair and maintenance, service robots are used for repetitive and precise tasks, while in other areas, their use is more difficult or less profitable. Considering these conditions allows for a better understanding of the structure of service robot adoption in Poland and indicates areas where technological or training support could enhance their use.

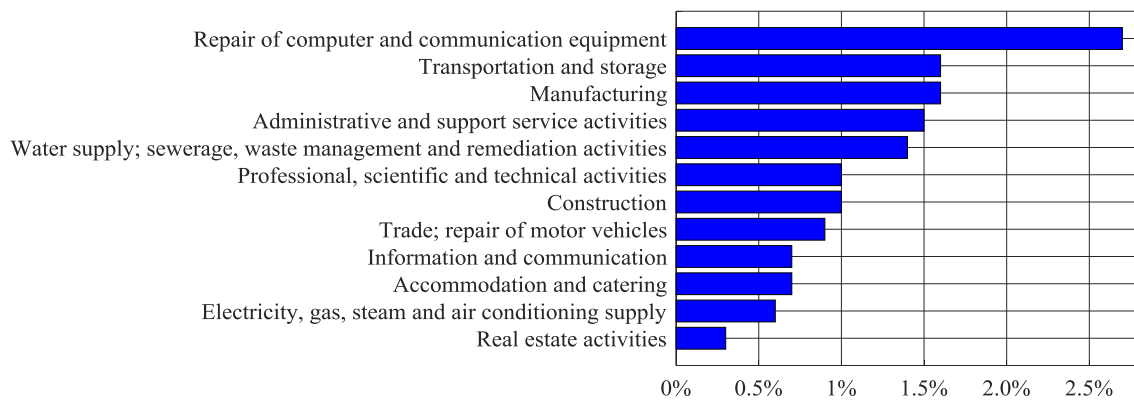


Figure 5. Enterprises in Poland using service robots in 2022.

Source: own study based on data from the Local Data Bank database – 16.06.2025.

Autonomous mobile robots constitute a significant part of the service robot market. Thanks to their ability to move independently and integrate with production systems, they are becoming a key element of modern industrial solutions. In recent years, the global mobile robot market has been experiencing dynamic growth, which is reflected in the growing number of units sold. In 2022, approximately 121,000 AGV and AMR robots were sold worldwide. Just a year later, in 2023, this number increased to 164,000, with AMRs accounting for more than half. Forecasts for the coming years are even more optimistic. By the end of 2025, annual sales are expected to exceed 250,000 units (Zrobotyzowany.pl, 2025).

According to data published by Statzon, presented in Figure 6, the global autonomous mobile robot market value in 2023 was USD 1.4 billion, which represents a 9% increase compared to the previous year (Statzon, 2025).

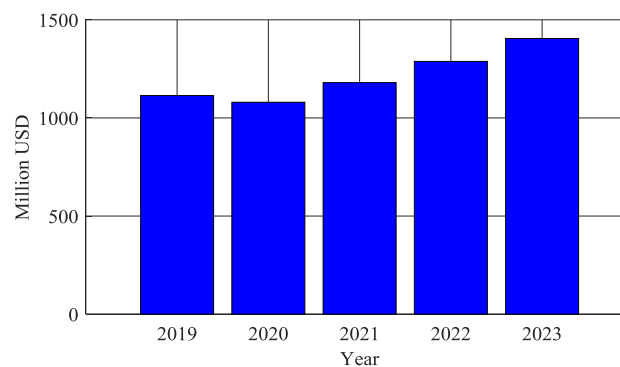


Figure 6. Global Autonomous Mobile Robot Market.

Source: Statzon – 15.06.2025.

The mobile robotics market is growing steadily. North America stands out in particular for the use of AMRs, clearly outperforming other regions. Market data analysis indicates that North America maintains its leading position in the global AMR market. The region's dominance stems from several factors: advanced technology and innovation, including the presence of market leaders, startups, and leading research centers; extensive logistics and warehousing infrastructure, including large distribution centers and developed e-commerce networks;

economic drivers for automation, such as high labor costs, pressure for process efficiency, and growing online ordering; and public acceptance and willingness to implement modern technologies, which facilitate the rapid adoption of robots in operational practice. These results underscore that North America remains a key market for the testing and implementation of AMRs, serving as a model for other regions, including Europe and Asia. The regional share of the global AMR market in 2023 is presented in Figure 7. The data shows that North America remains the clear leader, accounting for 35% of the global market. Asia-Pacific is second with a 30% share, while Europe accounted for 21% of the market value. Other regions of the world accounted for 14%. This structure reflects global trends and regions that have invested in the transformation and automation of intralogistics processes in recent years (Statzon, 2025).

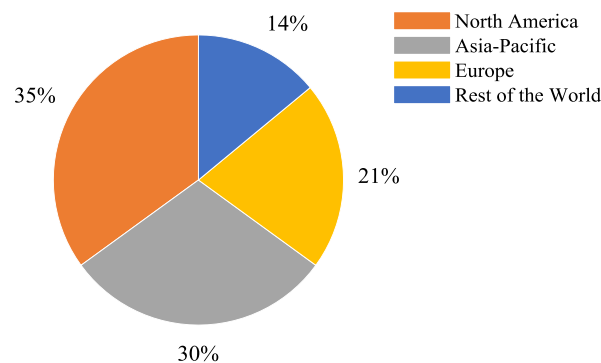


Figure 7. Regional share in the global autonomous mobile robots market.

Source: Statzon – 15.06.2025.

AMR robot technology is considered advanced, but its implementation still faces a number of barriers resulting from limited customer awareness, lack of standardization, lack of knowledge, and integration problems with existing infrastructure, which still result in low market penetration of this technology. It's worth noting that while the pandemic significantly increased interest in in-plant automation, accelerating solution testing, this hasn't contributed to a rapid and widespread increase in wider-scale implementations. Implementing AMR robots often requires close collaboration between multiple units within the organization, multi-stage planning, complex knowledge, and appropriate preparation of the technical infrastructure, particularly in terms of wireless connectivity, which is crucial for stable robot operation in dynamic industrial environments.

The degree of implementation of AMR solutions depends largely on the specific industry. The largest recipients of these technologies remain sectors such as logistics, the food industry, and healthcare. However, in many industries, insufficient awareness of the benefits, implementation expertise, and adequate budget remain barriers, significantly slowing down the implementation process of these solutions. An interesting solution to budgetary issues that lowers the entry threshold is the development of the RaaS (Robotics as a Service) model, which enables the use of robots via subscription. This approach increases the operational flexibility of enterprises, allowing them to test various automation scenarios without the need for high

upfront capital expenditures. As a result, the RaaS model is becoming increasingly popular, especially among smaller companies (IFR, 2025).

In 2023, the logistics industry was the most significant contributor to the global AMR market, accounting for 24% of the total market share. This high share is due to the rapid growth of the warehousing sector, e-commerce, and the expansion of distribution centers, where AMRs significantly increase efficiency and reduce operating costs. This was followed by the food industry (14%), healthcare (11%), and the fast-moving consumer goods (FMCG) sector (11%). All these dominant sectors are characterized by high requirements for the fast and hygienic transport of finished products. Additionally, sectors such as pharmaceuticals, electronics, and automotive also had significant shares. This structure demonstrates that AMRs are becoming a universally applicable technology, gradually entering a broader range of industries. Figure 8 shows the percentage share of these sectors in the global AGV and AMR robot market (Statzon, 2025).

In the European context, Poland represents a small segment of the AMR market, but estimates indicate a growing interest in internal transport automation. Although Poland's share in the European market is limited, domestic companies are gradually implementing autonomous mobile robots, which is consistent with the global trend of increasing adoption of this technology. Estimates indicate that the number of autonomous mobile robot installations in Polish companies represents only 2–3% of the overall European market. Despite their relatively small scale, clear signs of growing adoption of these technologies are observed, especially in warehouses, logistics centers, and the manufacturing sector, where internal transport automation is becoming increasingly economically attractive. The growing interest in AMRs in Poland is consistent with the global trend of increasing automation of logistics and production processes, indicating that the domestic market may accelerate the pace of autonomous mobile robot implementation in the coming years.

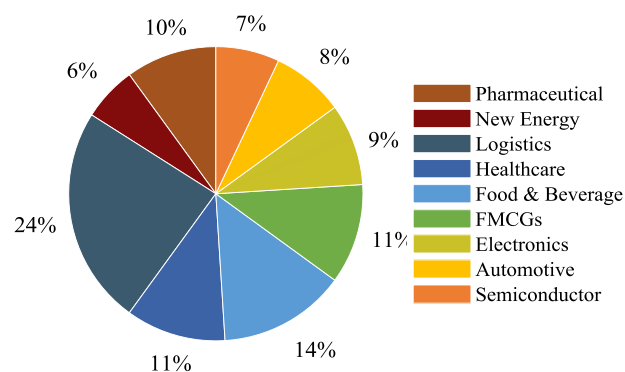


Figure 8. Types and market shares of autonomous mobile robots.

Source: Statzon – 15.06.2025.

The global market for autonomous mobile robots is growing at an extremely dynamic pace, with a projected average annual growth rate (CAGR) of approximately 22.3% between 2025 and 2034 (Precedence Research, 2025). This rapid growth is driven by the growing importance

of automation in the data-driven economy, the increasing demand for flexible logistics solutions, and the intensifying global demographic challenges. Europe, one of the leaders in industrial transformation, is also seeing rapid development of the mobile robot market. The average growth rate between 2022 and 2032 is estimated at approximately 18-20% (ASD Reports, 2025; OpenPR, 2025). This growth is fueled by both the ongoing digitization of industry and socioeconomic factors. Consequently, process automation, including the implementation of AMRs, is becoming a way for European companies to maintain business continuity, cost stability, and a high level of service quality. Analysis of the demographic structure of the working-age population (15–64 years) in EU countries and Poland shows a clear downward trend in recent years. In Poland, the percentage of the working-age population decreased from 70.1% in 2014 to 64.4% in 2024. Similar trends are observed in most EU member states, although at different rates (Table 1).

Table 1.

Working-age population in European Union countries (%)

	AT	BE	BG	CY	CZ	DE	DK	EE	ES	EU	FI	FR	GR	HR
2014	67.4	65.2	66.2	69.9	67.6	66.0	64.5	65.8	66.7	66.0	64.2	63.4	64.9	66.7
2024	65.8	63.8	62.1	67.0	63.6	63.6	63.6	63.5	66.4	63.8	61.8	61.6	63.6	62.9

	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK
2014	68.1	65.9	64.6	67.1	69.1	66.2	67.8	65.7	70.1	65.4	68.0	63.5	67.9	71.1
2024	64.9	65.6	63.5	65.1	69.2	63.0	69.3	64.4	64.4	63.1	64.1	62.3	63.5	65.7

Source: own study based on data from the Eurostat database - 20.09.2025.

Changes in the demographic structure of the working-age population in Poland and the European Union have a significant impact on the functioning of the labor market, as reflected in the unemployment rate and job vacancy rates. A comparison of data for the manufacturing, transportation, and warehousing sectors in Poland and the European Union in 2014 and 2024 indicates a significant shift in the labor market structure (Table 2, Table 3). In 2014, the average unemployment rate in these sectors in the EU was 10.9%, with a job vacancy rate of 1.0%. In Poland, the corresponding figures were 9.0% and 0.6%, respectively, reflecting low labor market absorption, limited demand for workers, and relatively low investment activity in industry and logistics. In 2024, the situation changed significantly—average unemployment in the manufacturing, transportation, and warehousing sectors in the EU fell to 5.9%, while the share of job vacancies more than doubled, to 2.1%. In Poland, unemployment was even lower, at 2.9%, with a job vacancy rate of 1.0%. These data clearly indicate a transition from a market characterized by a labor surplus to a market with a clear labor shortage.

Table 2.*Unemployment rate in European Union countries (%)*

	AT	BE	BG	CY	CZ	DE	DK	EE	ES	EU	FI	FR	GR	HR
2014	5.7	8.6	11.5	16.1	6.1	5.0	7.0	7.3	24.5	10.9	8.6	10.3	26.6	17.3
2024	5.2	5.7	4.2	4.9	2.6	3.4	6.2	7.6	11.4	5.9	8.4	7.4	10.1	5.1

	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK
2014	7.7	11.9	12.7	10.7	5.9	10.9	5.7	7.4	9.0	14.1	6.8	8.0	9.8	13.2
2024	4.5	4.3	6.5	7.1	6.4	6.9	3.1	3.7	2.9	6.4	5.5	8.4	3.7	5.4

Source: own study based on data from the Eurostat database - 20.09.2025.

Table 3.*Job vacancy rate in European Union countries (%)*

	AT	BE	BG	CY	CZ	DE	DK	EE	ES	EU	FI	FR	GR	HR
2014	1.4	1.6	0.5	0.6	1.1	1.6	1.2	1.2	0.3	1.0	1.2	0.7	0.9	0.6
2024	3.9	4.1	0.6	2.6	3.8	2.6	2.3	0.9	0.6	2.1	1.2	2.3	2.0	1.4

	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK
2014	1.4	0.6	N/A	1.1	0.4	1.8	N/A	1.3	0.6	0.4	0.8	1.2	1.4	0.7
2024	1.8	1.0	2.0	1.9	1.0	2.5	3.0	5.2	1.0	1.1	0.7	2.0	2.6	0.9

Source: own study based on data from the Eurostat database - 20.09.2025.

In the context of these demographic and labor market changes, it is worth examining the role of automation and robotization in enterprises. Analysis of data for EU countries indicates that the development of automation is the result of a complex interplay of demographic factors, the labor market, and investment strategies, and these relationships are not direct. Most countries observed a decline in the working-age population between 2014 and 2024, which theoretically increases the pressure for automation. For example, in Poland, the working-age population decreased from 70.1% to 64.4%, while the share of robots in enterprises reached 1.19% in 2022. In this context, low unemployment (2.9%) and moderate job vacancies (1.0%) in 2024 suggest that automation is complementing the limited labor supply. It is worth noting that the data comes from different periods – the robot utilization rate is from 2022, while the unemployment and job vacancy rates are from 2024. This comparison is justified because decisions on investments in automation respond to earlier demographic changes and labor market trends, and the process of implementing the technology takes time, so a direct comparison of indicators from the same year might not reflect the actual relationships.

In Germany (a decline from 66% to 63.6% of the working-age population) and Italy (64.6% to 63.5%), the share of robots is significantly higher, despite moderate unemployment and available job vacancies. This demonstrates that, in addition to labor supply, the development of robotization is shaped by capital availability, prior technological investments, and corporate policies. There are also significant cases where demographics and labor market indicators do not fully explain the level of automation. Spain, with a nearly unchanged working-age population (66.7% in 2014 and 66.4% in 2024), high unemployment (11.35%), and low job

vacancies (0.1%), maintains a relatively high share of robots (3.36%), demonstrating that technology investments can grow regardless of short-term labor supply. Similarly, Portugal, Finland, and Luxembourg indicate that structural, economic, and strategic factors are as important as demographics and the labor market.

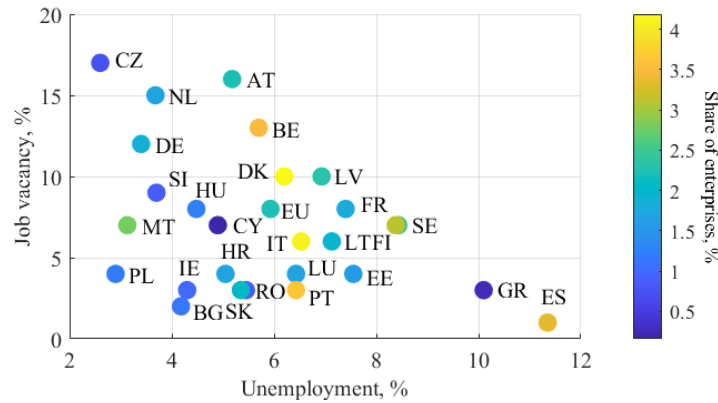


Figure 9. The relationship between the share of robots in enterprises (2022), the unemployment rate and the job vacancy rate (2024) in EU countries.

Source: own study based on data from the Eurostat database - 20.09.2025.

The conclusions from the analysis of the graph, which presents the relationships between unemployment, vacancies and the share of robots in enterprises, show general correlations: moderate labor market indicators may support automation, but they are not its only determinant (fig. 9). These trends confirm that robotization is a multifactorial process, in which demographics and the labor market influence investment decisions, but their impact is modulated by access to capital, company strategy, and national technological policies.

4. Discussion

Analysis of data on the use of service robots in manufacturing companies in EU countries shows that the development of automation is a multifactorial process. It is influenced by both demographic factors, such as the declining working-age population, and the labor market situation, including unemployment and job vacancy rates. Demographic changes, including an aging population and the growing share of older workers, favor the adoption of robots and automation technologies, as a reduced supply of working-age labor increases the pressure to replace human labor with technological capital. This relationship has been confirmed in the scientific literature: both in theoretical and empirical studies demonstrating the impact of population aging on automation (Acemoglu, Restrepo, 2022), quantitative models analyzing the mechanisms of this process (Jacobs, Heylen, 2024), and in macroeconomic perspectives, which show that population aging favors the increased use of robots and automation (Stähler, 2021). Research indicates that a limited supply of working-age labor can favor increased

investment in robotization, although the pace of technology implementation also depends on many other conditions.

There is also noticeable variation between countries: in some countries, despite moderate unemployment and labor availability, the share of robots is high, suggesting the role of companies' investment strategies, capital availability, and prior experience with technology. In other cases—such as Spain—high levels of automation occur despite a stable working-age population and high unemployment, demonstrating that decisions to implement robots may be driven by other factors, such as operational efficiency, the need to improve service quality, or improved competitiveness.

Differences in the pace of robot adoption across EU countries provide a better understanding of the potential barriers and determinants of autonomous mobile robot (AMR) adoption in industry. The high share of robots in countries with a limited working-age population suggests that investment costs and insufficient digital infrastructure may be the main constraints to implementation. In countries where the number of manufacturing vacancies remains high and the pace of robot adoption is moderate, barriers are organizational in nature, including the need to reorganize production processes and a shortage of qualified personnel to operate AMR systems. Consequently, the market growth rate and the degree of robot adoption in Europe are driven by a combination of financial factors, employment structure, availability of skills, and companies' ability to integrate new technologies. Comparing robot adoption rates across countries and sectors can indirectly indicate the relative importance of individual barriers. However, these conclusions are qualitative in nature and require further quantitative research for accurate verification.

In this context, the concept of smart factories is gaining increasing importance, where service robots, including autonomous mobile robots, are an integral part of integrated production and logistics processes. In smart factories, automation is not limited to individual machines – it encompasses comprehensive material flow management, performance monitoring, and adaptation to changing working conditions, allowing companies to better respond to demographic changes and labor supply constraints.

Overall, the data presented confirm that automation in the manufacturing sector, particularly in the form of service robots such as AMRs, does not follow demographic changes or labor market fluctuations linearly. It is the result of a complex interaction of structural, economic, and technological factors. These trends suggest that policies supporting automation development should consider not only labor shortages but also investments in technological infrastructure, employee training, and company adaptation strategies.

5. Summary

Autonomous mobile robots are paving a new direction in industrial transformation, integrating mobile automation with smart factory concepts. Their growing importance stems not only from the desire to streamline logistics processes but also from the need for companies to adapt to the changing demographic and market environment, including the shortage of skilled labor. The introduction of AMRs in manufacturing plants creates the opportunity to shape flexible and resilient production systems in which automation and human skills coexist, creating synergistic effects in terms of efficiency, quality, and process innovation. Furthermore, the development of mobile automation points to new organizational and strategic perspectives in the industrial sector – from the thoughtful allocation of human resources to the implementation of more complex, intelligent production management systems. AMRs not only support current operational needs but also shape future factory operating models, where the role of humans is shifting toward tasks requiring creativity, analysis, and decision-making, rather than merely repetitive work. In the long term, the development of the AMR market can contribute to increased competitiveness of companies, reducing staffing pressures, and introducing innovative production standards. An industry that effectively integrates autonomous technologies with qualified staff gains an advantage in adapting to dynamic market changes and creates the foundations for sustainable production development in the conditions of global digitalization and automation.

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OPTIMIZING PARKING OPERATIONS USING SMART CITY SOLUTIONS

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Purpose: The aim of the research was to compare the functioning of paid parking systems in two cities – Rzeszów and Košice – and to identify their optimization potential.

Design/methodology/approach: The research results presented in this paper were obtained through the use of benchmarking methods, document analysis, and expert interviews. The comparative analysis allowed for the compilation of data on paid parking systems in the analyzed cities. The analysis of city documents allowed for a review of mobility strategies and city reports. Expert interviews were conducted with city hall employees in Rzeszów and Košice responsible for the operation of the paid parking system to obtain information on the principles of operation, organizational structure and planned directions of development of the system.

Findings: In the context of the cities being compared, analyzing optimization opportunities allows us to assess which solutions are most effective in a given urban environment and how they can be adapted to other cities. Conclusions from such a comparison can form the basis for formulating recommendations for effective parking space management and the development of intelligent mobility systems.

Research limitations/implications: The research conducted is based on secondary data from official city sources, reports, and resolutions. It doesn't include empirical verification of user opinions.

Practical implications: The research results can serve as diagnostic and advisory material for local decision-makers when designing urban mobility policies.

Social implications: In the broader perspective, paid parking systems that help reduce the number of cars in city centers can contribute to improving residents' quality of life by reducing traffic congestion, noise, and air pollution. They therefore play a significant role in achieving sustainable development goals and promoting more conscious travel behaviors in urban society.

Originality/value: This work presents a comparison of similar mid-sized cities, allowing for a focus on technological and organizational factors while eliminating the influence of social and economic differences. Another original element of the work is an attempt to identify optimization potential in the context of different countries, which may be useful for city decision-makers planning modernization or introducing new parking solutions based on international experience. This ensures that the research results have practical and cognitive value, offering implications for both science and urban mobility management practice in various countries.

Keywords: smart city, paid parking system, intelligent parking, sustainable urban management.

Category of the paper: research paper.

1. Introduction

Modern cities face enormous challenges related to traffic management and limited parking space. The increase in the number of private vehicles in recent decades has led to problems such as congestion in city centers, excessive exhaust emissions, and a decline in residents quality of life. One of the key tools local governments use to mitigate these phenomena is paid parking systems. Their primary function is not only to generate revenue for the city budget but, above all, to regulate demand for parking spaces through the use of economic mechanisms. From a transport policy perspective, an effectively designed paid parking system can serve as an optimization tool, balancing driver needs with the efficient use of urban space. Key elements include the tariff structure, paid parking zones, digital systems for managing payments (e.g., mobile apps, e-parking meters), and mechanisms for dynamic pricing based on demand. Recent years have seen a growing interest in cities implementing smart parking solutions that combine IT technologies with real-time data analysis. These solutions not only enable better parking space management but also reduce search traffic, resulting in reduced congestion and emissions (Bismantoko et al., 2018). Smart Parking Systems utilize technologies such as space occupancy sensors, mobile applications, real-time information systems, and electronic payments to increase the efficiency of urban space use and reduce traffic congestion. Implementing such solutions aligns with the concept of a smart city, which bases decisions on data and strives to optimize urban processes through the digitalization of public services (Attaran et al., 2022; Battarra et al., 2018; Zapolsky et al., 2020).

The authors of many studies on parking management focus on optimizing the use of the limited number of parking spaces in cities. The goal of optimization is primarily to promote sustainable urban mobility. Through appropriately designed pricing policies, zoning, and the use of digital technologies, paid parking systems can influence residents' travel behavior and reduce excessive car traffic in city centers. These include research areas such as forecasting parking space occupancy using data from actual parking systems (Badii et al., 2018; Balmer et al., 2021), determining indicators describing system efficiency (Cats et al., 2016; Kuo et al., 2024; Zhu et al., 2018), and research on technical solutions for intelligent parking (Alkheder et al., 2016; Singh et al., 2022; Bismantoko et al., 2018; Hilmani et al., 2018).

Despite the extensive literature on urban parking policy, there is still a lack of comparative studies that consider the international context and analyze the optimization potential of existing solutions. Comparing paid parking systems in different cities allows for an assessment of the effectiveness of the solutions implemented and their optimization potential. The selection of two urban units with diverse spatial structures and approaches to transportation policy allows us to see the extent to which administrative and technological decisions influence the effectiveness of parking space management. Such an analysis can serve as a starting point for formulating recommendations for local governments regarding the further development of

parking systems, taking into account user needs, sustainable mobility principles, and the potential use of analytical and optimization tools.

The aim of this article is to compare paid parking systems in two selected mid-sized cities and assess their potential for optimizing urban space utilization and improving traffic flow. The analysis will consider aspects such as the systems' organizational structure, fee calculation method, technological solutions, and the effects of implemented regulatory mechanisms.

2. Methods

The aim of the study is to compare the operation of paid parking systems in two cities across different countries and identify their optimization potential. To achieve this goal, a variety of qualitative and quantitative research methods were employed: document analysis, benchmarking, and expert interviews. The use of several complementary methods allowed for a more comprehensive and credible picture of the phenomenon under study. The primary research method was document analysis, which involved a systematic review and interpretation of available written sources regarding the operation of paid parking systems. Primarily, official and planning documents were used, such as city council resolutions, paid parking zone regulations, reports on the activities of system operators, and city transport strategies. This qualitative analysis allowed us to determine the formal foundations of the systems operation, their organizational structure, pricing principles, zone validity periods, and the technological solutions used. The information obtained served as a starting point for further comparative analysis and interpretation of differences between the studied cities. The second method employed was comparative analysis, aimed at comparing and assessing selected features of the paid parking systems in the two cities in terms of their effectiveness, organization, and accessibility. Benchmarking allows for the identification of good practices and solutions used in various urban centers, which can serve as models or benchmarks for other local government units. The study utilized a mixed quantitative and qualitative approach. On the one hand, a set of measurable indicators was analyzed (e.g., the number of parking spaces and rates), while on the other, a descriptive interpretation of differences in pricing policies, space management, and the implementation of technological solutions was provided. This allowed for the benchmarking not only to compare numerical values but also to understand the organizational and legal context of the systems' operation. Document analysis and benchmarking were supplemented by expert interviews, which allowed us to obtain information directly from city hall employees in Rzeszów and Košice who have knowledge and experience in managing paid parking systems. Questions addressed, among other things, the objectives of introducing the paid parking system, its operational principles, management tools used, and development plans. The data obtained from the interviews allowed for a deeper quantitative

analysis with a practical and interpretative perspective, revealing the factors determining the effectiveness of individual solutions.

3. Research object

Two medium-sized cities – Rzeszów (Poland) and Košice (Slovakia) – located directly adjacent to the Polish-Slovak border were selected for the analysis. Rzeszów and Košice were chosen as the study subjects due to their similar size, administrative functions, and similar challenges related to the organization of paid parking systems. Both cities are regional development centers experiencing increasing traffic volumes and the need for effective parking space management. The aim of the analysis is to identify optimization measures and indicators that influence the efficiency, accessibility, and social acceptance of paid parking systems. Comparing Rzeszów and Košice will allow for the identification of differences in organization, technology, pricing policy, and integration with the urban transport system, as well as for identifying areas where improvements or the adoption of best practices are possible.

Rzeszów is a voivodeship capital located in southeastern Poland. It has a population of 198,000 and covers an area of 129.01 km² (Figure 1). The city is the capital of the Podkarpackie Voivodeship and a major economic, commercial, industrial, cultural, and academic center. It is located at the intersection of important road routes, close to the borders with Slovakia and Ukraine. Rzeszów has a clearly defined downtown development zone, which has a radial-concentric layout, with industrial and residential districts clearly demarcated. Within Rzeszów, transportation needs are met by public transport, including buses and individual vehicles. Individual transportation within the city requires access to infrastructure, including parking spaces. The current paid parking zone was established in 2016 (Dobrzański et al., 2023). A detailed description of the zone is presented in the Results section.



Figure 1. An overview map showing the location of the analyzed cities.

Source: Own study.

The second city analyzed is Košice. It is the second largest city in Slovakia, located in the eastern part of the country, and serves as a regional economic, cultural, and transportation center (Figure 1). Covering an area of approximately 243.7 km² and with a population of approximately 225,000, the city is a significant urban and metropolitan hub. In terms of transportation, Košice plays a significant role in the national and international transportation network – expressways and European routes, including the E571, run through the city, and the existing bypass helps alleviate transit traffic in the city center. Within the city, there is a well-developed public transportation system, including buses and an active tram network, which is a key element of public transportation. A paid parking zone was introduced in Košice in 2009 and was modified in 2023. Detailed characteristics of the zone is presented in the Results section.

4. Results

The aim of this research phase was to determine the extent to which the solutions operating in the two analyzed cities meet the assumptions of an effective paid parking system and what optimization potential they demonstrate. The analysis is based on a combination of selected organizational, economic, functional, and socio-environmental indicators, which allow for the assessment of the effectiveness and development of the systems studied. The use of indicators enables a comparative assessment based on objective data from publicly available sources, such as city reports, strategic documents, and data from city hall staff in Rzeszów and Košice managing the paid parking systems. The indicators were selected to capture key aspects of the systems' operation: from their organizational structure and tariffs, through economic efficiency, to social and environmental impact. The indicators were divided into four main groups:

- organizational, describing the scale and structure of the system,
- economic, relating to tariff policy,
- functional, relating to the availability of parking spaces and technology,
- socio-environmental, illustrating the impact of the system on residents and the quality of life in the city.

4.1. Organizational indicators

Analysis of organizational metrics allows us to identify areas requiring improvement and implement optimization measures, such as better adapting zones and the number of spaces to actual demand, modifying fee collection hours, or implementing modern digital solutions that increase the efficiency and availability of the parking system. The metrics detailed here include the number of paid parking subzones, the number of spaces subject to fees, the area of paid zones, the hours of application of fees, and the level of system digitalization.

In the case of Rzeszów, the range of the external border of the Paid Parking Zone in Rzeszów was determined primarily taking into account the natural boundaries occurring in the city space such as the river bed, railway tracks (Figure 2). Initially, the zone consisted of two subzones: I and II. In 2020, it was expanded to include two additional subzones: III and IV. Subzone I, marked in blue, covers the city center and downtown Rzeszów, including the area around the train station. Subzone II, marked in orange, covers the areas surrounding the city center. Subzone II complements Subzone I. This area surrounds subzone I and is not interrupted by it anywhere. Subzone II serves a crucial function, separating subzone I from the area without parking restrictions to the south, where there is no natural boundary. Besides providing convenient parking for residents, an additional benefit of the buffer zone is that the cars parked in the blue subzone are distributed over a much larger area, improving the overall parking situation in the Paid Parking Zone. The remaining two subzones, III and IV (green and red), encompass the area of two residential developments. The layout of each subzone is shown in Figure 2a. In Rzeszów, the zone is valid on weekdays, Monday through Friday, from 8:00 a.m. to 8:00 p.m. Parking is free at all other times and days. The Municipal Market and Parking Administration in Rzeszów, an organizational unit of the Rzeszów City Hall, has been appointed as the administrator of the Paid Parking Zone (Municipal Market and Parking Administration in Rzeszów, 2025). In 2021, in cooperation with the Rzeszów Municipality and Asseco Data Systems S.A., a parking space metering system was created within the Paid Parking Zone (Asseco Poland SA, 2025). Rzeszów is the first and only city in Poland to implement this type of solution for monitoring available parking spaces, based largely on camera image analysis, on such a large scale. This system perfectly aligns with the Smart City concept. The metering covers subzones I and II, and partially subzone IV. Subzone I contains 1,577 public parking spaces, and subzone II has 542 spaces. All are metered. Zone III contains 919 public parking spaces that are not metered, while Subzone 4 contains 453 public parking spaces, 81 of which are metered. The entire Paid Parking Zone has a total of 3,491 parking spaces. The area covered by the Paid Parking Zone is 3.8 km², of which Subzone I covers 1.06 km².

Residents can use the e-PARKING mobile app, available on Android and iOS. This app is a crucial part of the parking space occupancy information system in Rzeszów's Paid Parking Zone. It provides drivers with the most up-to-date and detailed information about available and occupied spaces. This information is generated based on data from cameras and sensors that continuously monitor and analyze parking space occupancy. The app is designed to support users in real-time while searching for available spaces, and at the end of the journey, present individual available spaces within the selected parking area. The app utilizes navigation provided by Google Maps. The app simplifies the user's search for available parking spaces. The map displayed within the app makes it easy to locate available spaces. During navigation, the system continuously verifies whether the selected parking lot still has spaces. If all spaces are occupied, the app has mechanisms that notify the driver in advance, allowing them to react

and potentially change their destination to a new space suggested by the system near their initial choice. While navigating to a destination, the app also reports the number of drivers heading to the same parking lot at the same time. The app menu also includes a function that allows you to start a countdown to the end of your paid parking time if you paid at a parking meter. Before the designated time expires, the app sends the user a reminder, allowing you to avoid additional fees for exceeding the parking time. In Rzeszów, variable message boards have also been implemented, providing information on the level of available parking spaces.

In the case of Košice, before 2023, the Paid Parking Zone consisted of: a central urban subzone, 10 subzones for residents, and special parking lots (excluding the central urban subzone and the residential zones). This division was based on the concept of static traffic solutions, with minor changes within the zone boundaries. Parking spaces in these zones (excluding parking lots with barriers) are primarily linear parking lots along sidewalks and roads – with the possibility of longitudinal, diagonal, or perpendicular parking. The regulations also cover so-called barrier parking lots with regulated entry, which are subject to a special tariff system and are located within the Paid Parking Zone or are part of special parking lots. In 2023, changes were introduced, resulting in six zones and special parking spaces being designated (Figure 2). The first subzone, designated as A, covers the city center, while the remaining five subzones are so-called residential zones. Special parking spaces are located near the shopping center and the Public Cemetery. The layout of the individual subzones is shown in Figure 2b. There are 8,099 parking spaces in the paid parking zone. The paid parking zone in Košice operates at different hours depending on the tariff zone type. Information on its validity periods is presented in Table 1. The area covered by the Paid Parking Zone is 4 km², including subzone A covering 1.44 km².

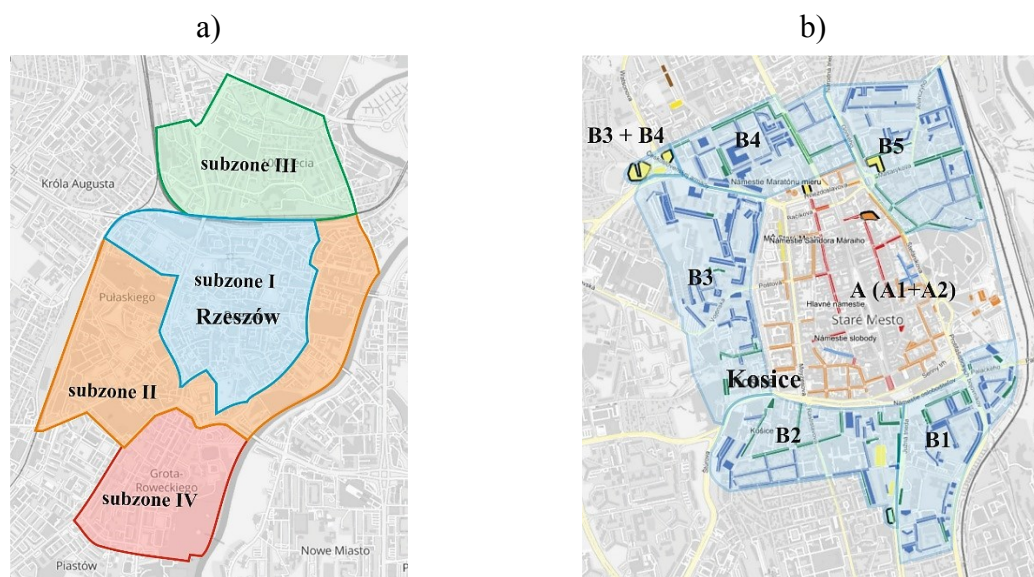


Figure 2. Paid parking zones in the cities of Rzeszów and Košice.

Source: own study based on data from the parking.kosice.sk – 06.10.2025.

Table 1.*Charging period in Košice Paid Parking Zone*

Tariff zone	Basic rate (30 min.)
■ A1	Mon. – Sat. 00:00 – 12:00 a.m.
■ A2	Mon. – Sat. 00:00 – 12:00 a.m.
■ BN	Mon. – Fri. 07:30 – 18:00 p.m.
■ CN	Mon. – Sun. 07:30 – 04:00 p.m. (max. 4 hours per day) Outside of charging hours, parking is only possible with a resident card or local subscription card.
■ N	Mon. – Fri. 07:30 – 18:00 p.m.

Source: parking.kosice.sk – 06.10.2025.

Until 2019, the Paid Parking System was managed by the private company EEI a.s. Subsequently, the Košice Municipality, specifically the Department of Parking, Road Maintenance, and Public Lighting at the Košice City Hall, took over exclusive management of the zone (Košice City Hall, 2025). This year, the City of Košice developed a conceptual plan – Smart City Košice, which envisages the introduction of an intelligent parking system, including space occupancy sensors, navigation to available spaces, and smart payment. Currently, mobile apps enable payment for parking.

4.2. Economic indicators

Economic indicators encompass the financial aspects of the paid parking system, such as the hourly rate structure, subscription fees, resident discounts, and pricing policy, as well as the average hourly cost of parking. These indicators allow us to assess the profitability and sustainability of the system, as well as the extent to which prices and tariffs meet actual user needs and the city's budget. Analyzing these indicators allows us to understand the impact of the adopted pricing policy on driver behavior and the efficiency of parking resource management.

Drivers parking in the Rzeszów Paid Parking Zone are required to pay the parking fee using one of the following methods: purchasing a parking ticket from a parking meter with a clearly defined parking time and vehicle registration number; paying via a mobile payment system; or purchasing one of the available subscription types. Monitoring the Paid Parking Zone by inspectors is a key element in ensuring the proper functioning of the city's parking infrastructure. Inspectors regularly patrol designated zones, verifying that parking fees have been paid by drivers. In the course of their duties, they use modern tools such as license plate readers, allowing them to quickly and effectively detect violations and issue any fines. The fee schedule for Rzeszów is presented in Table 2. The most expensive fees are in Parking Zone I, with the hourly rate increasing to the third hour of parking. For parking periods exceeding three hours, the fee is charged at the first hourly rate. When paying via mobile app, some apps allow drivers to pay only for the time the car was actually in the parking lot.

Table 2.*Fees in the Rzeszów Paid Parking Zone in*

Subzone	First hour	Second hour	Third hour	Fourth hour and each subsequent hour
Subzone I	1,18 €	1,42 €	1,70 €	1,18 €
Subzone II	0,71 €	0,85 €	1,01 €	0,71 €
Subzone III	0,71 €	0,85 €	1,01 €	0,71 €
Subzone IV	0,71 €	0,85 €	1,01 €	0,71 €

Source: Own study.

It is also possible to purchase one of the available subscriptions: resident, standard, for people with disabilities, for a hybrid vehicle and for an electric vehicle. A vehicle with a purchased subscription can park within the zone or a specific subzone on all days of the week and during all hours of paid parking.

In Košice, the paid parking area is divided into various tariff zones (including A1, A2, BN, and N). Each tariff zone differs in location, fee amounts, and hours of charge. Zones closest to the city center (e.g., A(A1, A2)) have the highest hourly rates, while zones further away or with less traffic (e.g., N) have lower rates. Furthermore, in some zones, the fee may apply to weekends or afternoons, while in others, the fee may be shorter or may not apply during part of the week. A summary of the fee rates in each tariff zone is presented in Table 3.

Table 3.*Fees in the Košice Paid Parking Zone*

Subzone	Basic rate (30 min.)	Maximum daily rate/ Price of daily ticket
Subzone A1	1,50 €	24,00 €
Subzone A2	1,00 €	16,00 €
Subzone BN	0,50 €	6,00 €
Subzone CN	0,30 €	3,60 €
Subzone N	0,30 €	3,00 €

Source: parking.kosice.sk – 06.10.2025.

Drivers using the Košice Paid Parking Zone pay the fees, just like in Rzeszów, using parking meters, mobile apps, or purchased resident cards or subscriptions. Additionally, payment can be made via SMS message on all mobile networks operated by Orange Slovensko, Slovak Telekom, O2 Slovakia, s, and SWAN), depending on the terms and conditions of the service provided to the specific mobile network user. A bonus system encourages users to use the Paid Parking Zone. The cheapest payment method is available via the app. A 10% discount will automatically be applied to the regular price. Some apps offer parking for less than 30 minutes (minimum 15 minutes), with the option to extend it at a per-minute rate. Košice residents can take advantage of a special 25% discount using the bonus card (combined with the 10% discount when paying via the app, a discount of up to 35%). The discount doesn't apply to payments via text message or parking at the barrier. For multi-day stays, it is possible to purchase a zone pass valid for 10 days. For long-term parking, it is advantageous to purchase a parking card. Paid Parking Zone monitoring is carried out by the municipal police, which operates a vehicle equipped with a camera and dedicated software. Connecting to the electronic

vehicle registration system allows for automatic checking of the database to determine whether a vehicle has a paid parking ticket for a given day and time, either via device or SMS message.

Based on the presented fee tables, the average hourly parking cost was calculated. This indicator is important because it allows for comparison of fee levels across different paid parking zones and an assessment of the overall affordability of parking spaces. Parking costs were analyzed in central urban subzones. Significant differences were found between the cities studied. In Rzeszów, the relative parking cost was 17% of the minimum wage, while in Košice it reached 58%. This means that parking costs in Rzeszów are relatively low, which may encourage vehicles to stay longer in the zone and thus limit parking space turnover. In Košice, however, the high financial burden on minimum wage earners may discourage some drivers from using the zone. The index calculated relative to the minimum wage allows for an assessment of economic accessibility for the most vulnerable income group. The results suggest that in the former, parking is relatively accessible, while in the latter, the zone is burdensome for those with the lowest incomes. Considering the optimal relative cost of parking in central subzones in relation to optimization policies, it typically falls within the range of 15-25% of the minimum wage. Indicators below this level suggest the possibility of introducing short-term parking mechanisms or moderate rate increases to increase turnover. Indicators significantly above this range require consideration of fee reductions or the introduction of discounts for residents and businesses to increase the efficient use of parking spaces. In the case of Rzeszów, this indicator is within the norm, while Košice implements a system of discounts and bonuses.

4.3. Functional indicators

Functional indicators allow us to assess the efficiency of the parking system from a user perspective and the effectiveness of urban space management. They focus on how quickly and easily drivers can find a space, how often spaces are used by different users, and the extent to which technologies support the daily operation of the system.

The parking space occupancy rate in Subzone I of the paid parking system in Rzeszów is 50-60% (Dobrzański, Dobrzańska, 2025). Similar results are achieved in Subzone A in Košice.

In the case of parking spaces for people with disabilities, they constitute approximately 4% of all public parking spaces in Rzeszów, while in Košice the figure is over 5%.

In Rzeszów, the fee for a parking permit for people with disabilities is 0.24€, unless they park in designated spaces, known as envelopes. If a driver parks on an envelope and has a European Parking Card, they are completely exempt from parking fees in the zone. The same rate applies to subscriptions for drivers with electric cars. In Košice, vehicles with a disabled parking permit and parked in designated disabled spaces, regardless of whether they are located in the city center or in residential areas, are exempt from parking fees. However, free parking is not available in parking lots with barriers. Parking in designated disabled spaces is not time-limited. Residents with disabilities can also benefit from discounts for purchasing a resident card.

4.4. Socio-environmental indicators

Socio-environmental indicators allow us to assess the impact of the Paid Parking Zone on residents, vehicle traffic, and the quality of the urban environment. They encompass demographic and mobility aspects, such as the number of residents, the number of cars per 1,000 residents, the number of passenger kilometers, as well as the ecological impact, including NO₂ emissions in the city's central zone.

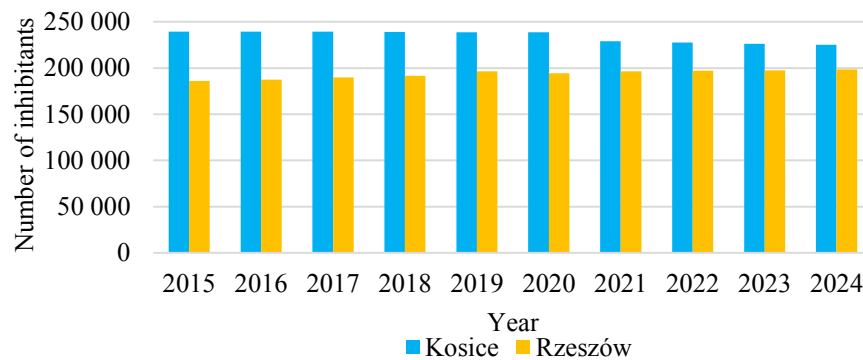


Figure 3. Number of inhabitants in Rzeszów and Košice.

Source: own study based on data from the Local Data Bank database – 16.06.2025 and Central meta information system of public administration 01.10.2025.

In terms of population, the city of Košice is slightly larger than Rzeszów. In 2024, Košice had 225,000 inhabitants, while Rzeszów had 198,000. Over the years, Košice's population has declined slightly, by approximately 0.5% year-on-year. The exception is 2021, when the population declined by 4% year-on-year. This may be due to the census conducted that year, which updated the data. Rzeszów, on the other hand, has seen a steady population growth of approximately 1% year-on-year. Only 2020 saw a decline in population. This may be linked to the effects of the Covid-19 pandemic (Figure 3).

Figure 4 shows the number of cars per 1000 residents. Data for Rzeszów and Košice are presented alongside data for the European Union, Poland, and Slovakia. Over the years, a systematic increase in the number of cars has been observed. This indicator reflects the level of urban mobility's dependence on individual transport. Its systematic growth indicates the growing demand for parking spaces, as well as challenges in traffic management and sustainable transport policies. This trend is upward for both Poland and Rzeszów, and for Slovakia and Košice. However, in the case of Poland and Rzeszów, the indicators were 595 and 655 cars per 1000 residents, respectively. In Slovakia, the indicators were 487 and 333 cars per 1000 residents, respectively. Thus, Košice has a value of this indicator that is more than half that of Rzeszów.

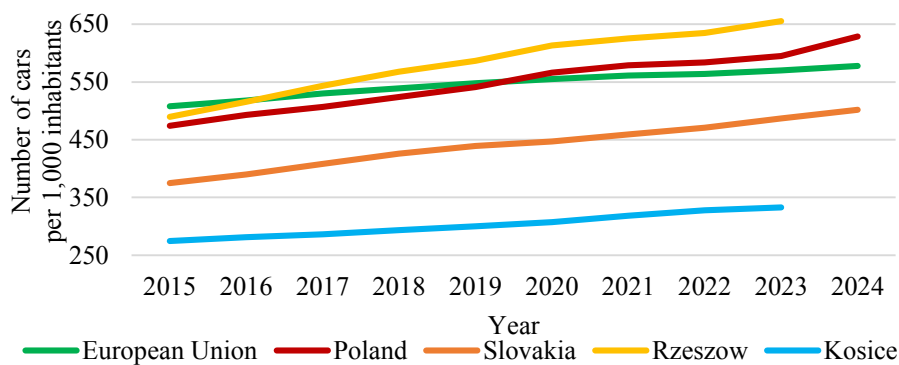


Figure 4. Number of cars per 1000 inhabitants.

Source: own study based on data from the Eurostat database - 20.09.2025.

An upward trend can also be observed when analyzing the number of passenger kilometers (Figure 5). In Poland, this increase was 2% in 2022 compared to 2021, while in Slovakia, it was 6%.

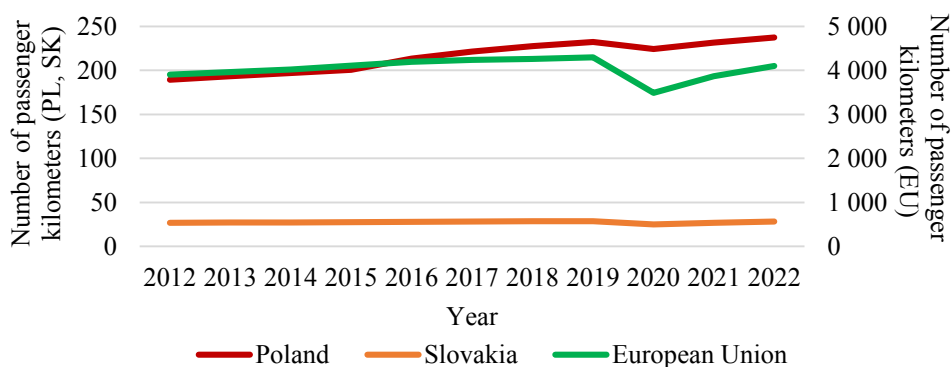


Figure 5. Number of passenger kilometers.

Source: own study based on data from the Eurostat database - 20.09.2025.

The next indicator analyzed was NO₂ emissions for the cities of Rzeszów and Košice. Data for Rzeszów and Košice are presented in the figure 6.

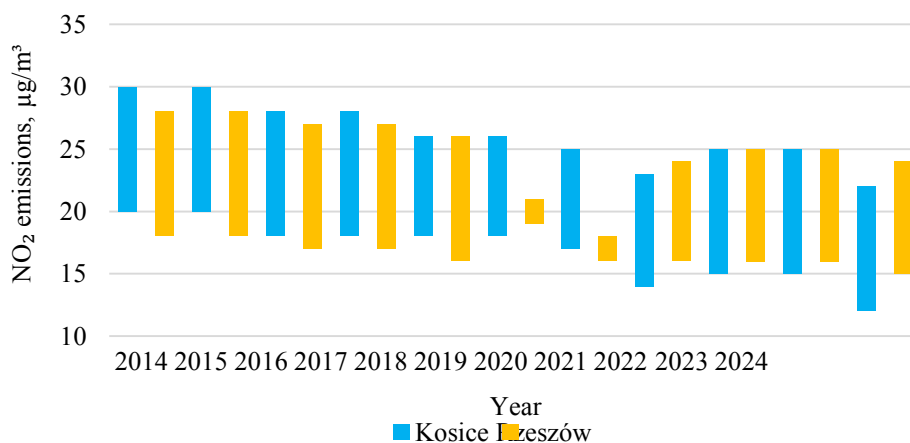


Figure 6. NO₂ emissions for the cities of Rzeszów and Košice.

Source: own study based on data from the Local Data Bank database – 16.06.2025 and Central meta information system of public administration 01.10.2025.

An analysis of estimated annual NO₂ concentrations shows that Košice saw a significant decline in average concentrations between 2014 and 2024, while NO₂ levels in Rzeszów remained relatively stable. This is despite the implementation of an intelligent parking system. This suggests that the system may reduce local cruising for parking spaces, but it is not sufficient to significantly reduce emissions across the entire area, especially with high vehicle numbers and additional pollutant sources.

5. Discussion

An analysis of the paid parking systems in both cities shows that each has developed a different approach to parking space management, tailored to its own demographic, spatial, and organizational characteristics. Rzeszów has implemented an intelligent parking space occupancy monitoring system, which enables the ongoing collection and analysis of data on parking space utilization. A mobile app allows drivers to check space availability in real time, simplifying trip planning and reducing parking search times. The system also supports municipal services in more efficient zone management and control. This solution exemplifies a modern approach to traffic management in the city center, based on the use of information technology and operational data.

In Košice, however, a system with a more diversified organizational structure has been implemented, allowing individual streets and subzones to have different fee application times and rates. This solution allows for flexible response to local needs and demand conditions. Additionally, a discount system has been introduced to support specific user groups, which increases public acceptance of fees and promotes a balance between the interests of residents and visitors. Inspections in Košice are conducted using a monitoring vehicle, streamlining the process of verifying paid fees and increasing the effectiveness of supervision.

In both cities, the occupancy rate in the city center remains similar – approximately 50-60% in Rzeszów and 50% in Kosice – indicating relatively stable parking space utilization. The two systems analyzed are therefore characterized by different management philosophies: in Rzeszów, the emphasis is on the use of modern technologies and data in the management process, while in Košice, it is on organizational flexibility and adapting rules to local conditions. Both approaches have their advantages and demonstrate different paths to achieving efficiency in parking space management.

6. Summary

From the perspective of urban parking infrastructure management, the optimization process can be considered at three levels: economic, organizational, and technological. At the economic level, dynamic pricing based on occupancy levels plays a key role. This allows for increased parking space turnover while simultaneously balancing traffic in the city center. At the organizational level, optimization potential is associated with better planning of paid parking zones and their flexible adaptation to changing user needs. Analyzing parking occupancy data can support decisions regarding the expansion or modification of zone boundaries, as well as differentiating rates between districts with different functions (e.g., business and residential). The introduction of intelligent reporting systems also facilitates improved monitoring and enforcement of fees, resulting in greater efficiency for the entire system. Finally, at the technical level, smart parking systems are gaining in importance. Integrating space occupancy sensors with mobile applications, information displays, and navigation systems allows drivers to quickly find available spaces, reducing the phenomenon of search traffic. Additionally, data collected by these systems can form the basis for optimization models, allowing for more sustainable and cost-effective planning of parking infrastructure development. In the context of the cities being compared, analysis of optimization options allows for assessing which solutions are most effective in a given urban environment and how they can be adapted to other cities. Conclusions from such a comparison can form the basis for formulating recommendations for effective parking space management and the development of intelligent mobility systems.

The benchmark analysis of paid parking systems in the studied cities provided significant benefits from an urban management perspective, serving as a tool supporting local government planning and decision-making processes. It allowed for the identification of the most effective organizational and regulatory solutions for parking space management, promoting the rational use of urban space and improving the system's operational efficiency. At the same time, it is important to emphasize that the effectiveness of transferring the identified best practices to cities with different spatial or socioeconomic conditions has not been empirically verified, necessitating their adaptation to local management conditions. Another limitation of the study is the lack of data-driven scenarios and quantitative models that allow for precise estimation of the effects of implementing specific parking policy instruments. However, the obtained results can serve as a starting point for further research focused on the development of analytical tools supporting parking system management, including the development of decision-making models, cost-benefit analyses, and pilot tests as part of a long-term urban mobility policy.

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DYNAMIC CAPABILITIES ARE INTEGRAL TO ENABLING THE TWIN TRANSITION FOR SUSTAINABILITY AND DIGITAL TRANSFORMATION

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Purpose: This paper explores how dynamic capabilities (DC) enable organizations to navigate the twin transition, the simultaneous pursuit of digital transformation (DT) and sustainability. It develops a conceptual framework explaining how DC, through their core processes of sensing, seizing, and reconfiguration, integrate technological and environmental logics to achieve sustainable digital performance (SDP). The study also examines the moderating role of sustainability orientation (SO) in shaping this relationship.

Design/methodology/approach: Adopting a narrative literature review approach, this study synthesizes theoretical and empirical research published between 2007 and 2025. Drawing from the dynamic capabilities, digital transformation, and sustainability literatures, it develops an integrative conceptual model. Rather than following a systematic protocol, the review applies a conceptual synthesis method (Snyder, 2019), allowing for theoretical interpretation and cross-disciplinary integration.

Findings: Dynamic capabilities are identified as the core integrative mechanism linking sustainability and digitalization. DC enable firms to sense emerging technological and ecological opportunities, seize them through innovation and resource orchestration, and reconfigure organizational structures to sustain advantage. The study introduces sustainable digital performance (SDP) as a holistic outcome that reflects the convergence of technological adaptability and sustainability objectives, demonstrating that organizations with strong DC and a robust SO achieve superior twin-transition outcomes.

Research limitations/implications: As a conceptual paper, the study lacks empirical validation. Future research should test the framework using quantitative and longitudinal methods to examine the dynamic relationships among DC, DT, SO, and SDP. Further work is needed to operationalize SDP and explore industry-specific and institutional contingencies.

Practical implications: For managers, the framework provides a diagnostic tool to strengthen the microfoundations of DC, leadership cognition, learning, and resource orchestration, supporting the twin transition. For policymakers, it suggests fostering incentives and partnerships that enhance both digital and sustainability competences at organizational and ecosystem levels.

Originality/value: This paper unites dynamic capabilities, digital transformation, and sustainability into a single framework, positioning DC as meta-capabilities that drive sustainable digital competitiveness. The concept of sustainable digital performance offers a new perspective on organizational success in the era of the twin transition.

Keywords: dynamic capabilities; twin transition; digital transformation; sustainability orientation; sustainable digital performance.

Category of the paper: Literature review, Conceptual paper.

1. Introduction

The twenty-first century has been marked by two simultaneous and transformative megatrends: sustainability and digitalization. Their convergence which is commonly referred to as the twin transition, represents one of the most profound strategic challenges and opportunities for organizations globally. While sustainability focuses on balancing economic growth with environmental and social responsibility, digital transformation emphasizes the adoption of technologies such as artificial intelligence, big data analytics, and Industry 5.0 systems to improve efficiency and innovation (Feroz, Zo, 2023). The intersection of these two paradigms is not merely technological or environmental but strategic: it requires organizations to develop capabilities that enable them to sense emerging opportunities, seize them through innovation, and reconfigure their resources and processes to sustain competitiveness in an evolving environment.

The theory of dynamic capabilities (DC) offers a powerful conceptual lens to understand how organizations navigate such complexity. Originating from Teece, Pisano and Shuen (Teece et al., 1997) the DC framework highlights the organization's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. Later refinements, including Teece (2007) and Wang and Ahmed (2007), operationalized DC into three microfoundational mechanisms: sensing, seizing, and reconfiguring. These capabilities underpin an organization's strategic agility and long-term performance, especially under conditions of turbulence and uncertainty (Dominiczewska, 2025).

In recent years, there has been a substantial increase in research connecting DC with digital transformation (Civelek, Krajčák, 2023; Mele, Capaldo, 2024) and sustainability (Amui et al., 2017; Buzzao, Rizzi, 2021). However, most research treats these domains separately. Studies on DC and sustainability tend to focus on environmental and social adaptation, exploring how organization develop green dynamic capabilities or sustainability-oriented DC to manage eco-innovation and stakeholder engagement (Albort-Morant et al., 2018). Conversely, literature on DC and digital transformation often emphasizes technological agility, IT-enabled sensing, and organizational learning for digital innovation (Feroz, Zo, 2023; Valdez-Juárez, Ramos-Escobar, 2024). The emerging reality of the twin transition where sustainability goals are deeply intertwined with digital technologies has not yet been systematically explored through the DC lens.

This gap creates an important opportunity for theoretical integration. The twin transition requires organizations not only to invest in technology and sustainability initiatives but to develop higher-order capabilities that allow these transformations to reinforce each other (Teece, 2023). Digital tools can accelerate progress toward sustainability (e.g., carbon tracking, digital twins, predictive maintenance for energy efficiency), but only if organizations possess the dynamic capabilities to align technological innovation with environmental and social objectives (Dominiczewska, 2025; Wijayarathne, Gunawan, 2024). The relationship is reciprocal: sustainability imperatives also reshape how organizations design and deploy digital strategies, requiring governance mechanisms, ethical oversight, and stakeholder integration (Wei, Zheng, 2024).

Despite the growing body of research linking dynamic capabilities with sustainability and digital transformation, existing studies predominantly examine these domains in isolation. While the literature provides valuable insights into dynamic capabilities in sustainability-oriented adaptation and digital transformation processes, the integrative role of dynamic capabilities in enabling their convergence within the twin transition remains insufficiently theorized. This lack of an integrative conceptual perspective constitutes a significant theoretical gap in the current literature. To address this gap, this conceptual study is guided by the following research question:

RQ: How do dynamic capabilities enable the twin transition for sustainability and digital transformation?

This research question provides the analytical foundation for the development of the proposed conceptual framework, which theorizes dynamic capabilities as the key enabling mechanisms that integrate sustainability and digital transformation within the twin transition, leading to sustainable digital performance.

2. Methods

This article synthesizes existing research at the intersection of dynamic capabilities (DC), sustainability, and digital transformation, offering a conceptual foundation for understanding how DC enable the twin transition. Unlike prior reviews, which examine either digital transformation or sustainability in isolation, this paper adopts a narrative integrative approach, following the methodological guidance of Snyder (2019). This approach allows for a critical and interpretive synthesis of existing literature rather than a rigid systematic protocol, enabling deeper theoretical analysis and cross-disciplinary integration.

The literature review encompasses the period 2007-2025, corresponding to the post-foundational phase of dynamic-capabilities theory. The search was conducted primarily in Scopus and Web of Science databases, complemented by targeted queries in Emerald Insight and EBSCO. Keywords and combinations included *dynamic capabilities*, *digital transformation*, *sustainability*, *twin transition*, and *Industry 5.0*. Articles were selected based on conceptual relevance, theoretical contribution, and citation significance, ensuring the inclusion of both seminal and recent works addressing the evolving role of DC in sustainability-oriented digital transformation.

An interpretive synthesis was applied to integrate insights across management, innovation, and sustainability literatures. The analysis focused on identifying convergent mechanisms, conceptual linkages, and research gaps across three streams: (1) Dynamic Capabilities and Sustainability – exploring how DC enable environmental and social innovation; (2) Dynamic Capabilities and Digital Transformation – examining how DC foster technological agility and strategic renewal; and (3) Dynamic Capabilities Enabling the Twin Transition – investigating how sustainability and digitalization interact as mutually reinforcing transformation logics.

This analytical integration forms the basis for the proposed conceptual model, which explains how DC, guided by sustainability orientation, drive sustainable digital performance through sensing, seizing, and reconfiguring mechanisms.

3. Results

The concept of dynamic capabilities (DC) has become one of the most influential theoretical lenses in strategic management, offering a framework for understanding how organizations sustain competitiveness in rapidly changing environments (Teece et al., 1997). Unlike ordinary capabilities, which enable organizations to perform existing activities efficiently, dynamic capabilities reflect the organization's higher-order abilities to sense opportunities and threats, seize them through strategic action, and reconfigure resources and competences to adapt to new circumstances (Eisenhardt, Martin, 2000; Teece, 2007). This theoretical perspective emerged as an extension of the resource-based view (RBV), addressing its main limitation, the RBV's static conception of competitive advantage (Barney, 1991).

Dynamic capabilities thus represent a strategic meta-capability, emphasizing how organizations renew their resource base to respond to technological, market, and institutional turbulence. Over the past two decades, the framework has evolved substantially. Early works (Teece et al., 1997; Eisenhardt, Martin, 2000) focused on defining DC conceptually. Subsequent studies, such as Wang and Ahmed (2007) and Ambrosini and Bowman (2009), developed typologies, measurement models, and microfoundations that connect DC to performance outcomes. More recent research positions DC as enablers of digital

transformation, sustainability, and organizational resilience (Dominiczewska, 2025; Mele, Capaldo, 2024).

Teece (Teece, 2007) identified three interrelated processes that constitute the foundation of dynamic capabilities. Sensing involves identifying, interpreting, and prioritizing signals of change in the external environment. It includes market scanning, technological foresight, and stakeholder engagement (Barrales-Molina et al., 2013). Seizing refers to mobilizing resources and organizational commitment to capture emerging opportunities through innovation, investment, or strategic alliances (Teece, 2018). Resource reconfiguration entails transforming existing resource bases, organizational structures, and processes to sustain alignment with the evolving environment (Helfat, Peteraf, 2009). Together, these mechanisms describe how organisations dynamically renew their competences to maintain strategic fit. In practice, sensing requires learning capabilities and absorptive capacity (Zahra, George, 2002), seizing depends on entrepreneurial orientation (Sirmon et al., 2007) and reconfiguration draws on resource orchestration supported by organizational flexibility and leadership intentionality that enable organizations to realign resources and structures effectively (Hitt et al., 2011; Teece, 2018; Dominiczewska, 2025).

The microfoundations perspective represents a more recent stream in the evolution of DC theory, seeking to explain how individual-level actions and organizational routines collectively enable dynamic change (Felin, Powell, 2015). Scholars emphasize the role of managerial cognition, leadership, learning, and collaboration as key antecedents of DC development (Helfat, Martin, 2014). For instance, microfoundations of sensing are rooted in cognitive diversity, knowledge sharing, and boundary-spanning behaviors that enhance environmental awareness (Adner, Helfat, 2003). Seizing is supported by decision-making flexibility, innovation culture, and cross-functional integration (Augier et al., 2009). Reconfiguring depends on change management, trust, and dynamic routines that institutionalize learning (Winter, 2003).

In sustainability-oriented contexts, these microfoundations often extend beyond organization boundaries integrating stakeholder engagement, ethical leadership, and institutional learning. Similarly, in digital transformation, DC microfoundations incorporate data literacy, digital skills, and technological absorptive capacity. The intersection of these microfoundations is particularly relevant to the emerging Industry 5.0 paradigm, where human-centric and sustainability-driven innovation are seen as integral to technological progress

Dynamic capabilities operate not in isolation but as an integrative bridge between technological innovation and sustainable value creation. They enable organizations to align internal structures and external ecosystems, balancing efficiency with resilience and long-term societal impact. This dual role positions DC as central enablers of the twin transition the process of integrating digital and sustainable transformation pathways. From a theoretical standpoint, the evolution of the DC framework parallels the evolution from Industry 4.0 to Industry 5.0.

While Industry 4.0 emphasized automation, digitization, and efficiency, Industry 5.0 introduces human-centricity, sustainability, and resilience as defining principles (Nahavandi, 2019). DC thus become critical for orchestrating the coexistence of these paradigms. They allow organizations to sense technological and societal shifts, seize innovation opportunities that contribute to sustainable goals, and reconfigure their resource base to foster inclusive, environmentally responsible, and digitally enabled growth (Teece, 2023).

Recent literature supports this integrative view. Dominiczewska (2025) demonstrated empirically that DC significantly enhance firm performance by fostering both technological flexibility and strategic adaptability. Mele and Capaldo (2024) and Wei and Zheng (2024) highlighted that DC serve as mediating mechanisms linking digital transformation to sustainability outcomes, such as energy efficiency, circular economy practices, and social responsibility. This growing body of evidence reinforces the theoretical claim that DC are not merely tools for survival in turbulent markets but strategic enablers of organizational transformation in the era of Industry 5.0.

3.1. Dynamic Capabilities and Sustainability

Sustainability has evolved from a normative concern to a strategic imperative for contemporary organizations. Global challenges such as climate change, social inequality, and regulatory pressure have forced organizations to integrate environmental and social dimensions into their strategic decision-making (Bansal, Song, 2017). Yet sustainability is not static, it requires ongoing adaptation to shifting institutional, technological, and stakeholder expectations. This dynamic and uncertain nature of sustainability makes it an ideal domain for the application of the dynamic capabilities (DC) framework (Amui et al., 2017; Dominiczewska, 2025).

Dynamic capabilities provide the theoretical bridge that links sustainability ambitions to actionable, adaptive strategies. Through the processes of sensing, seizing, and reconfiguration, organisations can identify sustainability-related opportunities and threats, mobilize resources to implement sustainable innovations, and realign structures to embed sustainability into their core operations (Teece, 2007). In this sense, sustainability-oriented DC represent a higher-order capability that enables the organization not only to comply with external requirements but to co-create long-term social and environmental value (Albort-Morant et al., 2018).

Sustainability-oriented sensing entails recognizing signals from diverse stakeholders, including customers, regulators, NGOs, and local communities and interpreting them as opportunities for innovation and differentiation (Hart, Dowell, 2011). Organizations with strong sensing capabilities engage in environmental scanning, stakeholder dialogue, and sustainability foresight, enabling them to anticipate emerging trends such as renewable energy transitions, ESG reporting standards, or circular economy regulations (Buzzao, Rizzi, 2021). Digital technologies further enhance this process by providing real-time environmental and social data through IoT sensors, big-data analytics, and AI-driven predictive models (Feroz,

Zo, 2023). Thus, sustainability sensing increasingly depends on both technological literacy and institutional awareness, a clear precursor to the twin transition perspective.

Once sustainability opportunities are sensed, organizations must develop the ability to seize them through innovation, investment, and partnership formation. This process often requires balancing short-term profitability with long-term value creation. The DC literature highlights the role of entrepreneurial orientation and strategic intent in mobilizing resources toward sustainability-driven projects (Teece, 2018). Organizations that successfully seize sustainability opportunities commonly adopt new business models, such as product-service systems, sharing economy models, or renewable energy integration, that align competitive advantage with environmental performance (Lüdeke-Freund, Dembek, 2017).

Moreover, seizing sustainability opportunities increasingly depends on collaborative capabilities, so the ability to co-innovate across organizational boundaries. This reflects the systemic nature of sustainability: no single firm can achieve it in isolation. Dynamic capabilities facilitate this collaboration by fostering trust, knowledge sharing, and joint learning with partners across supply chains and ecosystems (Albort-Morant et al., 2018). For example, green supply-chain collaborations and industrial symbiosis networks require firms to orchestrate external resources dynamically, aligning with the Industry 5.0 ethos of resilience and stakeholder inclusivity.

The reconfiguration phase represents the most transformative aspect of sustainability-oriented dynamic capabilities. It involves restructuring the organization's asset base, processes, and culture to embed sustainability as an enduring element of organizational identity (Teece, 2018). This transformation depends primarily on resource orchestration, the coordinated structuring, bundling, and leveraging of tangible and intangible resources to enable sustainability goals (Sirmon et al., 2007).

However, resource orchestration alone is insufficient; successful reconfiguration also relies on organizational flexibility and leadership intentionality that encourage adaptation and long-term vision (Adner, Helfat, 2003; Eisenhardt Martin, 2000). Leadership plays a pivotal role in fostering a culture of sustainability and aligning incentives with sustainable outcomes (Dominiczewska, 2025). Through this process, dynamic capabilities become embedded in routines that continuously integrate sustainability considerations into innovation, production, and stakeholder engagement. From this perspective, sustainability is not a separate strategic goal but a dynamic capability outcome, a manifestation of the organisation's ability to learn, adapt, and reconfigure its systems to address environmental and social imperatives. This conceptualization aligns with emerging views of resilient and regenerative organizations, which pursue value creation beyond efficiency and profitability (Williams et al., 2017).

The integration of DC and sustainability extends into the domains of the circular economy and ESG (Environmental, Social, and Governance) performance. Circular-economy strategies, such as 9R (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover) (Kirchherr et al., 2017), require organizations to reconfigure supply-chain structures, knowledge systems, and technological infrastructure (Holly, Schild, 2025). These processes exemplify reconfiguring at both the operational and ecosystem levels. In the context of ESG, DC enable organizations to sense stakeholder expectations, seize opportunities through responsible investment, and reconfigure governance systems to ensure transparency and accountability (Wei, Zheng, 2024). As regulatory frameworks such as the EU Taxonomy and the Corporate Sustainability Reporting Directive (CSRD) become mandatory, organizations need dynamic capabilities to align their digital and sustainability strategies with compliance and performance demands.

The convergence of DC, ESG, and circular-economy logics reflects the Industry 5.0 paradigm, where sustainability and human-centric digital innovation are inseparable (Nahavandi, 2019). Under this paradigm, DC are not only mechanisms of adaptation but strategic enablers of transformation, allowing organizations to move from reactive compliance to proactive value co-creation within sustainable ecosystems.

3.2. Dynamic Capabilities and Digital Transformation

Digital transformation has fundamentally altered how organizations create, deliver, and capture value. Beyond mere technological adoption, it represents a deep organizational transformation that reshapes processes, structures, and business models through the integration of digital technologies such as artificial intelligence (AI), the Internet of Things (IoT), cloud computing, and big data analytics (Vial, 2019). From a dynamic capabilities (DC) perspective, successful digital transformation requires more than technological investment, it depends on the organization's ability to sense digital opportunities, seize them strategically, and reconfigure resources to achieve sustainable competitive advantage ((Teece, 2018); Dominiczewska, 2025).

The sensing dimension of DC in digital contexts involves scanning and interpreting technological trends, market disruptions, and data-driven insights. Organizations with advanced sensing capabilities continuously monitor emerging digital technologies, evaluate their strategic potential, and integrate external signals from customers, competitors, and ecosystems (Mikalef, Pateli, 2017). Digital platforms, data analytics, and AI enhance sensing by enabling real-time monitoring of both operational performance and environmental conditions (Feroz et al., 2023).

In particular, digital sensing supports sustainability by helping firms predict environmental impacts, optimize energy consumption, and identify opportunities for circular innovation. For example, digital twins, virtual replicas of physical assets, allow firms to simulate and optimize resource use, reducing waste and emissions (Qi et al., 2018). Through digital sensing,

organizations bridge technological agility with environmental awareness, reflecting the core logic of the twin transition.

The seizing process involves translating digital insights into actionable strategies. This requires entrepreneurial orientation, innovation management, and cross-functional collaboration to integrate digital tools into products, services, and business models (Teece, 2018). DC enable organizations to seize digital opportunities by orchestrating resources toward experimentation, learning, and scaling digital initiatives (Mikalef, Pateli, 2017).

Importantly, seizing is not limited to efficiency gains but includes the development of new forms of digital value creation. In the context of sustainability, digital technologies facilitate traceability (e.g., blockchain for supply-chain transparency), energy efficiency (e.g., AI-driven smart grids), and dematerialization (e.g., digital services replacing physical goods). Thus, the seizing of digital opportunities increasingly supports sustainable outcomes consistent with the principles of Industry 5.0, where technology serves human and environmental well-being (Nahavandi, 2019).

The resource reconfiguration dimension represents the organization's capacity to realign structures, processes, and culture to embed digitalization into its DNA. From a DC perspective, reconfiguration requires resource orchestration, the structuring, bundling, and leveraging of tangible and intangible assets (Sirmon et al., 2007). It also depends on organizational flexibility and leadership, which enable strategic coherence and cultural adaptation (Teece, 2018; Dominiczewska, 2025).

In digital contexts, reconfiguring involves developing data governance systems, agile organizational structures, and continuous-learning mechanisms (Warner, Wäger, 2019). It may also include rethinking value chains through digital ecosystems and platforms that enhance knowledge exchange and innovation speed (Mele, Capaldo, 2024). These routines underpin digital resilience, the ability to absorb, adapt, and recover from technological and environmental disruptions.

Ultimately, the relationship between dynamic capabilities and digital transformation cannot be separated from sustainability. Digital transformation enables efficiency, data-driven innovation, and dematerialization, while sustainability provides purpose, legitimacy, and direction. DC enable organizations to integrate these trajectories converting digital potential into sustainable performance.

This integration aligns with the European Union's twin transition agenda, which promotes simultaneous progress in digitalization and sustainability as drivers of competitive advantage (European Commission, 2023). In this context, DC are not simply enablers of technological adaptation but strategic capabilities for responsible and regenerative transformation. The intersection of DC, digital technologies, and sustainability thus represents a new research frontier, one that extends beyond Industry 4.0 toward an Industry 5.0 logic centered on human well-being.

3.3. The Intersection – Enabling the Twin Transition

The convergence of sustainability and digital transformation commonly termed the twin transition has become a defining challenge for organizations seeking long-term competitiveness and legitimacy. Achieving progress in both domains simultaneously demands that firms enhance their technological responsiveness while embedding environmental and social priorities within strategy and operations. The dynamic-capabilities (DC) framework offers a coherent lens for explaining how organizations can align these dual imperatives.

DC enable organizations to integrate the technological and sustainability dimensions of change through their core mechanisms of sensing, seizing, and reconfiguring. In practice, this means identifying emerging digital and sustainability opportunities, mobilizing resources to act on them, and continuously realigning structures and processes to sustain advantage. Rather than viewing digitalization and sustainability as parallel trajectories, the DC perspective highlights their mutual reinforcement: digital tools enhance environmental performance, and sustainability goals provide direction and legitimacy for technological investment.

Through sensing, organizations interpret technological trends and environmental signals to anticipate disruption. Seizing involves orchestrating resources and partnerships to pursue innovation that meets both efficiency and responsibility targets. Reconfiguration requires redesigning routines, culture, and governance to embed these objectives as enduring capabilities (Sirmon, Hitt, Ireland, 2011). Empirical evidence shows that organizations with stronger DC adapt more effectively to regulatory change, technological turbulence, and stakeholder expectations, achieving superior resilience and long-term value (Mikalef, Pateli, 2017; Warner, Wäger, 2019).

Digital technologies play a critical enabling role in this process. Data analytics, Internet-of-Things infrastructures, and artificial intelligence support real-time sensing of environmental and operational performance (Feroz et al., 2023). These same technologies enhance seizing by facilitating innovation in cleaner production, energy optimization, and traceable supply-chain systems. Meanwhile, digital platforms and agile organizational forms strengthen reconfiguration by accelerating learning and collaboration across ecosystems. As organizations embed these routines, the twin transition becomes less an external pressure and more a continuous internal capability for sustainable digital adaptation.

The integrative potential of DC suggests that sustainable competitiveness in the twin transition depends not merely on resource possession but on the ability to renew and recombine them dynamically. Organizations that develop these higher-order capabilities can simultaneously exploit technological opportunities and explore pathways toward environmental and social impact, thereby translating digital transformation into lasting sustainable performance.

Future research should investigate how specific microfoundations, such as leadership cognition, employee learning, and cross-sector collaboration, shape the dynamic interaction between technological and sustainability capabilities. Greater empirical attention is also needed to understand how governance and ESG mechanisms condition the development of DC in digital contexts. By focusing on these links, scholars can clarify how dynamic capabilities act as the connective tissue through which organizations orchestrate the twin transition effectively and responsibly.

Building on the conceptual framework of dynamic capabilities as the enabler of the twin transition, this study proposes a process-based model that specifies how these capabilities translate into organizational outcomes. Dynamic capabilities (DC) constitute the foundational enablers of transformation, equipping organizations with the capacity to sense, seize, and reconfigure in response to both digital and sustainability-related challenges (Teece, 2018; Dominiczewska, 2025). Their deployment facilitates digital transformation (DT) the restructuring of business models, processes, and organizational culture through digital technologies (Vial, 2019).

At the same time, sustainability orientation (SO), an organization's strategic commitment to environmental and social goals, acts as a moderating force that guides how dynamic capabilities are exercised. High sustainability orientation channels digital transformation efforts toward socially responsible and environmentally aligned outcomes (Feroz, Zo, Eom, 2023; Wei, Zheng, 2024). Thus, organizations with both strong DC and a robust SO are more likely to implement digital technologies in ways that contribute to long-term resilience and legitimacy.

The joint effect of these mechanisms results in sustainable digital performance (SDP) a holistic measure capturing an organization's ability to achieve technological excellence while maintaining ethical, social, and ecological responsibility. In this model, digital transformation mediates the relationship between dynamic capabilities and sustainable digital performance, while sustainability orientation moderates it, strengthening the positive effect of DC on DT. This dual pathway underscores that sustainable competitiveness in the twin transition arises not from technology adoption alone but from the dynamic orchestration of capabilities, values, and digital strategy.

The synthesis of digital and sustainability transitions can be conceptualized as a layered framework in which dynamic capabilities act as the integrative engine linking technological, organizational, and societal dimensions of change. Building on the foundational works of Teece (2007, 2018) and the resource orchestration perspective (Sirmon, Hitt, Ireland, 2011), the framework positions sensing, seizing, and reconfiguring capabilities as the core routines through which organizations manage the twin transition and achieve sustainable digital performance.

At the core layer, dynamic capabilities constitute the organization's ability to detect, interpret, and act on complex digital and sustainability signals. Sensing refers to environmental scanning and the recognition of opportunities emerging from technological and ecological disruption. Seizing captures the entrepreneurial mobilization of resources to implement innovations that align digital tools with sustainability objectives. Reconfiguring describes the transformation of organizational routines, structures, and cultures that embed these dual logics into everyday operations (Teece, 2018). Collectively, these routines form the basis of digital transformation (DT), the ongoing redefinition of business processes and models enabled by digital technologies.

The enabling layer represents the microfoundations that sustain these dynamic processes: leadership cognition, organizational learning, and resource orchestration (Warner, Wäger, 2019). Within this layer, sustainability orientation (SO) acts as a strategic moderator, guiding how dynamic capabilities are applied in the context of digital transformation. Organizations with a stronger sustainability orientation tend to direct their digital initiatives toward long-term ecological and social goals, ensuring that digital transformation enhances both competitiveness and responsibility (Feroz, Zo, Eom, 2023; Wei, Zheng, 2024). This orientation therefore strengthens the positive relationship between dynamic capabilities and digital transformation by embedding ESG-driven values into strategic and operational decision-making.

The outcome layer reflects the organizational realization of the twin transition as organizations achieve sustainable digital performance (SDP), the synergistic integration of technological adaptability and sustainability outcomes. Sustainable digital performance represents a firm's ability to leverage digital technologies for innovation, efficiency, and resilience, while simultaneously advancing environmental stewardship, stakeholder trust, and social value creation. This outcome captures the essence of the twin transition: the convergence of digital excellence with sustainability responsibility.

Crucially, the process is dynamic and iterative. Each transformation feeds back into the DC system, generating new learning cycles and capability renewal. The twin transition thus becomes an emergent capability configuration—a continuous alignment of technological and sustainability logics through dynamic resource orchestration and adaptive governance. By framing the twin transition as a multi-layered capability system, this conceptual model contributes to theory in three key ways. First, it extends dynamic-capabilities theory by positioning sustainability and digitalization as co-evolutionary mechanisms rather than independent strategic domains. Second, it bridges the resource-based and socio-technical perspectives by demonstrating how sustainability orientation shapes the enactment of dynamic capabilities during digital transformation. Third, it advances management scholarship on sustainable competitiveness by conceptualizing sustainable digital performance as a holistic outcome of these interlinked processes.

4. Discussion

The framework developed in this paper positions dynamic capabilities (DC) as the central mechanism enabling organizations to integrate digital transformation and sustainability imperatives into a coherent system of sustainable digital performance (SDP). By embedding sustainability orientation (SO) as a moderating force within this system, the model reconceptualizes how organizations achieve competitive advantage in the era of the twin transition—not merely through digital efficiency or environmental compliance, but through their continuous ability to reconfigure and align technological and sustainability logics dynamically.

This study contributes to the growing intersection of dynamic-capabilities theory, digital transformation, and sustainability research in three interrelated ways. First, it advances the theoretical understanding of dynamic capabilities by reframing them as dual-purpose capabilities that simultaneously drive digital and sustainable transformation. Traditional research conceptualizes DC primarily as mechanisms for adaptation and renewal in volatile environments (Helfat, Peteraf, 2009; Teece, 2007). In contrast, this framework introduces a more integrative perspective, arguing that DC not only enable firms to respond to technological and market changes but also to internalize sustainability principles as strategic guides for digital innovation. This reframing extends the adaptive function of DC toward a generative and normative role, aligning technological transformation with environmental and social outcomes (Mikalef et al., 2020; Warner, Wäger, 2019).

Second, the paper contributes conceptually by introducing sustainability orientation (SO) as a strategic moderator in the DC–DT relationship. Prior research has acknowledged the importance of ESG principles in shaping innovation trajectories (Feroz et al., 2023; Wei, Zheng, 2024), but few studies have articulated the specific mechanism through which sustainability values influence the enactment of dynamic capabilities. By embedding SO within the capability system, this model clarifies that sustainability-oriented organizations are more likely to deploy their sensing, seizing, and reconfiguring routines in ways that promote long-term societal and ecological outcomes. Consequently, SO operates as both a cognitive frame and a strategic filter that channels digital transformation toward responsible innovation and shared value creation.

Third, the framework contributes to the literature on organizational performance by defining sustainable digital performance (SDP) as an integrated outcome construct. Existing studies often treat digital and sustainability performance as parallel domains, measured separately through productivity or ESG indicators. The concept of SDP unites these dimensions, offering a theoretically grounded measure of how digital transformation and sustainability goals co-evolve through dynamic capabilities. It captures technological adaptability, innovation resilience, and stakeholder legitimacy as complementary outcomes of

the twin transition. This integrative approach advances the ongoing discussion on what constitutes sustainable competitiveness in the digital era (Teece, 2018; Vial, 2019).

Taken together, these contributions provide a novel conceptual lens for understanding how organizations not only adapt to digital disruption but also harness it to pursue sustainability-driven transformation. By framing DC as meta-capabilities that balance efficiency and responsibility, the model aligns with recent calls for human-centric and regenerative paradigms of Industry 5.0 (Nahavandi, 2019).

While the proposed framework advances the theoretical integration of dynamic capabilities and the twin transition, it also reveals important research gaps that warrant empirical investigation.

1. Microfoundations of Sustainable Dynamic Capabilities

Although the literature acknowledges that DC emerge from lower-level routines and managerial cognition (Felin, Powell, 2015), empirical evidence remains limited on how these microfoundations evolve when sustainability and digitalization co-occur. Future studies could examine leadership cognition, organizational learning, and cross-sector collaboration as antecedents of sustainable dynamic capabilities. Qualitative case studies and longitudinal designs could explore how these microfoundations shape sensing and seizing behaviors across technological and environmental domains.

2. The Moderating Role of Sustainability Orientation

The conceptualization of SO as a moderator introduces an important empirical avenue. Further research should operationalize sustainability orientation not only as a cultural or strategic construct but as a multidimensional capability encompassing environmental values, stakeholder integration, and governance practices. Quantitative studies could test how SO strengthens or weakens the DC-DT link using structural equation modeling or moderated regression approaches (Hayes, 2018). Cross-country comparisons could also reveal contextual variations depending on institutional pressures or industry digital maturity.

3. Measuring Sustainable Digital Performance

The proposed SDP construct requires rigorous empirical validation. Researchers should develop and test multi-dimensional measurement scales that capture both digital (e.g., process automation, data-driven innovation, agility) and sustainability dimensions (e.g., carbon reduction, social impact, ethical technology use). Future work could apply mixed-method approaches, combining survey data with secondary sustainability reports or digital-readiness indices, to establish robust validity and reliability.

4. Dynamic Interactions and Temporal Evolution

Another promising direction involves examining how DC, DT, and SO interact dynamically over time. Existing research often treats these constructs as static variables, yet the twin transition is inherently temporal and path-dependent. Longitudinal or panel-data designs could reveal feedback effects and co-evolutionary patterns, for example, how successful digital

transformation projects reshape sustainability orientation or how sustainability-driven learning fosters new DC.

5. Contextual and Sectoral Differences

Finally, future studies should investigate contextual contingencies. The effectiveness of DC in achieving sustainable digital performance may differ across industries, such as manufacturing, energy, or services, depending on their technological intensity and sustainability pressures. Comparative research could identify sector-specific configurations of DC and SO that best support the twin transition.

Synthesizing these insights, this paper positions the dynamic-capabilities framework as a bridge between strategic management and sustainability and digitalization. It offers a pathway for empirical research that transcends descriptive accounts of digitalization or ESG adoption, focusing instead on the processual mechanisms through which organizations build, renew, and deploy capabilities for sustainable digital performance. In practical terms, this integration underscores that achieving sustainable competitiveness in the twin transition is not merely about acquiring technology or adopting green policies. It requires cultivating organizational systems that continuously learn, adapt, and reconfigure in alignment with environmental and societal imperatives. Future research grounded in this framework can therefore deepen theoretical understanding while providing actionable insights for managers seeking to navigate the complexities of sustainable digital transformation.

5. Summary

This paper has examined how dynamic capabilities (DC) enable organizations to navigate the twin transition, the simultaneous pursuit of digital transformation and sustainability. Drawing on a synthesis of strategic management and sustainability literature, the study proposed a conceptual framework in which DC function as integrative mechanisms linking digital innovation and environmental stewardship through a continuous process of sensing, seizing, and reconfiguring. Within this framework, sustainability orientation (SO) moderates the relationship between DC and digital transformation (DT), guiding how organizations apply their adaptive and learning capacities to achieve sustainable digital performance (SDP), a holistic outcome that captures the alignment of technological excellence with social and ecological responsibility.

The findings of this conceptual inquiry contribute to the advancement of dynamic-capabilities theory and sustainability-oriented management research in several important ways. First, by reframing DC as dual-purpose capabilities, this study expands their role beyond mere adaptability to encompass purpose-driven innovation. It shows that the same microfoundations that underpin technological agility, such as resource orchestration, learning, and effectuation,

can also serve sustainability objectives when guided by appropriate strategic orientation. This theoretical extension bridges two previously separate literatures, positioning dynamic capabilities as the meta-capabilities through which digital and sustainability goals converge.

Second, the integration of sustainability orientation as a moderator enriches our understanding of how values and norms influence the enactment of capabilities. Organizations with a strong sustainability orientation do not simply pursue efficiency or competitiveness; they enact their dynamic capabilities in ways that promote ethical, responsible, and regenerative outcomes. This insight adds a normative dimension to the DC framework, aligning it with contemporary management paradigms such as Industry 5.0, which emphasize resilience, inclusivity, and well-being.

Third, the introduction of sustainable digital performance as an integrative construct contributes to the emerging dialogue on how performance should be conceptualized in the digital era. It moves beyond traditional economic metrics to include dimensions of environmental impact, social legitimacy, and long-term resilience. This conceptualization invites new empirical approaches to measuring organizational success, emphasizing the interplay between technological progress and sustainability outcomes.

Together, these insights underscore that achieving competitive advantage in the twin transition depends not on isolated investments in technology or sustainability but on the organization's capacity to dynamically align them through learning, adaptation, and reconfiguration. Dynamic capabilities thus emerge as the connective tissue of strategic transformation in an age where agility and responsibility must coexist.

Beyond its theoretical relevance, this framework provides actionable implications for practitioners and policymakers seeking to implement sustainable digital transformation. For managers, the framework highlights the need to view digital transformation not as a technological project but as a capability-building journey. Organizations should focus on developing microfoundations of sensing, seizing, and reconfiguration, such as environmental scanning systems, cross-functional innovation routines, and agile resource allocation mechanisms. Strengthening these microfoundations enhances the organization's ability to pursue digital initiatives that also generate sustainability impact. Furthermore, cultivating a strong sustainability orientation, through leadership commitment, ESG metrics, and stakeholder engagement, ensures that digital investments are ethically grounded and socially aligned. The outcome is not only greater efficiency but also a deeper form of strategic resilience, where digital agility supports sustainable value creation.

For policymakers and institutional actors, the model suggests that enabling the twin transition requires systemic support for capability development. This involves designing incentive systems, innovation policies, and training programs that foster both digital literacy and sustainability competence. Public-private partnerships and cross-sectoral innovation networks can facilitate knowledge exchange and diffusion of best practices in sustainable digitalization. Policy frameworks should therefore encourage firms not only to adopt digital

technologies but also to integrate them with sustainability principles, transforming compliance into capability.

In summary, this paper has positioned dynamic capabilities as the critical enablers of the twin transition, demonstrating how firms can harmonize digital transformation with sustainability imperatives to achieve sustainable digital performance. By embedding sustainability orientation within the capability system, the study emphasizes that the future of competitiveness lies not in technological sophistication alone but in the capacity to use technology responsibly, inclusively, and regeneratively.

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CYBERSECURITY AS A COMPONENT OF CORPORATE GOVERNANCE IN ESRS REPORTING: DISCLOSURE PRACTICES IN THE TRANSITION TO MANDATORY CSRD REPORTING

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Purpose: The aim of the article is to examine how companies, listed on the Polish Stock Exchange in the energy sector disclose cybersecurity issues in Management Board Reports and Sustainable Development Reports before and after the implementation of mandatory reporting in accordance with the European Sustainability Reporting Standards (ESRS 2), "General Disclosures" and "Business Conduct" (ESRS G1). The study focuses on identifying changes in the transparency, scope and quality of disclosures.

Design/methodology/approach: An analysis of the content of the Management Board Reports and Sustainable Development Reports of companies from the energy sector for 2023 (the period before the implementation of the CSRD) and for 2024 (the period after the implementation of the CSRD) was used. Based on the ESRS guidelines, the company's an author-developed Cybersecurity Disclosure Index was developed, covering four areas: Governance, Strategy, Risk Management and "Metrics and Targets".

Findings: The results of the study showed that most of the analysed companies increased the amount and scope of reported information on cybersecurity after the introduction of mandatory ESRS reporting requirements. However, the disclosures still lack several key elements considered essential in this area.

Originality/value: The study contributes to expanding the understanding of governance in social responsibility reporting, encompassing cybersecurity. The study analyzes information security in non-financial reporting before and after the implementation of the mandatory provisions of the CSRD Directive and the ESRS standards. To the author's knowledge, this is the first study in Poland on this topic.

Keywords: cybersecurity, risk management, CSRD Directive, ESRS standards.

Category of the paper: Research paper.

1. Introduction

Global challenges such as environmental pollution, the depletion of natural resources, and biodiversity loss have become urgent realities, requiring businesses to take greater responsibility for their impact on the environment (Nicolò et al., 2024, Szadzińska et al.,

2021). In response to these challenges, the concept of corporate social responsibility (CSR) has begun to play a key role in shaping corporate strategies. Organizations are now assessed not only through their financial performance but also in the context of their environmental, social, and ethical activities.

In parallel with the growing importance of environmental, social and ethical considerations, the modern economy is experiencing a rapid expansion of technology-driven business processes. Contemporary digital solutions provide organizations with significant opportunities for development and innovation, yet they also introduce serious and entirely new types of risks (Strupczewski, 2021). These risks may have financial, economic, environmental and social consequences. Although the original concept of corporate social responsibility primarily focused on reducing the negative environmental impact of business activities and supporting local communities, in the era of digitalization it should also encompass responsible information management, the security of technological processes, and the protection of data. Information collected and processed in cyberspace is exposed to leakage, loss of availability or integrity, and breaches of privacy, which may occur either accidentally or intentionally (Frank et al., 2021). Cybersecurity incidents lead to reputational damage as well as financial consequences resulting from such breaches (Khan et al., 2025). According to the World Economic Forum (2023), cybercrime and the lack of digital security currently rank among the ten most severe global risks in both the short and long term. In the era of digital transformation and the rapid advancement of artificial intelligence (AI), “information” has become one of the most valuable organisational assets, and its protection is a critical condition for maintaining stakeholder trust. Considering the rapid evolution of AI, ethical considerations have become paramount for businesses and are expected to gain even greater significance in the future, particularly with respect to issues such as deprofessionalisation, the responsibility gap and the expectation gap (Arena, Mazzitelli, 2025).

From a CSR perspective, a properly designed and reported cyber risk management system in place within an enterprise, encompassing identification, measurement, assessment, and response processes, not only protects information assets but also strengthens stakeholder trust. This assumption is consistent with the Corporate Sustainability Reporting Directive (CSRD) (2022/2464/EU) and the European Sustainability Reporting Standards (ESRS) developed by the European Financial Reporting Advisory Group (EFRAG). From a corporate governance perspective, cybersecurity is an important category of corporate responsibility, combining social (protecting stakeholder privacy and data), environmental (effective use of IT infrastructure), and management (building trust and organizational resilience) dimensions.

In accordance with the requirements of ESRS 2 and ESRS G1, companies are obliged to disclose information on the policies, processes, strategies and oversight systems that enable effective risk management and ensure information security. These requirements include, among others, the description of internal control mechanisms, incident response procedures, methods for monitoring threats, as well as the links between information security and the corporate risk

management system. In the author's view, an important aspect of this framework is the inclusion of cybersecurity within sustainability reporting structures in line with ESRS requirements. Against this background, the aim of the present study is to assess the scope of cybersecurity related information disclosed in Management Reports and Sustainability Reports before and after the introduction of mandatory reporting under the ESRS, with a particular focus on corporate governance aspects - ESRS 2 and ESRS G1. The study seeks to address the following research questions:

1. To what extent do companies disclose information about cybersecurity risk policies, processes, and systems in their management and sustainability reports?
2. Does reporting in this area meet the requirements of transparency and comparability?

The study is based on a content analysis of the Management Board Reports and Sustainable Development Reports published by companies for 2023 and 2024, during the period of preparation for the implementation of the CSRD and after the implementation of mandatory reporting regulations. The research sample includes selected listed companies from a sector particularly exposed to technological and information risks, i.e. the energy sector. Based on the ESRS 2 and ESRS G1 guidelines, a proprietary Index of Cybersecurity Disclosures has been developed. Each Management Board Report and Sustainability Report was assessed in terms of compliance with ESRS 2 and ESRS G1 (0 - no disclosure; 1 - partial disclosure; 2 - full disclosure).

The results obtained will determine the extent to which companies are prepared to report cybersecurity information in accordance with the requirements of the ESRS, as well as identify areas that require further clarification in reporting and regulatory practice. The study contributes to broadening the understanding of governance in sustainability reporting, including the aspect of information security as an integral part of transparency and accountability. This article is up-to-date and innovative, filling the research gap by providing information on the level of compliance of cybersecurity disclosures with the ESRS requirements. To the best of the author's knowledge this is the first article that offers information on the readiness to change companies not covered by the exemptions from the Omnibus Package.

2. Literature review

Growing social pressure on corporate transparency (Agostini et al., 2021), the need to rebuild public trust, the need to harmonize regulations between Member States, and a crisis of confidence in reported financial information influenced the adoption of the NFRD (2014/95/EU) by the European Parliament and the Council of the European Union on 22 October 2014. The directive required large public interest entities to disclose non-financial information regarding the environment, social affairs, respect for human rights,

anti-corruption activities, and corporate governance principles (Cuomo et al., 2024). Corporate social responsibility (CSR) ceased to be a voluntary initiative and became a subject of legal regulation. The directive contributed to an increase in the number of companies preparing and disclosing CSR reports, including their social and environmental performance (Christensen et al., 2021). However, the NFRD had significant limitations: the form and content of reports were voluntary, varied in scope, and inconsistent, and disclosures were incomparable and fragmented. This was due to the lack of a standardized reporting format. Companies could use GRI and ISO 26000 standards, and could publish them as part of their management report or in a separate non-financial report (Sethi et al., 2017). Many companies continued to use non-standard disclosure frameworks, which hindered the assessment of non-financial risks (Ho, 2022). Therefore, the EU introduced more comprehensive reporting solutions – the Corporate Sustainability Reporting Directive. The CSRD covered a broader range of entities subject to the reporting obligation and introduced references to uniform standards – the European Sustainability Reporting Standard (ESRS) developed by EFRAG. CSRD acts as a catalyst for integrating sustainability into firms' business operations and reporting practices, recognizing the interdependence between corporate actions, the regulatory environment, and sustainability goals (Kosi, Relard, 2024). The introduction of the ESRS standards aimed to increase the transparency, consistency, comparability, and verifiability of information regarding environmental, social, and governance issues. The ESRS standards are currently a key tool for implementing CSRD. They consist of ESRS 1 (general requirements), ESRS 2 (general disclosures), and thematic standards (E, S, G).

The roles of supervisory authorities, the process of identifying and assessing significant risks, policies and internal control mechanisms are defined by the ESRS G1 "Business Conduct" standards (Hummel, Jobst, 2024) and ESRS 2. In practice, this means that a company covered by CSRD must describe, among other things, its governance structure, risk identification processes, policies on ethics, compliance, data protection and, although not always explicitly mentioned, cybersecurity management. Due to its capacity and multidisciplinary, cybersecurity is defined differently in the literature (Schatz et al., 2017). Cybersecurity refers to all actions taken to achieve the postulated state in which the risks threatening operations carried out in cyberspace are minimized as much as possible (Yang et al., 2020). Cybersecurity is the protection of cyberspace, i.e. electronic information, information and communication technologies, and cyberspace users in terms of their personal and social interests, both material and immaterial, who are vulnerable to attacks from cyberspace (Craig, et al., 2014). The literature emphasizes that cybersecurity is linked to three pillars of corporate social responsibility: economic, environmental, and social. Research (Balboni, Francis, 2024) places cybersecurity within the ESG framework, in which digital trust serves as social capital and cyber resilience as a public good.

Economically, investments in information security systems reduce the risk of data loss, operational downtime, and reputational damage (Jerman-Blažič, 2008). Furthermore, investments in cybersecurity infrastructure (Arcuri et al., 2018) are consistent with corporate responsibility and cyber risk reduction. Information security breaches can lead to significant financial losses related to repairing damage after attacks (replacing devices that were destroyed or damaged by the attack). Another significant threat to companies is the lack of transparent information about the level of security, which can complicate investor risk assessment. This can make raising capital more costly, as investment attractiveness tends to decrease with increasing uncertainty about ESG risk (Healy et al., 2001). Increasingly, investors are considering cyber risk management as a key element of the environmental, social, and governance analyses they conduct when making investment decisions (Sherman, 2020).

In the environmental dimension, cybersecurity supports sustainable development by protecting critical infrastructure from threats resulting from cyberattacks. Technologies such as blockchain and cloud solutions, when used safely and effectively, can reduce the carbon footprint and improve the energy efficiency of IT systems (Fraga-Lamas et al., 2024). Properly designed cybersecurity technology, by optimizing the operation of computer systems, can indirectly contribute to energy savings and mitigate negative environmental impacts. Furthermore, sustainable supply chain management, supported by appropriate cybersecurity practices, can reduce emissions and improve the efficiency of transportation and logistics processes (Litvinenko, 2020). Currently, most decarbonization and CO₂ emission reduction strategies are based on digital transformation and the use of intelligent technologies that monitor, manage, and distribute energy.

In the social dimension, cybersecurity strengthens stakeholder trust, protects customer privacy, and is a significant element of an organization's reputational capital (Fan et al., 2023). In the cyber context, "trust" is particularly important for users of computer hardware and software, who expect performance to be consistent with their expectations. Implementing cybersecurity measures, such as protection against data theft and service interruptions, contributes to corporate social responsibility (Morales-Sáenz et al., 2024). Axelton, Chandna's (2023) article also highlights the social responsibility aspects of cybersecurity. According to the authors, responsible data management, respect for privacy, and information protection are not only legal requirements but also a responsibility to society and stakeholders. Shackelford et al. (2016) express a similar opinion, arguing that organizations should treat cybersecurity as a component of CSR to protect their customers and society, for example by securing critical national infrastructure. In the digital world, responsibility for protecting consumer and stakeholder data, ensuring privacy, and maintaining robust cyber defenses is increasingly seen as a direct reflection of an organization's commitment to social responsibility (Khan et al., 2025). However, empirical research indicates that the level of cybersecurity disclosure is low, often general (Fortin, Héroux, 2020). At the same time, international guidelines such as

ISO 27001, NIS 1.2, and ESRS attempt to standardize expectations regarding the scope and manner of narrative (Lam, Seifert, 2023).

Cybersecurity, previously treated as a technical element of IT, should be incorporated into corporate governance and internal risk management processes (Craig et al., 2014). A growing body of research also points to the need to incorporate cybersecurity into corporate governance. As Morales-Sáenz et al. (2024) point out, digital resilience is a prerequisite for maintaining a sustainable business model, and the lack of appropriate security measures can lead to material risks in financial, environmental, and social dimensions. In the context of corporate risk management, cybersecurity should be considered a strategic risk. Research by Smaili et al. (2023) indicates that effective cyber threat management systems are associated with higher board effectiveness and better corporate governance practices. Kluiters et al. (2023) demonstrates that the quality of cyber governance impacts the market value and risk assessment of companies. Effective cybersecurity policies increase investor confidence and can reduce the cost of capital (Frank et al., 2023). Although the ESRS does not include a separate thematic standard on cybersecurity, this topic is indirectly addressed in, among others, the ESRS 2 "General Disclosures" and the ESRS G1 "Business Conduct" corporate governance framework. The General Disclosures require descriptions of governance, risk roles and responsibilities, internal control systems, and risk identification and response processes. The analysis of the ESRS provisions enabled the author to identify key elements related to cybersecurity that should be disclosed under ESRS 2. The summary is presented in Table 1.

Table 1.

Identification of Cybersecurity Disclosure Requirements in ESRS 2

ESRS 2 GOV-1 (The role of the administrative, management and supervisory bodies)	How the administrative, management and supervisory bodies and senior executive management oversee the setting of targets related to material impacts, risks and opportunities, and how they monitor progress towards them.
ESRS 2 GOV-2 (Information provided to and sustainability matters addressed by the undertaking's administrative, management and supervisory bodies)	How the administrative, management and supervisory bodies consider impacts, risks and opportunities when overseeing the undertaking's strategy, its decisions on major transactions, and its risk management policies, including any assessment of trade-offs and analysis of sensitivity to uncertainty that may be required; and a list of the material impacts, risks and opportunities addressed by the administrative, management and supervisory bodies, or their relevant committees during the reporting period.
ESRS 2 IRO- 1 (Description of the processes to identify and assess material impacts, risks and opportunities)	Focus(es) on specific areas due to heightened risk of adverse impacts.
ESRS 2 SBM-3 (Material impacts, risks and opportunities and their interaction with strategy and business model(s)	How the material risks and opportunities relate to the undertaking, specifying which risks and opportunities the undertaking reasonably expects could have financial effects, including affecting its business model(s) and strategy, and the reasonably expected time horizons for those effects.

Source: author's own elaboration.

Under ESRS 2 (GOV-1, GOV-2), companies are required to disclose their corporate governance structure, including the roles and responsibilities of management and the supervisory board in setting objectives and managing risks and opportunities. Therefore, corporate social responsibility aspects must also be considered. In practice, this also includes risks and opportunities related to information security, data protection, and cyber threats, if they are deemed material in the double materiality assessment. Furthermore, ESRS 2 IRO-1 and SBM-3 require entities to disclose how they identify and assess material risks and opportunities and integrate them into the company's business model and strategy, which will incorporate CSR aspects.

The ESRS G1 Standard specifies that its objective is to provide an understanding of an undertaking's strategy, processes and performance in conducting business in an ethical and responsible manner. Based on the author's own analysis, several ESRS G1 disclosure requirements were identified as relevant to the area of cybersecurity. These linkages are presented in Table 2.

Table 2.

Identification of Cybersecurity Disclosure Requirements in ESRS G1

G1-1 Corporate culture and business conduct policies	A description of the mechanisms for identifying, reporting and investigating concerns about unlawful behaviour or behaviour in contradiction of its code of conduct or similar internal rules; and whether it accommodates reporting from internal and/or external stakeholders. Details on the establishment of internal whistleblower reporting channels, including whether the undertaking provides for information and training to its own workers and information about the designation and training of staff receiving report.
G1-2 Management of relationships with suppliers	The undertaking's approach to its relationships with its suppliers, taking account of risks to the undertaking related to its supply chain and of impacts on sustainability matters.
G1-3 Prevention and detection of corruption or bribery	A description of the procedures in place to prevent, detect, and address allegations or incidents of corruption and bribery.
G1-4 Confirmed incidents of corruption or bribery	Any actions taken to address breaches in procedures and standards of anti-corruption and anti-bribery.

Source: author's own elaboration.

ESRS G1 regulations require organizations to disclose information regarding the existence of a system for reporting and analyzing legal violations, the operation of internal reporting channels, employee training policies, and procedures for handling incidents of business ethics violations. In the context of cybersecurity, these requirements cover data breaches, cyberattacks, information misuse, and the protection of individuals who report security breaches. Furthermore, ESRS G1 requirements also encompass staff training in responding to irregularities, including digital incidents. In practice, this means that a company can, and indeed should, also include a cybersecurity incident response policy and a description of the structure of data breach reporting channels. This approach strengthens transparency, organizational resilience, and stakeholder trust in the company's management system. Integrating cybersecurity with ESG reporting represents a new dimension of corporate responsibility,

where data protection, compliance with regulations such as the GDPR, and system security are perceived as significant non-financial risk factors.

Although cybersecurity has become a critical component of corporate responsibility and governance in the digital economy, prior research has largely overlooked its role within sustainability reporting frameworks. In particular, there is a lack of empirical studies assessing the compliance of cybersecurity disclosures with ESRS 2 and ESRS G1 requirements, especially in the context of the transition to mandatory CSRD reporting. This study addresses this gap by providing evidence on the scope and quality of cybersecurity disclosures from a governance perspective.

3. Research methodology

Based on prior studies on corporate governance, sustainability reporting, and cybersecurity risk management as well as on the CSRD framework the key analytical constructs of the study were identified. These include cybersecurity governance, cybersecurity risk management and compliance with ESRS disclosure requirements. Following the reviewed literature and the structure of ESRS 2 and ESRS G1 the constructs were operationalized through a set of measurement variables capturing disclosures on policies, processes, oversight mechanisms and the integration of cybersecurity into the corporate risk management system. On this basis a proprietary Cybersecurity Disclosure Index was developed to assess the level of compliance with ESRS 2 and ESRS G1.

Companies from the WIG-Energia index were selected for analysis because the energy sector is a key critical infrastructure sector, meaning entities operating within it are particularly vulnerable to cybersecurity risks. In an era of digitalized operational processes, automated transmission networks, and the use of smart meters, any information security breach can lead to serious economic, environmental, and social consequences. Therefore, disclosures regarding information security management and cyberattack prevention mechanisms are particularly important for stakeholders in this sector, both investors and regulators. Furthermore, energy companies listed on the Warsaw Stock Exchange (GPW) are among the first large public interest entities to be required to report in accordance with the CSRD and ESRS standards.

According to the ESRS 2 and ESRS G1 standards, cyber risk management, data protection, and information security are among the elements of assessing corporate governance and responsible business conduct. Examining companies in the energy sector, where the level of exposure to cyber threats is particularly high, allows us to assess whether these companies reported existing risks before the introduction of the mandatory ESRS, and also to verify whether they are actually implementing the ESRS 2 and ESRS G1 requirements in their reporting practices in the year of mandatory application of the standards. Selecting companies

from the WIG-Energia index also allows for an assessment of the comparability of results, as the index includes entities with similar business profiles. This allows for a more precise capture of changes in the scope of cybersecurity disclosures before and after the implementation of the ESRS.

To assess the scope and quality of cybersecurity disclosures in energy company reports, an author-developed Cybersecurity Disclosure Index was constructed and applied. The index's design was based on an integrated approach, taking into account the requirements of ESRS 2 and ESRS G1. The index's goal was to combine key aspects of both sets of standards into a single framework to showcase companies' cybersecurity disclosures. Four key reporting areas were considered, which, in the author's opinion, best reflect the link between cybersecurity and corporate governance, strategy, and risk:

1. Governance – the system for managing and overseeing cybersecurity.
2. Strategy – the integration of information security with the business model and strategy.
3. Risk Management – processes for identifying, assessing, and responding to cybersecurity risks.
4. Metrics & Targets – disclosure of indicators and information security incidents.

Each area includes specific data points reflecting the information requirements of ESRS 2 and ESRS G1. A total of eight assessment points have been developed, as presented in Table 3.

Table 3.

Cybersecurity Disclosure Assessment Points Based on ESRS 2 and ESRS G 1

No.	Area	Link to ESRS2/ESRS G1	Data point	Refinement
1	Governance	G1-1, GOV 1, GOV 2	Information Security/Cybersecurity Policy and Accountability of Management and Supervisory Bodies	Disclosure of a formal information security or cybersecurity policy
2		G1-1	Incident and breach reporting channels	
3	Strategy	SBM-3, G1-2	Cybersecurity in Business Strategy / ESG	Describe how cybersecurity is integrated into the business strategy and sustainability strategy
4		G1-2, SBM-3	Strategic objectives and plans for information security	Disclosure of measurable information security goals and action plans
5	Risk Management	IRO-1, G1-2, G1-3, G1-4	Process of identification, assessment, response to incidents (cyber risks)	
6		IRO-1, G1-2	Risk management in the value chain (suppliers and subcontractors)	
7	Metrics & Targets	G1-4	Number and nature of cybersecurity incidents	
8		G1-1	Cybersecurity training and awareness of employees	

Source: author's own elaboration.

4. Results

Based on eight data points, we analyzed the content of energy companies' reports for 2023 and 2024 (individual reports, Management Board Reports, and Sustainability Development Reports). Companies that did not prepare a separate Management Board Reports and Sustainable Development Reports were not included. A comparison of cybersecurity disclosures in the 2023 and 2024 reports among ten energy companies listed on the Warsaw Stock Exchange (GPW) shows a clear improvement in both the scope and quality of the information presented. Data coded on a three-point scale (0 - no disclosure, information not included in the report; 1 - partial disclosure, descriptive, fragmentary information; 2 - full disclosure, complete information compliant with ESRB requirements, containing quantitative data or indicators) indicates that the number of items with a value of "0" decreased by as many as 15 cases.

This indicates that in 2024, companies significantly reduced the scope of areas that had previously been entirely disregarded in relation to cybersecurity. In turn, many disclosures previously assessed as partial were expanded and converted into full disclosures (11 such instances in total). This indicates a growing maturity of the reporting approach, consistent with the requirements of ESRS 2 and ESRS G1.

In the 2023 reports, the disclosed information was descriptive and general in nature, often lacking measurable indicators. The most significant gaps were observed in the areas of strategy, risk management across the value chain, and quantitative data. Regarding governance, companies typically referred only to the application of information security principles. They lacked a comprehensive policy framework, clear references to the role of management bodies, and information on dedicated channels for reporting cybersecurity incidents. Among the analysed companies PGE, Tauron, and Columbus presented the most comprehensive disclosures in this area, including the development of ICT systems, efforts to ensure process automation and digitisation, and the implementation of an Integrated Management System and IT infrastructure security principles (particularly within the Distribution and Railway Energy segments). However strategy-related disclosures were generally limited to emphasising the importance of digitisation, ICT system modernisation plans, strengthening infrastructure resilience, and the development of remote customer service solutions. They did not include explicit measurable indicators.

In the area of Risk Management, companies briefly referred to ensuring IT security and compliance with internal procedures, without describing response processes. There were also references to the Integrated Management System and updated security procedures, and descriptions of incident response procedures, resilience testing, and cooperation with national security structures. However, there was no description of incident management.

In the Metrics & Targets area, there were general references to occupational health and safety and ethics related training, but no dedicated cybersecurity specific training. Only PGE reported on regular cybersecurity and data protection training for employees, including e-learning initiatives and phishing simulations.

5. Discussion

Modern organizations operate in an environment where dependence on digital infrastructure creates both new development opportunities and systemic threats (Ciborra, 2007). The effects of cyberattacks damage corporate reputation, violate privacy, and lead to negative financial consequences, which can lead to disastrous consequences for long-term sustainability. Cybersecurity is therefore crucial to all three dimensions of social responsibility. Organizations should consider cybersecurity reporting at every stage of considering sustainability factors, as it is crucial to ensuring the credibility of all nonfinancial reporting.

The results of the survey of companies listed on the Warsaw Stock Exchange in the energy sector confirm that the implementation of ESRS 2 and ESRS G1 has contributed to a shift from a declarative approach to effective, data-driven reporting, particularly in terms of strategy and risk management, including cybersecurity. Our study is consistent with the findings of Fortin and Héroux (2020), who indicate that despite increasing regulatory requirements, the level of cybersecurity disclosure remains low, and information is often general, inconsistent, and poorly comparable. Although the ESRS standards do not explicitly require the inclusion of cybersecurity aspects, companies have begun to present more systematic, transparent, comparable, and transparent information in their SZ and SZR, which better reflects the actual activities, processes, and outcomes related to cybersecurity.

The largest number of new or expanded disclosures in 2024 reports concerned the following areas:

- cybersecurity training and employee awareness (an increase in the number of companies disclosing from 3 to 8) – most companies began presenting specific figures on the types of training, number of participants, and frequency of educational activities,
- incorporating cybersecurity into business strategy and ESG (also an increase from 3 to 8 companies) – detailed descriptions of the integration of cyber risks with strategic planning and value management appeared,
- disclosure of the number and nature of cybersecurity incidents (from 0 to 2 companies) – new, quantitative disclosures indicate the inclusion of metrics and targets in reports in accordance with ESRS requirements,

- risk management in the value chain – an increase from 1 to 3 disclosures, demonstrating the expansion of reporting boundaries. Governance remained consistently high – nine out of ten companies reported this area in 2023, meaning that the implementation of the ESRS did not so much compel disclosure, but rather streamlined and structured its presentation. In total, between 2023 and 2024, the number of "2" scores increased from 4 to 13, representing a more than three-fold increase in the number of full disclosures. The average score on a 0-2 scale increased from 0.48 to 0.78, confirming significant progress in reporting quality. These changes demonstrate that since the ESRS came into force, companies are no longer limiting themselves to laconic statements about the existence of a security policy, but are increasingly presenting specific figures, metrics, and a description of cybersecurity risk management processes.

This means a gradual shift from a narrative and declarative approach to reporting that effectively incorporates metrics, objectives, and strategies, increasing the usefulness of disclosures for stakeholders, including investors and regulators. However, the level of disclosure remains insufficient. However, our research findings differ from those conducted by Hashemi and Ray (2023), who found that many companies still limit themselves to declarative statements such as "we have a security policy", without presenting measurable indicators of effectiveness or the impact of cybersecurity incidents. The author believes that in the context of CSRD and ESRS, there is a need to standardize cybersecurity reporting, such as the number of incidents, the degree of security audit coverage, and the level of employee training, which can become important ESG indicators.

6. Conclusions

The findings of this study indicate a clear transition from narrative and declarative cybersecurity reporting toward disclosures that increasingly incorporate metrics, objectives, and structured descriptions of risk management processes. This evolution enhances the usefulness of sustainability reports for key stakeholders, including investors and regulators. From a regulatory and governance perspective, the results highlight the need for further standardization of cybersecurity disclosures, particularly with regard to indicators such as the number and type of cybersecurity incidents, the scope of security audits, and the level of employee training. Such indicators could serve as meaningful ESG metrics and support greater transparency and comparability across companies and sectors.

Including cybersecurity in sustainability reporting in accordance with ESRS not only increases information transparency but also strengthens the trust of investors and business partners. The regulatory framework for sustainability reporting in the European Union, shaped by the CSRD Directive and the ESRS standards, sets new standards for transparency in

environmental, social, and digital responsibility. Integrating cybersecurity into non-financial reporting is an expression of regulatory compliance and a key element of corporate governance, the disclosure of which is a tool for building trust, credibility, and organizational resilience.

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INTERNAL COMMUNICATION AND MOTIVATING MEMBERS OF CONSTRUCTION INDUSTRY PROJECT TEAMS

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Purpose: The main aim of this article is to identify and assess the role and importance of internal communication in the process of motivating members of project teams in the construction industry.

Design/methodology/approach: The survey was conducted among project team members and project managers in the construction industry. An anonymous survey was conducted to identify and assess the role and importance of internal communication in motivating project team members in the construction industry.

Findings: Effective internal communication plays a crucial role in employee motivation. Transparency fosters trust, which is particularly important in the construction industry, dominated by teamwork, changing conditions, and time pressures. Furthermore, motivating project team members requires the use of diverse strategies, encompassing both tangible factors (e.g., bonuses, project allowances) and intangible ones (e.g., recognition, development opportunities, and autonomy). The most effective motivational practices are closely linked to the quality of the relationship between management and team members.

Research limitations/implications: The main limitation is the limited size and nature of the sample: managers and members of project teams in the construction industry, as well as the dynamic nature of the industry and project teams. The construction industry is subject to technological, regulatory, and market changes that affect the way project teams communicate and are managed.

Practical implications: The results obtained may contribute to the development of project management practices in the construction industry in the area of internal communication and motivation of project team members, providing practical guidance on key channels and forms of communication and information flow in relation to motivation.

Originality/value: Construction projects require the integration of activities carried out by specialists representing different fields, and the results of empirical research contained in this article deepen the understanding of the role and importance of internal communication in the context of motivating project team members.

Keywords: internal communication, motivating project teams members, construction industry.

Category of the paper: Research paper.

1. Introduction

Internal communication has long been a subject of interest for both management researchers and practitioners responsible for the effective coordination of organizational activities. Modern organizations operate in conditions of increasing complexity, requiring rapid information exchange, adapting to change, and making decisions in an environment of dynamic employee interactions (Schein, 2017). This is particularly evident in project-based organizations, where work efficiency depends largely on the cohesion of interdisciplinary teams and the ability to collaborate harmoniously under time pressure and high levels of responsibility (PMI, 2021). Effective internal communication is a key factor in the effectiveness of project teams in the construction industry, characterized by a high degree of complexity, changing conditions, and the need to integrate the activities of multiple stakeholders. As Schein (2017) emphasizes, communication plays a fundamental role in building organizational culture and supporting the coordination of team activities. In construction projects, where rapid response to change and effective information transfer are essential, the quality of communication becomes crucial to project success. Project management research indicates that insufficient communication is one of the most common causes of project failure (Robbins, Judge, 2021). PMI (2021) considers internal communication a key area of expertise, essential for effective information management and maintaining cohesion among project team members. At the same time, the literature emphasizes that the quality of communication affects not only operational efficiency but also employee motivation and engagement (Maslow, 1987; Hackman, Oldham, 1980). Transparent, regular, and two-way communication can strengthen a sense of meaningful work, increase identification with project goals, and foster shared responsibility for team outcomes.

From an employee motivation perspective, it's also important that internal communication influences a sense of agency, commitment, and identification with project goals. Transparent employee information policies, frequent and constructive feedback, and management's accessibility directly influence team members' attitudes and willingness to put in extra effort (Hackman, Oldham, 1980; Arnold et al., 2016). Research on project teamwork emphasizes that communication serves a regulatory and relational function—enabling both task control and coordination, as well as building social relationships based on trust, respect, and a sense of shared purpose (Bizjak, Faganel, 2020).

The construction industry, characterized by the specific nature of project work, large-scale projects, and the need to integrate engineering, economic, and management knowledge, provides a particularly challenging context for research on communication and motivation. Construction projects engage diverse groups of specialists – from architects and designers, through construction managers, to occupational health and safety and logistics specialists – which requires a constant, precise, and multi-channel flow of information (Malik, 2018). The literature indicates that project communication in construction is not only a technical

function but also a social one, influencing the work climate, collaboration, and employee engagement (Dainty et al., 2006). Detailed empirical research on the specifics of the construction industry remains lacking, as projects are dispersed, time-pressured, and coordination with multiple subcontractors is essential, creating a unique context for communication and motivation management. In the construction industry, employee motivation has traditionally been primarily linked to material factors, working conditions, and a sense of security (Malik, 2018). Significantly less research has been devoted to the role of internal communication, understood as a tool for supporting intrinsic motivation and increasing the engagement of project team members. In this area, there is a gap in the relationship between communication practices and motivation levels in teams implementing construction projects.

The main purpose of the article is to identify and assess the role and importance of internal communication in the process of motivating members of project teams in the construction industry. Three research questions were formulated: (1) What is the relationship between internal communication and the motivation level of project team members in the construction industry? (2) Does the lack of clearly defined internal communication policies impact the motivation and performance of project team members? (3) Does a formalized reward system shape employees' positive attitudes toward their responsibilities?

The article begins with a theoretical section, including a review of the literature. This is followed by a description of the methods and tools. The results are presented and discussed in the next section. The work ends with a summary, conclusions, and indicated limitations of the empirical research.

2. Literature review

The literature on construction project management increasingly emphasizes that the quality of internal communication and employee motivation have a significant impact on project effectiveness. Communication is a hot topic nowadays and many studies have been developed on its basis. Nevertheless, in the project management field, the research developed is still scarce (Barros, et al., 2024). Research suggests that internal communication is crucial for organizational outcomes (Ruck, Men, 2021). Given the high organizational complexity, volatile work environments, and dispersed project teams, communication is becoming one of the most important factors determining the success of construction projects (Dainty et al., 2006; Agyekum et al., 2021). Internal communication is pivotal to a company's performance during construction projects (Chi et al., 2021). Research shows that ineffective information exchange and a lack of clear communication channels lead to delays, implementation errors, and an increased risk of conflict between project participants (Çelik, Kamali, 2021; PMI, 2019).

Hernández et al. (2019) revealed that internal communication is the most important aspect of project management, as most project managers communicate to coordinate their activities. One of the key challenges in internal communication is ensuring equal access to relevant information for all team members. Therefore, it is important to utilize a variety of communication channels, such as regular meetings, emails, digital platforms, and discussion forums, to ensure that all voices are heard. By creating a culture of inclusive communication, organizations can empower employees to share ideas and opinions, ultimately enriching the creative process (Safapour, 2019).

Internal communication is defined as the process of transmitting information between project team members, construction managers, designers, and subcontractors. As Love et al. (2016) note, the complexity of the construction environment makes quality communication crucial for accurate planning, progress control, and decision-making.

Zulch (2014) argued that communication is the process of gathering all relevant information, interpreting it, and effectively communicating it to those who may need it. Project team members must collaboratively share, gather, and integrate information and knowledge to achieve project goals. Meta-analyses indicate that implementing digital tools such as BIM, integrated communication platforms, and mobile apps improves the transparency and accuracy of information, although their effectiveness is limited by barriers related to user competence and organizational culture (Zhou, Zhang, 2024; Oraee et al., 2017).

Gamil and Rahman (2019) found that a lack of communication also leads to negative consequences, such as frustration, confusion, discouragement, and a tense atmosphere in which construction personnel are reluctant to be productive and collaborate. Good communication within a team is essential to determining project success or failure. Frequent communication between members strengthens trust and, consequently, the relationship between them, which translates into increased performance (Júnior, Chaves, 2014; Sarhadi, 2016). However, motivation does not stem solely from communication. A project manager must play a leadership role alongside a communicator role to motivate people (Zulch, 2014).

In the area of employee motivation in construction projects, research shows that both external factors (remuneration, working conditions, safety) and internal factors (autonomy, meaningful work, professional development) have a significant impact on employee engagement and performance (Hashiguchi et al., 2020; Al-Sabah et al., 2022). Construction as an industry is characterized by specific conditions, including the temporary nature of project teams, high physical demands, and dynamically changing working conditions. For these reasons, motivational models must be adapted to the project realities and take into account the specific needs of different employee groups (Shen et al., 2017). Leadership also plays a significant role. Larsson's (2018) research showed that leadership behaviors based on trust, support, and clear goal communication are crucial for maintaining high team member motivation. Similarly, Alabdulkarim and Haq (2020) emphasize that effective leader communication increases job satisfaction and employee engagement in project tasks.

The link between communication and motivation has been extensively explored in recent research, which indicates that communication also serves a motivational function—building trust, reducing uncertainty, and strengthening interpersonal bonds (Owusu-Manu et al., 2023). Regular feedback, recognition, and clarity about employees' roles and responsibilities increase a sense of belonging and positively impact their performance (PMI, 2019; Han et al., 2021). In multicultural teams, which are increasingly common in construction, communication is a key factor in minimizing the risk of conflict and supporting team integration (Agyekum et al., 2021).

A review of the main studies in this area is included in Table 1.

Table 1.

Selected studies on communication and motivation in construction projects

Author/ year	Country/ Region	Topic	Main findings
Larsson (2018)	Europe	Leadership and motivation	Leadership style strongly influences the motivation of project teams and the efficiency of construction processes.
Hashiguchi et al. (2020)	Japan	Intrinsic and extrinsic motivation	The value of motivators depends on employee age and experience; intrinsic factors have a strong influence on older employees.
Owusu-Manu et al. (2023)	Africa	Communication and productivity	Improving communication increases overall project efficiency and reduces conflict.
Zhou, Zhang (2024)	Japan	Communication-motivation relationships	Communication supported by digital technologies improves team motivation and collaboration.

Source: own study.

In summary, the literature consistently confirms that both internal communication and employee motivation are key elements of construction project success. The strong relationship between these areas indicates the need to analyze and integrate them concurrently in project management practices. However, a contemporary approach to human resources management in construction requires in-depth and multidimensional research that takes into account both the influence of psychosocial factors and the dynamic development of communication technologies.

3. Methods

This section presents the results of empirical research on the role of internal communication and motivational practices in project teams operating in the construction industry. In this sector, characterized by highly complex processes, a highly volatile environment, and the need for close cooperation between specialists with diverse competencies, effective communication and adequate employee motivation are key determinants of project success. The main purpose of the article is to identify and assess the role and importance of internal communication in the process of motivating members of project teams in the construction industry. Three research

questions were formulated: (1) What is the relationship between internal communication and the motivation level of project team members in the construction industry? (2) Does the lack of clearly defined internal communication policies impact the motivation and performance of project team members? (3) Does a formalized reward system shape employees' positive attitudes toward their responsibilities?

In order to achieve the objective of the article and obtain answers to the research questions, empirical research was conducted in February and March 2025. The tool used in the research was a questionnaire containing a total of 17 research questions in the main part and metric questions.

The survey used a 5-point Likert scale, ranging from 1 (strongly agree) to 5 (strongly disagree). In addition to addressing the link between internal communication and employee motivation, the role of project managers and their involvement in the communication and motivation process, the questions also referred to the lack of clearly defined internal communication rules and the reward system in shaping positive employee attitudes towards their work. The research was conducted among 147 members of project teams and project managers in the construction industry, where the main objective was to collect respondents' opinions on the issues analyzed, identify links between them, and possibly identify areas for improvement.

The survey was conducted online and was completely anonymous. The questionnaire was made available in electronic form to a total of 197 managers and members of project teams implementing construction projects in southern Poland. A total of 147 fully completed questionnaires were returned. Twenty-three were not completely filled out and were therefore excluded from further analysis. The description of the research sample is included in Table 2.

Table 2.
Sample description

Respondent	Statistics	
Age	20-25	8 %
	26-35	29%
	35-50	39%
	> 50	24%
Gender	Male: 98	66 %
	Female: 49	34%
Work experience	< 5	18%
	6-10	43%
	> 10	39%

Source: own study.

The survey questionnaire was completed by 98 men and 49 women. People aged 26-35 accounted for 29%, and people aged 20-25 accounted for 8%. The largest group (39% of respondents) were people aged 36-50, and 24% of respondents were over 50 years old. The most numerous group in the sample were employees with 6 to 10 years of service (43% of respondents). Another large group consisted of employees with over 10 years of service (39% of respondents), while the smallest group consisted of respondents with less than 5 years of service in the industry (18% of respondents).

4. Results

The main part of the questionnaire consisted of 17 questions. The first question concerned the link between internal communication and motivation and commitment at work. A significant proportion of respondents recognized the important role that communication plays in this area, with 40% selecting “definitely yes” and 53% selecting “yes”. Only 6% of respondents said they had no opinion on the subject, and only 1% believed that communication did not affect their motivation and engagement. The second question concerned receiving feedback on their work and its results during project implementation. The largest number of respondents, 41%, indicated that they receive such information sporadically. 29% of respondents admitted that they receive such information regularly. In turn, 27% admitted that they receive this information very rarely. Only 3% of respondents indicated a complete lack of feedback on the results of their work and commitment to the tasks assigned to them.

The next question concerned the respondents' opinion on the transparency of internal communication rules during project implementation and whether these rules are understandable and widely communicated to project team members. A decisive “yes” was indicated by 19% of respondents, while “yes” was chosen by 21%, suggesting a moderately positive assessment of level of an internal communication. The answer “I don't know” was chosen by 11%, which may suggest a lack of clear opinion or insufficient experience with information flow in the project team. In turn, 33% of respondents gave a negative answer, while 16% selected “definitely no”.

The next question concerned whether there were areas in which internal communication could be improved. Twenty-seven percent of respondents answered “definitely yes”, and 33% answered “yes”, meaning that a total of 60% of respondents believed that there were areas where internal communication could be improved. Twenty-two percent answered “I don't know”, and 16% answered “no”. Only 2% of respondents answered “definitely no”.

The fifth question concerned the attitude of project managers and their approach to communication. A definite positive assessment was given by 11% of respondents, while 41% chose the answer “yes”. The “I don't know” option was selected by 36% of respondents, which may suggest a lack of contact with management. In turn, 12% of respondents answered “no”. None of the respondents selected the “definitely no” option.

The next question concerned attitudes and practices related to sharing experiences, ideas, and opinions within the team, as well as open communication during project implementation. 19% of respondents answered “definitely yes”, while 27% answered “yes”. In total, 46% of respondents responded positively to open communication within the project team and sharing experiences. A significant number of respondents, as many as 34%, chose the answer “I don't know”. A total of 20% of respondents believe that there are no practices that encourage the sharing of ideas and opinions or open communication. Respondents were then asked to indicate whether they had access to all the information necessary to perform their tasks while working

in a project team. The majority, as many as 52% of respondents, answered “yes”, which clearly indicates that more than half of the employees have access to the information necessary to perform their professional duties. 19% of respondents selected “I don't know”. Twenty-nine percent of respondents, which is almost one-third of those surveyed, indicated that they do not have access to all the necessary data and information. None of the respondents selected “definitely yes” or “definitely no”.

Next, respondents were asked about the possibility of direct, open communication about problems with the project manager and within the project team. Twelve percent of respondents answered “definitely yes”, and 37% chose “yes”, which means that almost half of the respondents perceive project managers as accessible and open to discussions about difficulties and problems during project implementation. The answer “I don't know” was selected by 18% of respondents, which may indicate uncertainty about the actual openness of supervisors and colleagues. The answer ‘no’ was selected by 33%, while no one selected the option “definitely not”.

The next question concerned the use of internal communication tools, including platforms and instant messengers. A positive response, indicating their use, was given by 76% of respondents, which indicates the widespread use of tools that facilitate communication during the implementation of projects. The answer “I don't know” was selected by 6% of respondents, which may indicate a lack of awareness of their use or limited access to these tools. The answer ‘no’ was selected by 18%, while no one selected the answers “definitely yes” or “definitely no”.

Next asked about the most frequently used methods and channels of communication during project implementation. Respondents could select more than one answer. The most frequently chosen method of information exchange was face-to-face meetings, selected by 29% of respondents, followed by online meetings (28%). Next were instant messaging (Messenger, WhatsApp) (26%) and telephone (24%). The least popular, but still important, channel of communication is email, which was indicated by 18% of respondents. The next question addressed the issue of balance between electronic and face-to-face communication. Twenty-two percent of respondents answered “definitely yes”, while 50% answered “yes”, indicating that almost three-quarters of respondents perceive the relationship between electronic and face-to-face communication as balanced. Seven percent of respondents selected “I don't know”. Twenty-one percent selected “no”, while no one selected “definitely no”.

The next question concerned appreciation of commitment and recognition for their work. Only 6% of respondents answered “definitely yes”, while 22% chose “yes”. Twenty-eight percent answered “I don't know”, and 44% of respondents gave a negative answer—23% chose ‘no’ and 11% chose “definitely no”.

The next questions concerned financial and non-financial tools and instruments used to motivate employees working on construction projects. At the beginning, respondents were asked to indicate which of the listed financial motivational factors they had encountered while working in project teams. Respondents could select more than one answer. The most frequently

indicated form of financial motivation was discretionary bonuses, which was selected by 69% of respondents. Respondents also indicated gift cards (21%), material rewards (19%), and training subsidies (15%).

The next question concerned non-financial motivation tools used in the implementation of construction projects. Respondents could select more than one answer. The most frequently indicated form of non-financial motivation was additional training, which was selected by 41% of respondents. This was followed by flexible working hours (32% of respondents). Opportunities for development and promotion were indicated by 31%, and recognition and praise from superiors by 23%. Respondents were then asked which of these instruments most effectively motivate them to work in a project team. Respondents could select more than one answer. By far the most frequently cited factor was discretionary bonuses for a job well done, which 73% of respondents indicated as one of the most effective forms of motivation. In second place was the possibility of promotion, which was indicated by 42% of the survey participants. Training and professional development were indicated by 28% of respondents. Positive relationships with colleagues received 16% of responses, and flexible working hours received 13%. The least frequently indicated factor was educational subsidies, which received only 7% of the votes.

In the next question, respondents were asked to assess whether the way management communicates with employees is related to their motivation to perform their work. The answer “definitely yes” was chosen by 29% of respondents, and “yes” was indicated by 36% of respondents. In total, more than half of the respondents believe that the manner of communication has a significant impact on their motivation to work on projects. Fifteen percent of respondents selected “I don't know”. Eleven percent selected “no”, and 9% selected “definitely no”.

The last question concerned the most common internal communication challenges during the implementation of construction projects. The most frequently mentioned challenge was the lack of clear guidelines, which was indicated by as many as 37% of respondents. Less numerous, but still noticeable challenges included communication noise (26%) and interpersonal conflicts (20%). Difficulties in accessing information were indicated by 15% of respondents, and the lack of effective communication tools by 2%.

5. Discussion

Empirical research clearly shows that internal communication plays a significant role in shaping the motivation levels of project team members in the construction industry. An analysis of the collected results shows that effective information exchange between the manager and project team members is not limited to an informational function, but can also serve as

a motivational tool, supporting commitment and activity in achieving project goals. Most respondents indicated that messages and information from managers were an important factor influencing their willingness to work and perform the tasks assigned to them in the project. Such a high percentage indicates that the quality of internal communication at the project site can be an integral part of human resource management strategy, especially in the context of strengthening internal motivation. Despite the significant and positive role of internal communication, the survey results also revealed a number of serious shortcomings in this area. The process of information transfer is not always carried out in a systematic, regular, or orderly manner.

In many cases, the process of information transfer is not carried out in a systematic, regular, or orderly manner. A significant proportion of respondents indicated that they receive messages concerning important aspects of project implementation sporadically. The lack of regularity in the communication of guidelines or the evaluation of work to date results in a sense of confusion about the tasks being performed, a lack of transparency about current project priorities, and an inability to respond to various project situations on an ongoing basis, all of which have a negative impact on the sense of security and job stability. The responses also suggest that motivating project team members is largely based on financial instruments, with little use of intangible factors such as recognition, praise, opportunities for development, or promotion. The results of the study clearly indicate that non-financial motivation also plays an important role in shaping proactive attitudes and strengthening commitment.

Another area requiring attention is the low level of feedback received by project team members. More than half of respondents indicated that they receive feedback rarely or sporadically, which undoubtedly limits the possibility of self-correction and professional development. These practices could be supplemented by the development of uniform standards for periodic performance reviews, which could serve as a basis for motivational discussions and support employees in identifying their strengths and areas for improvement. The survey results indicate an imbalance between individual communication with employees and discussions during general meetings. Furthermore, the lack of regular and scheduled meetings has a negative impact on building relationships based on trust, understanding, and mutual respect.

The issue of professional development and improving qualifications is also important. Respondents emphasized that they value the opportunity to participate in training and acquire new skills. Unfortunately, in the group surveyed, these were not often used as motivational tools that also support professional development.

6. Conclusion

The main purpose of the article was to identify and assess the role and importance of internal communication in the process of motivating members of project teams in the construction industry. Three research questions were formulated: (1) What is the relationship between internal communication and the motivation level of project team members in the construction industry? (2) Does the lack of clearly defined internal communication policies impact the motivation and performance of project team members? (3) Does a formalized reward system shape employees' positive attitudes toward their responsibilities?

Based on the results, several recommendations can be made to improve internal communication and increase employee motivation. The first step is to implement regular, periodic project team meetings. This will enable the systematic sharing of key project-related information and allow for direct recognition of individual employee contributions. Consider implementing short, weekly one-on-one meetings, which would facilitate ongoing information exchange and allow for the submission of comments, suggestions, and ideas. It is also recommended to create a constructive feedback system based on standardized evaluation forms, enabling comprehensive analysis of work results and providing project team members with the opportunity to correct any errors on an ongoing basis. It is also crucial that feedback is not solely critical in nature but also demonstrates appreciation for effort, progress, and commitment. Recognition also plays a significant role in building motivation. It is also worth considering implementing mixed, traditional and digital forms of communication with project team members.

In answering the first research question regarding the relationship between internal communication and the motivation of project team members in the construction industry, it should be emphasized that the majority of respondents indicated that the clarity of information provided, the availability of superiors, and open relationships significantly impact their motivation to work. Internal communication not only fosters a better understanding of expectations but also builds a sense of belonging and influence on the professional situation. The second research question concerned the effects of a lack of formalized internal communication policies. Respondents' responses indicated that the lack of clearly defined communication channels and policies leads to information chaos, a lack of control over one's work. This negatively impacts motivation and reduces the effectiveness of tasks performed. Respondents indicated that they do not always know what is expected of them or how their work is assessed, which translates into their attitudes when carrying out assigned tasks. The final research question addressed the relationship between the reward system and the attitudes and motivation of respondents. The empirical data obtained indicate that although financial elements (bonuses, allowances) are important, many respondents also expect non-material forms of recognition, such as praise, distinctions or recognition.

In summary, the empirical research confirmed that effective internal communication plays a significant role in employee motivation. As the literature emphasizes, organizations characterized by clearly defined communication channels and regular information exchange between management and the team demonstrate higher levels of coordination and a reduced risk of errors resulting from misunderstandings. Transparency in communication fosters trust, which is particularly important in the construction industry—dominated by teamwork, changing conditions, and time pressures. Motivating project team members requires the use of diverse strategies that incorporate both tangible motivators (e.g., bonuses, project allowances) and intangible ones (e.g., recognition, development opportunities, autonomy in action). The most effective motivational practices are closely linked to the quality of the relationship between management and team members. Good communication practices increase the effectiveness of motivation, and properly motivated employees are more willing to engage in the project implementation process.

The main limitations of the research are: the limited sample size and nature. The research was conducted on a limited number of respondents and project teams, which may not fully reflect the diversity of communication practices across the construction industry. The sample selection was partially purposive, further limiting its representativeness. The second limitation is the dynamic nature of the industry and project teams. The construction industry is subject to technological, regulatory, and market changes, which impact how teams communicate and manage.

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GOING CONCERN ASSUMPTION – LITERATURE REVIEW

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Purpose: The main goal of this paper is to identify the main areas studied by scientists related to the going concern principle, the assessment of the ability to continue as a going concern of entities and the examination of the validity of such an assessment by auditors.

Design/methodology/approach: The main research method of this study is literature review of 1023 selected papers recorded in Scopus database. To identify research areas, the functionality of the VOSviewer program was used, which allows to determine connections between the keywords used and to visualize them into thematic groups that represent research areas.

Findings: Four main clusters of scientific articles related to the going concern assumption were identified. These clusters were related to contemporary socioeconomic topics, the links between going concern and finance and auditing, auditing and its quality, and internal auditing and management accounting. New possible research gaps were also identified related to accounting theory in the field of going concern and the connection of these issues with contemporary socio-economic issues

Research limitations/implications: The study was conducted exclusively on papers included in the Scopus database. Research gaps were only identified based on statistics and keyword relationships among the sample articles, which included a wide scope of papers, mostly connected with auditing. Therefore, a narrower thematic scope, focusing solely on going concern assumption in the context of financial accounting, would be worthwhile.

Originality/value: This article outlines the main research directions related to the topic of going concern assumption. It also shows possible research gaps in this subject matter.

Keywords: going concern assumption, going concern principle, literature review, bibliometric analysis.

Category of the paper: Research paper, Literature review.

1. Introduction

Information from companies' financial statements provides the basis for assessing their operational effectiveness and their asset and financial situation. This information is used by various stakeholders. Therefore, information from financial statements should be useful to

them. The usefulness of the information is provided when it is comparable, verifiable, timely and understandable (Stolovy, Ding, Paugam, 2024). Moreover, the primary purpose of financial statements is to present a faithful and accurate picture of the company's situation. To achieve this, the preparation of financial statements requires, among other things, an assessment of the entity's ability to continue as a going concern in the near future (Holda, 2006). The going concern principle is considered one of the overarching accounting principles, along with the accrual principle, matching costs and revenues, prudent valuation, continuity and materiality (Pfaff et al., 2023).

The going concern principle is described in International Financial Reporting Standards. Entities prepare financial statements on a going concern assumption, except when "management either intends to liquidate the entity or to cease trading, or has no realistic alternative but to do so" (IAS 1, paragraph 25). If an entity does not prepare financial statements on a going concern assumption, it must disclose this fact and the reason for not doing so. The scope of the analysis of a given entity's situation should always be fact-specific and may include factors such as current and expected profitability, debt repayment schedule, and potential sources of alternative financing (IAS 1, paragraph 26).

The going concern principle is also important when auditing financial statements. The auditor examining the financial statements should verify the validity of the assessment of the entity's going-concern. International Standard on Auditing 570 identifies examples of factors that may affect the entity's ability to continue as a going concern. These include, among others, a situation in which liabilities exceed assets, the inability to settle liabilities on a timely basis, the loss of a key market or customer, or shortages of important raw materials (ISA 570).

The main objective of this paper is to identify the main areas studied by scientists related to the going concern principle, the assessment of the ability to continue as a going concern of entities and the examination of the validity of such an assessment by auditors. Doing so would allow for the identification of research gaps in this area. To achieve this, a bibliometric analysis of scientific papers indexed in the Scopus database was conducted, along with the analysis and visualization of thematic areas using VOSviewer software. The study also aims to identify and characterize the most frequently cited scientific papers in this field. The main research questions are:

1. What are the main research areas related to the going concern assumption?
2. What topics are the subject of the most frequently cited works in the area of the going concern assumption?
3. What are the research gaps regarding the going concern assumption?

The study identified the main thematic groups of research on the going concern assumption. The study also includes a summary of the most frequently cited scientific articles in this field. This allowed us to identify research gaps and determine directions for further research. The next section provides a synthetic review of the scientific literature related to the going concern assumption. Next, the research methods used are described and the database is

characterized. A basic statistical analysis of the studies and a description of the most frequently cited articles are presented. Finally, the identified research areas are visualized and characterized, and finally potential research gaps are identified.

2. Literature review

Topics related to the going concern principle in accounting, and in particular the assessment of threats to the ability to continue as a going concern of economic entities, are widely discussed in the global scientific literature, particularly in the period following the global financial crisis. The need to verify the quality of financial statements, particularly in the context of the threat of bankruptcy, has become more widely recognized (Hołda, 2021). Ensuring a proper assessment of the going-concern ability of enterprises has become desirable for governments, financial market participants, and lenders alike. Cases of enterprises that failed to identify any threats in their financial statements merit special attention (Carson et al., 2013). Bradbury et al. (2022) point to a still limited understanding of the appropriate methods for reporting threats by those responsible for preparing financial statements. Even when these threats are mentioned in reports, the information is insufficiently detailed. These researchers believe that accounting regulations and standards should address these issues more broadly.

Research on going concern assumption in economic entities is conducted worldwide. This topic is important regardless of the legal regulations in a given country and the accounting standards used (Grosse, Scott, Zang, 2023). Work on this issue is primarily empirical in nature, with studies conducted, among others, on selected samples of enterprises at risk of going concern (Read, 2015; Ruiz-Barbadillo, Guiral, 2019) or on all enterprises listed on a given stock market or indexed in a given economic database (Cha, Hwang, Yeo, 2016; Grosse, Scott, Zang, 2023). Some studies also employed comparative studies – groups of companies at risk of going concern versus those still operating (Sundgren, Svanstrom, 2022; Gallizo, Saladrigue, 2016). Other studies also employed surveys, targeting auditors and accounting and auditing researchers (Bava, Gromis di Trana, 2019; Bauer, Hospodka, 2020; Hamza, 2022), as well as students (Hapsoro, 2017) and investors (Brunelli et al., 2023).

Anggarini and Zulfikar (2022), examining companies listed on the Indonesian stock exchange, primarily emphasize the impact of audit reliability on the appropriate going concern opinion. Financial liquidity, profitability, and debt ratios are of lesser importance. Stancheva-Todorova (2021) highlights the particular importance of providing adequate information about threats to going concern during the Covid-19 pandemic. Alexeyeva and Sundgren's (2022) study highlights the links between disclosures in the management report of conditions that could threaten going concern, auditors' reporting on going concern, and the likelihood of company bankruptcy.

Most of the articles cited above are empirical in nature, examining specific phenomena on groups of selected entities. There is not much theoretical or review research, although it should be noted that the topic of going concern assessment has also been a topic of bibliometric analysis, but only with connection to financial distress (Chiosea, Hategan, 2024). That study was carried out only of the articles published in Web of Science database. Our study, filling the research gap, focuses exclusively on topics related to the assumption of going concern, and the data source is the Scopus database.

3. Methods

The main research method of this study is literature review of selected papers recorded in Scopus database. Basic statistical analysis and visualization of selected articles was also performed. To identify research areas, the functionality of the VOSviewer program was used, which allows to determine connections between the keywords used and to visualize them into thematic groups that represent research areas. This type of literature review in connection with bibliometric analysis is a commonly used research method in various scientific disciplines. There is 257,448 papers containing the phrase "literature review" in the title and 22,745 papers containing the phrase "bibliometric analysis" in the Scopus database (as of September 13, 2025).

Literature reviews with bibliometric analysis are also commonly used in research in accounting area. For example, Kureljusic and Karger (2024) conducted a systematic literature review about artificial intelligence based forecasting in financial accounting. This led to the definition of future research agenda in this field. Theuri, Campbell and Owens-Jackson (2024) analyzed technology-related research in accounting education journals. Łazarowicz and Wachowicz (2025) conducted a systematic literature review about ChatGPT in accounting using papers from the EBSCO, Web of Science, Scopus and Google Scholar databases. Khelil and Khlif (2025) studied literature connected with fair value and investment property in accounting literature.

The widespread use of this method in accounting research justifies its use in this study as well. The process of selecting research sample was presented on figure 1.

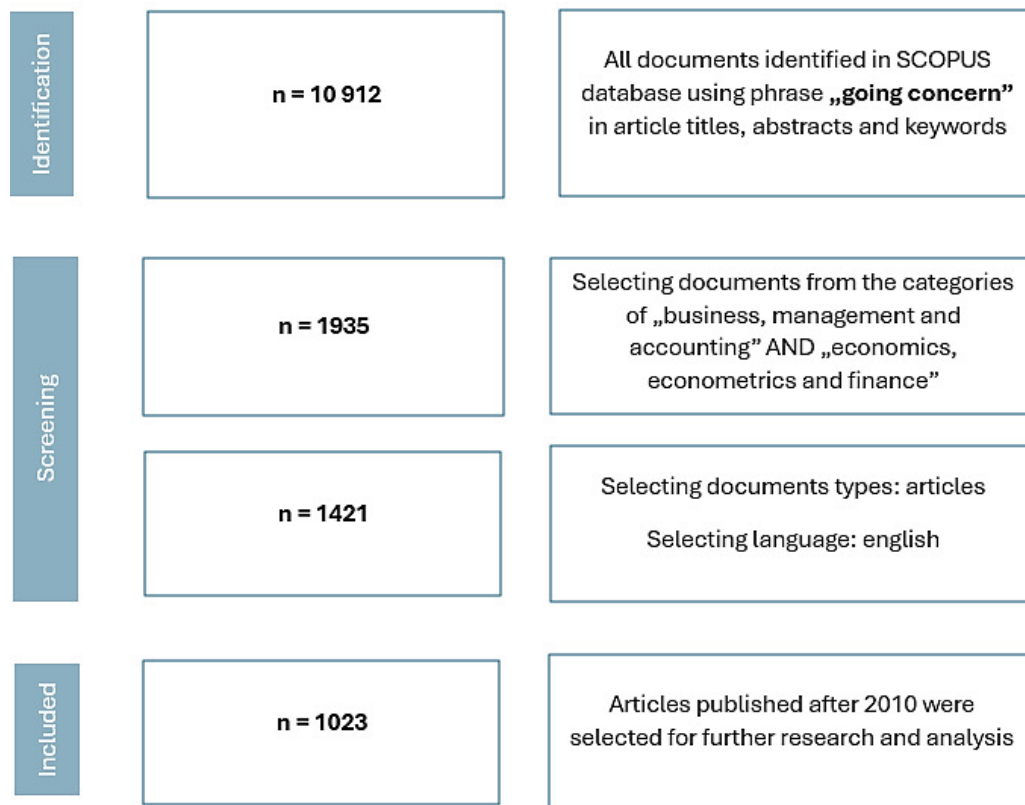


Figure 1. Sample selection via Scopus database.

Source: Own elaboration based on Scopus database (as of 13 September, 2025).

To conduct a broad literature review, we decided to use only the phrase "going concern" in our search. However, this resulted in a significant number of papers from fields unrelated to accounting. Therefore, we decided to limit the categories of papers to "business, management, and accounting" and "economics, econometrics, and finance". The most excluded papers at this stage fell into the categories of "social sciences", "medicine", and "environmental science". To standardize the results, only documents from the "Articles" category were considered for further analysis, excluding, among others, reviews and conference proceedings. For the same reason, papers published in languages other than English were excluded. Initially, we considered all selected works. The distribution of years in which these works were published is presented in Figure 2.

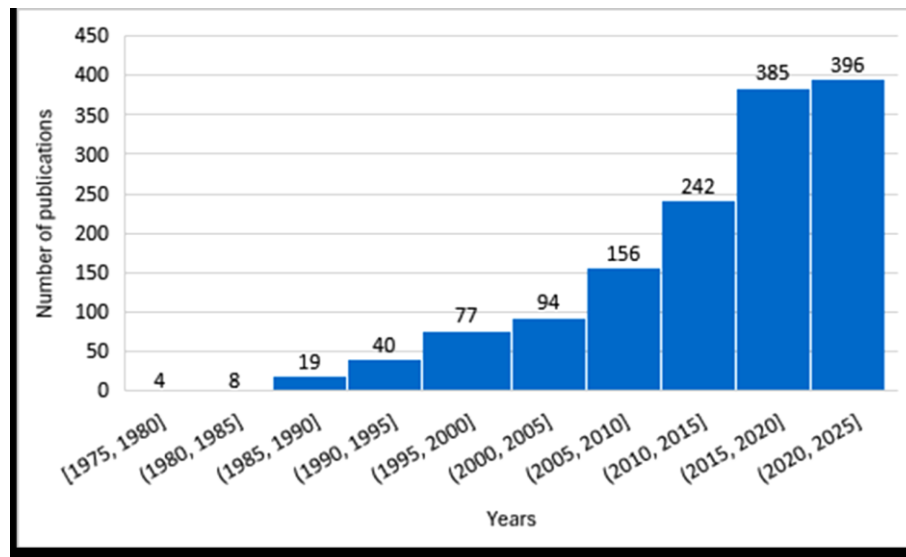


Figure 2. Distribution of years of publication of articles.

Source: Own elaboration based on Scopus database.

The vast majority of publications included in the analyzed database were published after 2010. Taking this into account, as well as new circumstances related to the challenges of assessing the ability to continue as a going concern after the global financial crisis, we decided to use only works published after 2010 in the further part of the study. Therefore, the final sample amounted to 1023 articles.

4. Results and discussion

First, the authors of the largest number of papers in the sample were identified. Table 1 presents the authors of five or more papers cited at least once.

Table 1.

Authors of at least 5 papers in the sample

Author	Number of papers	Total citations
Marshall Geiger	9	538
Elizabeth Carson	7	560
Neil Fargher	7	493
Emiliano Ruiz-Barbadillo	7	82
Gopal Krishnan	6	267
Adi Masli	6	170
Sarowar Hossain	6	147
Nathan Berglund	6	116
Clive Lennox	5	528
Kannan Raghunandan	5	371
Marleen Willekens	5	321
Chan Li	5	84
Andrés Guiral	5	69
Renu Desai	5	36

Source: Own elaboration based on Scopus database.

It was decided to include only authors whose papers have at least one citation in the Scopus database. This was done to identify the most influential authors of works in the field under study, including Marshall Geiger, Elizabeth Carson, Neil Fargher, and Clive Lennox. The next step was to analyze the journals in which the sample articles were published. Table 2 presents the journals in which at least 10 papers were published.

Table 2.
Journals which published at least 10 papers in the sample

Journal	Number of papers
Auditing	37
Contemporary Accounting Research	25
International Journal of Auditing	19
Accounting and Finance	14
Managerial Auditing Journal	14
Journal of Accounting and Public Policy	13
Journal of Accounting, Auditing and Finance	12
Journal of Business Ethics	11
Journal of Cleaner Production	11
Cogent Business and Management	10
Emerald Emerging Markets Case Studies	10
International Journal of Applied Business and Economic Research	10

Source: Own elaboration based on Scopus database.

The largest number of papers were published in the journal "Auditing", suggesting a connection between the topic of going concern assumption and the audit of financial statements. Other significant journals are most often directly related to accounting, although it is worth noting the relatively frequent occurrence of the papers from the sample in journals related to business ethics, management, and emerging markets, among others. The next step was to systematize the topics contained in the most frequently cited works in the sample. Table 3 lists the 10 most cited papers from the sample that are related to the accounting and auditing topics.

Table 3.
Most cited papers in the sample

Authors	Title	Year	Cited by
Carson, E.; Fargher, N.; Geiger, M.; Lennox, C.; Raghunandan, K.; Willekens, M.	Audit reporting for going-concern uncertainty: A research synthesis	2013	237
DeFond, M.; Lennox, C.	The effect of SOX on small auditor exits and audit quality	2011	228
Lukka, K.; Vinnari, E.	Domain theory and method theory in management accounting research	2014	223
Francis, J.; Michas, P.; Yu, M.	Office size of big 4 auditors and client restatements	2013	209
Mayew, W.; Sethuraman, M.; Venkatachalam, M.	MD&A disclosure and the firm's ability to continue as a going concern	2015	183
DeFond, M.; Lim, C.; Zang, Y.	Client conservatism and auditor-client contracting	2016	174
Krishnan, G.; Wang, C.	The relation between managerial ability and audit fees and going concern opinions	2015	160
Albitar, K.; Gerged, A.; Kikhia, H.; Hussainey, K.	Auditing in times of social distancing: the effect of COVID-19 on auditing quality	2021	152

Cont. table 3.

Lamoreaux, P.	Does PCAOB inspection access improve audit quality? An examination of foreign firms listed in the United States	2016	144
Hardies, K.; Breesch, D.; Branson, J.	Do (Fe)Male Auditors Impair Audit Quality? Evidence from Going-Concern Opinions	2016	139

Source: Own elaboration based on Scopus database.

The table above does not include all the most frequently cited articles from the sample. It excludes works completely unrelated to accounting and auditing, such as "The role of application assistance and information in college decisions" (Bettinger et al., 2012) or "Analysis of travel times and CO2 emissions in time-dependent vehicle routing" (Jabali, Van Woensel, de Kok, 2012). The selected works are mostly from the period 2011-2016, with the exception of one article from 2021.

The most frequently cited work is the research synthesis on audit reporting for going-concern uncertainty (Carson et al., 2013). This work identifies three most common research directions in the field of going concern modified audit opinions, which are:

- determinants of going concern modified audit opinions that include client factors, auditor-client relationships, auditor factors, and other environmental factors,
- accuracy of going concern modified audit opinions,
- consequences arising from going-concern modified audit opinions (Carson et al., 2013).

This work is an excellent summary of research topics related to going concern, but only in the scope of examining this ability by auditors. Therefore, further syntheses regarding the broader aspect of going concern seem warranted. The second most thematically related article is the work of Mayew, Sethuraman and Venkatachalam (2015). The authors explored the role of textual disclosures in management reports in predicting a firm's ability to continue as a going concern. This paper connects the topic of going concern assumption with bankruptcy predictions. The conclusion of this work is that management's opinion about going concern and the linguistic tone of the report together provide significant explanatory power in predicting if a firm will continue as a going concern.

In the selected group, some articles referred to the going concern assumption only indirectly. The DeFond and Lennox study (2011) does not directly address the going concern assumption, but describes the characteristics of the activities and exits of small auditors. Lukka and Vinnari (2014) also do not focus on going concern assumption, but on domain theory and method theory in management accounting research. Francis, Michas and Yu (2013) tested client restatements and going concern audit reports of big 4 auditors. DeFond, Lim and Zang (2016) believe that auditors of more conservative clients charge lower fees, issue fewer going concern opinions, and resign less frequently.

Lamoreaux (2016) examined the association between the Public Company Accounting Oversight Board's access to inspect auditors and audit quality. The study stated that inspected auditors provide higher quality audits as measured by more going concern opinions, more reported material weaknesses, and less earnings management, relative to other auditors.

Hardies, Breesh and Branson (2016) examined the relationship between audit quality and the presence of a male or female audit partner. They found that female auditors were more likely to issue going concern modified audit opinions than male auditors. Krishnan and Wang (2015) examined the relation between managerial ability and audit fees and going concern opinions. They found that incremental to firm-level attributes, both the likelihood of issuing a going concern opinion and audit fees are decreasing in managerial ability. The latest paper concerns the effect of COVID-19 on auditing quality. The authors believe that the COVID-19 pandemic can largely affect, among others, audit fees, going concern assessment and audit procedures (Albitar et al., 2021).

In summary, the majority of the most frequently cited papers in the sample are not directly related to the going concern assumption. However, the issue of proper going concern assessment is very important in research on audit quality. This leads to the conclusion that this is a crucial topic for ensuring high-quality audit services, yet the going concern assumption itself is not a very popular research topic.

The next step in this study was to analyze keywords in the articles from the sample and the relationships between them. In this and the next part of the study, some keywords were standardized to avoid duplication due to different spellings. For example, the phrase “going-concern” was replaced by the phrase “going concern”, which was more common. The most popular keywords in the sample are presented in Table 4.

Table 4.
Most frequently occurring keywords in the sample

No.	Keyword	Occurrences
1	going concern	128
2	going concern opinion	88
3	audit quality	72
4	audit fees	41
5	bankruptcy	37
6	covid-19	29
7	sustainability	28
8	audit report	26
9	financial distress	24
10	audit opinion	23
11	auditing	20
12	auditor independence	19
13	sustainable development	18
14	financial crisis	15
15	innovation	15

Source: Own elaboration based on Scopus database.

Among the most frequently occurring keywords, the phrases "going concern" and "going concern opinion" are obvious, which stems directly from the adopted selection method. Other significant keywords are primarily related to financial auditing, which again indicates a significant connection between these topics. It's also worth noting the connection between the topic of going concern assumption and "bankruptcy" and "financial distress", which is directly

related to bankruptcy forecasting and financial distress prediction. Moreover, there is a frequent occurrence of terms related to sustainable development, which is not surprising given the popularity of these topics in recent years. To clearly present the connections between keywords, Figure 3 presents a map prepared using VOSviewer software.

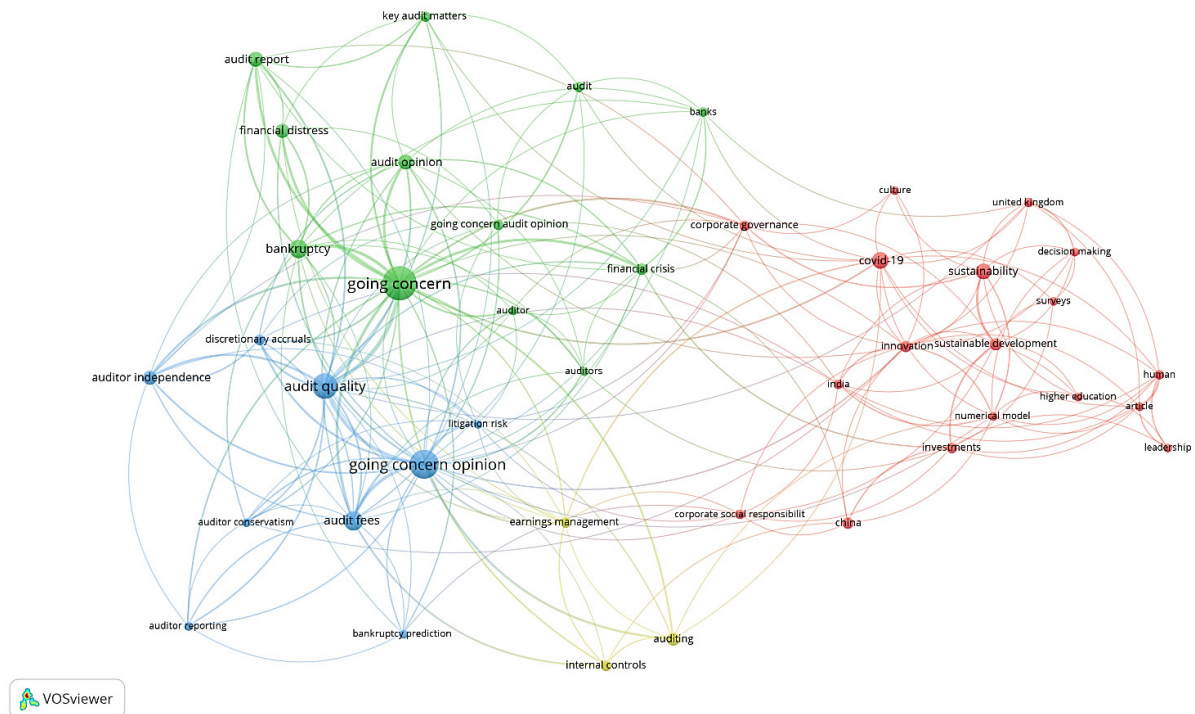


Figure 3. Network visualization map of keywords.

Source: Own elaboration based on Scopus database, prepared in VOSviewer software.

The map depicts the co-occurrence network of keywords which appeared in at least 7 papers in the sample. On this map each circle represents one keyword, and the links between them show how often those keywords appear in papers. The entire set of keywords is divided into 4 clusters, each of which presents thematically similar groups of keywords. The next step is to characterize the groups thus separated:

- Cluster 1 (red):
 - most frequently occurring keywords: sustainability, sustainable development, covid-19, innovation, corporate governance,
 - papers in this cluster focus on many relevant today topics which can be connected with going concern assumption. It also contains some regional studies (ex. In United Kingdom and in India). This is the most diverse cluster.
- Cluster 2 (green):
 - most frequently occurring keywords: going concern, bankruptcy, financial distress, audit report, financial crisis,
 - going concern term in this cluster is related to financial and partly auditing topics. It is also worth mentioning topics related to financial distress and bankruptcies.

Articles in this field may be related to econometric methods of forecasting the bankruptcy of economic entities, taking into account also audit issues.

- Cluster 3 (blue):
 - most frequently occurring keywords: going concern opinion, audit quality, audit fees, audit independence,
 - this cluster focuses on audit issues, auditor's going concern opinion, often connected to audit quality measurement. This research area comprised most of the most cited studies from the sample.
- Cluster 4 (yellow):
 - most frequently occurring keywords: earnings management, internal controls, auditing,
 - this smallest cluster is related to research in the field of internal auditing and management accounting, although the topic of going concern assumption is most often related to financial accounting and financial reporting. It is the furthest from the other clusters.

The largest connections occur between the green cluster and the blue cluster. Both groups of keywords are associated with audit. Significantly smaller connections occur between the remaining groups. There is no group focusing on research in the field of accounting theory unrelated to auditing, among other things.

This cluster analysis, in combination with previously analyzed keywords and the most popular articles, indicates possible research gaps, which might include:

- research combining audit topics and going concern assumptions with contemporary issues such as sustainability or global crises (e.g. covid-19, ongoing wars, inflation),
- research related to accounting theory not directly related to auditing,
- research related to accounting law or standards.

5. Conclusions

This article outlines the main research directions related to the topic of going concern assumption. Topics related to the going concern principle, which is one of the overarching accounting principles, are present in the global scientific literature. This topic has emerged particularly frequently in recent years, demonstrating the growing relevance of the issue under study.

The literature review and bibliometric analysis answered the research questions. Based on keyword analysis, four main clusters of scientific articles related to the going concern assumption were identified. These clusters were related to contemporary socioeconomic topics; the links between going concern and finance and auditing; auditing and its quality; and internal

auditing and management accounting. The most frequently cited works in the area of the going concern assumption raised the topic primarily related to the quality of audit and going concern modified audit opinions. The importance of bankruptcy prediction in our results is consistent with Hammond et al. (2023), while the emerging sustainability cluster highlights a research shift towards non-financial risks. This is supported by, among others, Lee et al.'s (2022) findings on ESG and auditing. Future research should therefore also bridge the gap between these predictive models and emerging environmental variables.

New possible research gaps were also identified related to accounting theory in the field of going concern and the connection of these issues with contemporary socio-economic issues. To operationalize these gaps, future research could, among others, investigate how differences in national accounting laws regarding insolvency thresholds impact the timing and content of management's voluntary going concern disclosures. It could be also important to test whether sustainability performance metrics serve as significant predictors of going concern opinions alongside traditional financial ratios. Empirical work is also needed to determine if the inclusion of pandemic- and war-related variables significantly improves the quality of going concern assessment models in crisis periods.

The study, however, has numerous limitations that should be noted here. First, the study was conducted exclusively on papers included in the Scopus database. Future research should also utilize other available sources of research. The study was also limited in time and language. Furthermore, a detailed selection of articles was not conducted. Research gaps were only identified based on statistics and keyword relationships among the sample articles. Most of the papers were related to auditing. Therefore, a narrower thematic scope, focusing solely on going concern in the context of financial accounting, would be worthwhile. This type of study could further refine the thematic groups of studies and identify specific research gaps.

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AI AS A TOOL FOR SUPPORTING RESEARCH ON THE QUALITY OF E-SERVICES – A METHODOLOGICAL PERSPECTIVE

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Purpose: The main objective of this paper is to present how artificial intelligence can support research on e-service quality and to propose methodological frameworks integrating traditional and AI-based research methods.

Design/methodology/approach: The study reviews classical approaches to e-service quality research (e.g., Servqual, Kano model, surveys, opinion analysis) and examines AI applications such as natural language processing (NLP), machine learning, and behavioral data analytics. A conceptual framework is proposed that integrates declarative, behavioral, and textual data sources to enable comprehensive, real-time analysis.

Findings: AI enhances traditional research by enabling faster, more objective analysis, revealing hidden patterns in user behavior, and supporting predictive modeling of satisfaction and churn. The proposed framework demonstrates the potential for a holistic, data-driven assessment of e-service quality across sectors such as e-commerce, e-education, and e-government.

Research limitations/implications: The framework is conceptual and requires empirical validation in diverse e-service contexts. Limitations include data quality, standardization challenges, ethical considerations, and the need for researcher expertise to interpret AI-generated insights. Future research should test the model in multiple sectors and develop AI tools tailored to management and quality science.

Practical implications: Organizations can use AI to monitor and improve e-service quality in real time, optimize user experience, and inform decision-making processes. Implementation of the framework can enhance service delivery, reduce customer churn, and support adaptive service design.

Social implications: Improved e-service quality can increase accessibility, trust, and satisfaction for digital service users, contributing to higher quality of life and more inclusive digital environments. Insights may also guide public policy and corporate social responsibility initiatives in digital service provision.

Originality/value: The paper presents a novel, integrated methodological framework that combines classical e-service research with AI-driven analytics. It provides guidance for researchers and practitioners seeking to enhance the evaluation, monitoring, and prediction of e-service quality in a data-rich digital environment.

Keywords: e-service quality, artificial intelligence (AI), methodological framework, customer satisfaction, data integration.

Category of the paper: Conceptual paper.

1. Introduction

E-services play an increasingly important role in the digital economy, encompassing areas such as online commerce, distance education, and public administration. The growing number of digital platforms makes the quality of provided services a key determinant of user satisfaction, trust, and loyalty (Parasuraman et al., 2005; Kim, 2006; Pilarz Kot, 2019). Maintaining high service quality in the online environment has become a strategic challenge for organizations seeking to strengthen their competitive advantage and build long-term relationships with users (Kowalik, Klimecka-Tatar, 2018; Bagińska, 2022).

At the same time, the rapid development of artificial intelligence (AI) in management and business research opens new opportunities for improving the understanding and measurement of service quality. AI techniques such as machine learning, natural language processing (NLP), and predictive analytics enable the analysis of large and diverse data sets, providing insights that are difficult to obtain using traditional research methods (Alnor et al., 2026; Mukala et al. 2025; Elkharrat et al., 2026).

Traditional approaches to studying e-service quality, such as surveys, Servqual models, or manual content analysis, remain valuable but have clear limitations. These methods required modification due to the very fact that traditional services and e-services differ fundamentally and therefore need to be evaluated based on completely different attributes. They are often time-consuming, rely heavily on subjective assessments, and provide only static results, which may not capture the dynamic nature of user experience in digital environments. It is particularly challenging, mainly due to the fact that customer requirements are constantly changing, and service enterprises need up-to-date information on how their services are perceived by customers.

Therefore, there is a growing need to develop integrated methodological frameworks that combine the strengths of traditional methods with the analytical potential of AI-based tools. Such integration can enable researchers to obtain more comprehensive, real-time, and context-sensitive insights into how users perceive and evaluate e-services.

Despite the growing body of literature on e-service quality and the increasing use of artificial intelligence in management research, existing studies remain methodologically fragmented. Prior research typically applies classical service quality models or selected AI techniques in isolation, focusing on single data types or specific sectors, most often e-commerce. As a result, there is a lack of integrated research frameworks that systematically combine declarative, behavioral, and textual data and use artificial intelligence to analyze their interrelationships in the context of e-service quality. This methodological gap limits the ability to capture the dynamic, multidimensional nature of digital service quality and to translate analytical results into actionable insights.

The main objective of this paper is to present how artificial intelligence can support research on e-service quality and to propose methodological frameworks integrating traditional and AI-based research methods.

The following research questions guide the analysis:

- What classical methods are used to study e-service quality in management sciences?
- How can AI support or complement these traditional methods?
- What new methodological framework can be proposed for studying e-service quality using AI tools?

Addressing these issues provides a structured basis for identifying the potential of artificial intelligence in e-service quality research and for developing an integrated methodological approach that responds to the dynamic nature of digital services.

The novelty of this study lies in its methodological perspective on e-service quality research. Unlike existing studies that focus on isolated applications of artificial intelligence or single data sources, this paper proposes an integrated research framework that systematically combines declarative, behavioral, and textual data with AI-based analytical tools. By linking classical service quality methods with machine learning and natural language processing, the study introduces a coherent approach that enables dynamic, data-driven, and multidimensional assessment of e-service quality across different digital service sectors.

2. Literature review

2.1. Conventional approaches to e-service quality research

Research on e-service quality traditionally relies on well-established tools and conceptual models adapted from the study of offline services. The most frequently applied methods include the Servqual model, which measures the gap between customer expectations and perceptions of service performance, the Kano model, which distinguishes between basic, performance, and excitement attributes, as well as customer satisfaction surveys and opinion analysis based on qualitative data (Midor, Kučera, 2018; Cieśła, 2024, Sitinjak, Ober, 2025). These approaches have provided valuable insights into understanding how users evaluate digital interactions and what determinants shape perceived service quality.

Research on the quality of e-services is based both on the adaptation of classical service quality assessment methods and on the development of approaches specific to the digital environment. Traditional models, such as Servqual, Servperf, and Kano, were originally designed for traditional services; however, over time, they have been modified to account for the characteristics of interactions occurring in online contexts (Ingaldi, 2018; Nadziakiewicz, Mikolajczyk, 2019; Cao et al., 2025; Khouj et al., 2024). In e-service quality research,

the E-Servqual model plays a particularly important role, as it adapts the original quality dimensions (tangibility, reliability, responsiveness, assurance, empathy) to the online context, focusing, among other aspects, on efficiency, fulfillment of promises, system availability, and privacy protection. The use of such models enables the measurement of users' subjective perceptions of quality, the analysis of gaps between expectations and actual experiences, and the identification of areas requiring improvement (Cotîrlea, 2011; Setiawan et al., 2025; Rol, Alaeddinoğlu, 2025).

Survey research is commonly employed to assess e-service quality, taking the form of traditional questionnaires or integrated online forms. These are complemented by focus group studies, in-depth interviews, and content analysis of user reviews posted on social media or review platforms. Increasingly, researchers focus on the analysis of user experience (UX), encompassing functional, aesthetic, emotional, and cognitive aspects of interaction with digital services. In this context, observational and experimental methods, such as clickstream analysis, eye-tracking studies, and usability testing, are gaining importance, as they provide deeper insights into user behavior in online environments (Melo, Monteiro, 2025; Njuguna, Qingfei, 2026; Kazakoff et al., 2025).

Contemporary e-service quality research increasingly adopts a holistic approach, combining the customer perspective with an analysis of organizational and technological processes. This implies that e-service quality is not perceived solely as a result of user satisfaction but also as an outcome of the quality of IT infrastructure, data security, system reliability, and the efficiency of service processes. Consequently, integrated quality measurement models, such as E-Servqual, WebQual, Sitequal, Piruqal, IRSQ, .comQ, E-TailQ, E-S-QUAL, E-SQ, e-RecS-Qual, E-A-S-Qual, eTransQual, eSelfqual, E-SQual-ERec-SQual are increasingly applied in research practice, enabling the assessment of both users' subjective perceptions and objective technical and functional parameters of the service (Webb, Webb, 2004; Wolfinbarger, Gilly, 2003; Ghosh, 2018; Ingaldi, 2022).

The entire process of e-service quality assessment can be illustrated using a diagram (Fig. 1). Taking into account customer expectations, a subjective evaluation of quality is conducted with respect to two key dimensions, such as organizational processes and technology. This evaluation results in information about the overall level of e-service quality.

By systematically integrating feedback from multiple data sources, researchers can obtain a more comprehensive and nuanced understanding of service performance. The model also allows for the identification of critical factors that influence user satisfaction and loyalty, supporting targeted improvements in both service delivery and technological infrastructure. Ultimately, this approach enables organizations to not only assess but also dynamically monitor and enhance the quality of digital services in response to evolving customer expectations.

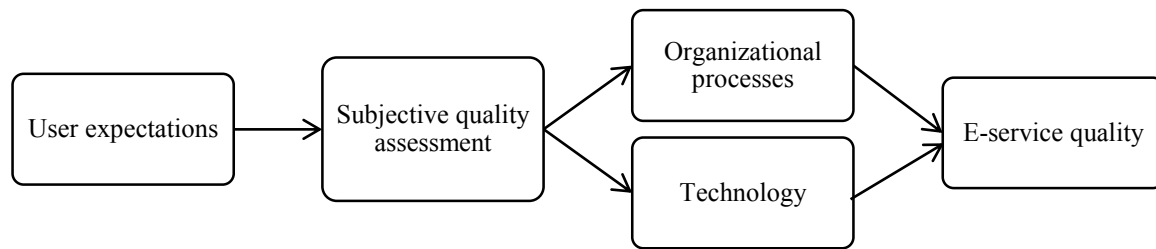


Figure 1. Conceptual Diagram of E-Service Quality Assessment Process.

Source: own study.

It should be remembered, that traditional tools have several methodological limitations when applied to the online environment. They are often time-consuming and rely on subjective user declarations, which may not fully reflect actual behavior. Moreover, they typically produce static results, offering only a snapshot of user perceptions at a specific moment in time, without capturing the dynamic and continuous nature of digital interactions.

As e-services become more complex and data-rich, there is a growing demand for research approaches that enable real-time measurement, automatic data processing, and integration of multiple data sources, including behavioral and textual data. This methodological shift creates a space for the application of AI-based analytical tools, which can complement and enhance classical research designs by providing more objective, scalable, and adaptive insights into service quality.

Building upon these traditional approaches, the following section explores how AI extends the methodological landscape of e-service quality research.

2.2. Applications of Artificial Intelligence in e-service quality research

The application of artificial intelligence (AI) in research on digital service quality significantly expands analytical and interpretative capabilities compared to traditional research methods. AI enables not only the processing of large and unstructured datasets but also the identification of hidden patterns in consumer behavior, relationships between variables, and changes in the perception of service quality over time (Chrysikou et al., 2026; Noor et al., 2022; Gerlich et al., 2021).

One key application is natural language processing (NLP), which allows for the analysis of user-generated texts, such as reviews, comments on social media, or customer service chat logs. NLP tools can automatically classify statements according to emotional tone (sentiment analysis), identify the most frequently occurring issues, and analyze satisfaction with specific aspects of a digital service (Alnor et al., 2026; Mukala et al., 2025; Elkharrat et al., 2026). The use of these techniques enables the creation of dynamic maps of quality perception, which can support customer experience management (CEM).

Another important area is machine learning (ML), which facilitates modeling the relationships between factors affecting customer satisfaction and their actual behavior. ML algorithms can predict satisfaction levels, user loyalty, or the risk of service abandonment (churn prediction). These models can be integrated with CRM systems or e-commerce platforms, allowing for personalized offers and early intervention when dissatisfaction is detected (Budhathoki et al., 2026; Zhan et al., 2025; Khabusi et al., 2025).

A third significant direction is the analysis of behavioral data, such as clickstream, time spent on a website, click sequences, or user navigation paths. The use of unsupervised learning algorithms (e.g., clustering or self-organizing neural networks) allows for the identification of typical behavior patterns and user segments (Suratno et al., 2025; Baek, 2025; Gerlich et al., 2021). This enables researchers to better understand how users interact with digital services and to identify key critical points influencing perceived service quality.

The application of AI in service quality research can also be seen as a new methodological dimension that combines classical approaches (e.g., surveys or interviews) with the analysis of digital data. Such an integrated approach enables triangulation of results and enhances the reliability of interpretations (Noor et al., 2022; Hamedani et al., 2025; Zachurzok-Srebrny, 2024). In the context of e-service quality research, AI thus serves not only as a computational tool but also as a method supporting the exploration and validation of phenomena that are difficult to capture in traditional social research.

Despite the growing number of studies, there is a lack of an integrated methodology combining traditional approaches with AI tools in the context of e-services. Most research focuses on a single sector, such as e-commerce, leaving gaps in areas like online education or digital administration. This highlights the need to develop frameworks that integrate declarative, behavioral, and textual data, which can be analyzed with AI support.

2.3. Identified gaps in the literature

Despite the growing interest in the use of artificial intelligence in research on e-service quality, there remains a lack of coherent and comprehensive methodological frameworks that integrate traditional research approaches with advanced AI analytical tools. Most existing studies are fragmentary in nature, focusing on selected aspects such as customer review analysis, satisfaction prediction, or user behavior modeling, while often neglecting the broader systemic context.

The dominant research trend mainly targets the e-commerce sector, which, due to its large data availability and measurable interactions, constitutes a natural testing ground for AI-based solutions. In contrast, other areas of digital services such as remote education, online public administration, or e-health, receive considerably less attention, even though they represent critical spaces for shaping user experiences and service quality in the digital society.

As a result, there is a lack of integrated research models that combine:

- declarative data (e.g., survey and interview results),
- behavioral data (e.g., user activity, click paths, response times),
- and textual data (e.g., reviews, comments, chats).

The integration of these three types of information, analyzed using AI algorithms (e.g., NLP, neural networks, predictive models), could enable a more comprehensive assessment of e-service quality and the identification of hidden relationships between user perceptions and actual behaviors.

Future research should therefore focus on developing an interdisciplinary methodological framework that combines knowledge from quality management, data analytics, and artificial intelligence. Such an approach could contribute to the emergence of a new research paradigm, e.g. “AI-driven quality research”, which would not only diagnose but also dynamically forecast the quality of digital services in real time.

3. Methods

The proposed research model defines a methodological procedure for e-service quality analysis. However, it is not empirically applied in this study and serves as a conceptual reference framework for illustrating potential applications across different sectors.

3.1. Integration of data

The proposed research model for e-service quality (Tab. 1, Fig. 2) assumes the integration of three main categories of data: declarative, behavioral, and textual. Their combination enables a more comprehensive understanding of the user experience (UX) and a more reliable assessment of digital service quality. Table 1 summarizes the structure of the proposed research model, highlighting the role of AI in analyzing different data categories.

Table 1.
Research model for e-service quality

Data Type	Examples	Role of AI
Declarative Data	Surveys, SERVQUAL questionnaires, interviews	Statistical analysis, identification of key satisfaction factors, integration with behavioral data
Behavioral Data	System logs, clickstreams, UX data	Pattern detection, predictive analysis, user segmentation
Textual Data	Reviews, comments, chats, social media posts	NLP, sentiment analysis, topic classification, emotion detection

Source: own study.

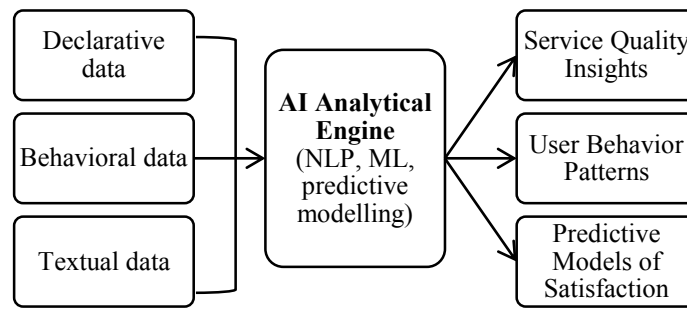


Figure 2. Conceptual model of data integration for e-service quality research.

Source: own study.

The integration of these three data sources enables methodological triangulation, enhancing the reliability and depth of the findings. Declarative data capture the subjective perception of quality, how users perceive the service. Behavioral data reveal actual patterns of user behavior, while textual data provide contextual qualitative information that can be automatically analyzed using AI algorithms, overcoming the limitations of manual content analysis.

From a methodological perspective, the model assumes the use of hybrid data analysis methods, in which AI supports the researcher in processing, classifying, and interpreting results. Supervised learning models (e.g., logistic regression, decision trees) can be applied to predict satisfaction or loyalty, while unsupervised learning (e.g., clustering) can be used to segment users based on behavioral patterns.

Figure 3 presents the proposed conceptual framework integrating declarative, behavioral, and textual data with AI analytical modules. The diagram illustrates how various data types are processed through natural language processing (NLP), machine learning (ML), and predictive models to generate actionable insights for improving e-service quality.

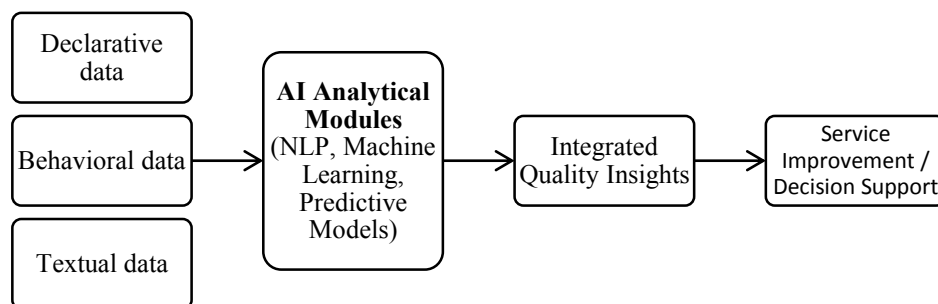


Figure 3. Conceptual AI-Driven Framework for E-Service Quality Research.

Source: own study.

This framework visualizes the data flow within the proposed model, emphasizing the integrative and iterative nature of AI-assisted quality analysis. It also demonstrates the transition from raw data to practical insights that can inform managerial decision-making and service improvement strategies.

3.2. Methodological Benefits

The implementation of the proposed model offers several methodological advantages:

- Faster and more efficient data analysis – the use of AI tools enables the analysis of large volumes of data in real time, which is particularly important in the dynamic environment of digital services.
- Integration of heterogeneous data sources – combining quantitative and qualitative information allows for a multidimensional assessment of e-service quality.
- Detection of hidden patterns and relationships – machine learning algorithms can reveal connections between user behaviors, their opinions, and survey results that would be difficult to identify using traditional analytical techniques.
- Increased objectivity and replicability of research – automating parts of the analytical process reduces the influence of subjective researcher interpretations while enabling repeatable analyses.

Thanks to these advantages, the model can serve as a foundation for the development of intelligent e-service quality monitoring systems and dynamic decision support tools (DSS) for managers responsible for customer experience.

3.3. Challenges and limitations

Despite numerous advantages, data integration and the use of artificial intelligence in e-service quality research also involve certain challenges:

- Data quality and standardization – data from different sources often vary in structure, level of detail, and reliability. It is essential to develop procedures for cleaning, harmonizing, and validating input data.
- Ethical and legal aspects – the use of user data, particularly textual and behavioral data, requires compliance with privacy principles and regulations such as GDPR. Ensuring participant anonymity is also crucial.
- Risk of algorithmic bias – AI models can reproduce or amplify existing biases in the data, potentially leading to incorrect conclusions. Therefore, the interpretation of results should be supported by expert researcher judgment.
- Interpretative complexity – although automated analyses provide rapid results, contextual interpretation in light of service quality theory and consumer behavior is necessary to ensure cognitive validity.

Developing ethical, technical, and interpretative standards for such research represents a key step toward fully leveraging the potential of AI in digital service quality analysis.

In summary, the proposed methodology combines traditional research approaches with advanced AI-based data analysis techniques. This approach enables a multidimensional assessment of e-service quality and provides a foundation for the development of new research tools and conceptual frameworks in quality management within the digital environment.

4. Results

The Results section presents objective methodological outcomes in the form of sectoral illustrations and structured examples demonstrating how the proposed research framework could be applied in different e-service domains, without empirical implementation or interpretative analysis.

The use of artificial intelligence in research on e-service quality is reflected across various sectors of the digital economy. Each sector is characterized by a specific user profile, data structure, and distinct quality assessment criteria. Below, three illustrative areas are presented in which AI methods can significantly support the research process.

E-commerce

In the e-commerce sector, artificial intelligence is used both to analyze service quality and to personalize user experiences. Natural Language Processing (NLP) tools allow for the analysis of customer reviews posted on sales platforms, social media, or customer service systems. This enables the automatic classification of statements according to quality-related categories (e.g., delivery time, customer service, product quality) as well as sentiment analysis.

Behavioral data, such as clickstreams, number of visits, purchase paths, or cart abandonment rates, can be analyzed using machine learning algorithms to predict purchase intentions and identify barriers in the buying process. Predictive models (e.g., gradient boosting, random forest) can estimate the likelihood of cart abandonment and suggest intervention strategies, such as automated reminders or personalized offers. This approach allows for both the improvement of service quality and the optimization of e-commerce processes from the perspective of customer experience.

E-education

In the context of digital education, AI supports the analysis of educational service quality by processing both declarative and behavioral data. Based on survey results, student feedback, and activity on e-learning platforms, it is possible to examine course satisfaction, the effectiveness of learning materials, and participant engagement.

Machine learning algorithms can be used to cluster students according to activity patterns (e.g., login frequency, number of completed modules, forum interactions), enabling the identification of groups with high or low risk of course dropout. Additionally, textual analysis of open-ended responses or comments allows the detection of areas needing improvement, such as the quality of communication with instructors or the usability of the platform.

AI also facilitates the creation of adaptive e-learning systems that personalize content and learning paths according to user preferences and progress, directly impacting the perceived quality of the educational experience.

E-government

In the public online services sector, the application of AI is particularly important for improving the accessibility and efficiency of citizen interactions with government administration. The analysis of textual data from contact forms, inquiries to offices, or chatbot conversations enables the assessment of communication quality, the identification of recurring issues, and the automatic grouping of inquiry topics.

NLP-based systems can support administration in monitoring citizen service quality, for example, by analyzing emotions in statements, evaluating satisfaction after completed interactions, or detecting difficulties in understanding procedures. Similarly, the analysis of behavioral data, such as portal visit frequency, task completion time, or the number of incorrect form submissions, allows for the identification of bottlenecks in digital processes and their optimization.

As a result, AI can support not only the assessment of e-government quality but also the design of more user-friendly and inclusive digital systems, which is one of the pillars of modern public management in the digital era.

Tables 2 and Figure 4 present a summary of AI applications in assessing quality across the illustrated areas. The overview demonstrates that in each of the analyzed sectors, it is possible to leverage a combination of declarative, behavioral, and textual data. AI enables the transformation of these data into actionable knowledge on service quality, paving the way for more integrated, empirical models for evaluating user experiences in the digital environment.

Table 2.
Applications of AI in E-Service Quality Research

E-Service Sector	Types of Data Analyzed	AI Tools Applied	Potential Research Benefits
E-Commerce	Textual data (reviews, comments), behavioral data (clickstream, cart abandonment)	NLP – sentiment analysis, topic classification; Machine Learning – cart abandonment prediction, customer segmentation	Identification of key factors affecting customer satisfaction and loyalty; prediction of purchasing behavior; optimization of service quality
E-Education	Declarative data (student surveys), behavioral data (platform activity), textual data (comments)	Machine Learning – student clustering, predictive analysis of dropout risk; NLP – analysis of opinions and emotions	Understanding engagement patterns; personalization of educational content; improvement of e-learning experience quality
E-Government	Textual data (messages, inquiries, chatbot conversations), behavioral data (portal interactions, response time)	NLP – language and sentiment analysis, topic classification; Predictive analysis – identification of user issues	Assessment of citizen service quality; streamlining administrative processes; enhancement of accessibility and user satisfaction

Source: own study.

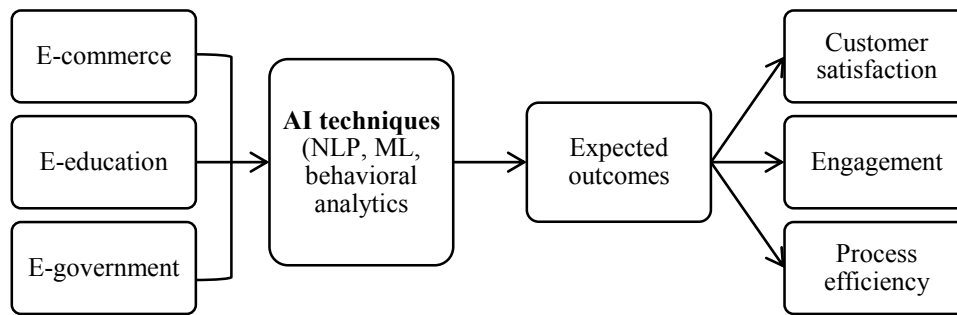


Figure 4. Overview of AI Applications in E-Service Quality Assessment Across Different Sectors.

Source: own study.

The applications of artificial intelligence across various e-service domains demonstrate that AI not only supports quality analysis but also serves as a tool actively shaping the user experience. The integration of declarative, behavioral, and textual data enables a more holistic understanding of digital service quality, opening new research opportunities in the fields of quality management and innovation.

5. Discussion

The integration of artificial intelligence with traditional research methods represents a significant step toward the development of modern approaches to analyzing e-service quality. Combining statistical, survey, and qualitative tools with machine learning algorithms and natural language processing (NLP) techniques enables research with a higher level of objectivity, speed, and precision. This makes it possible to process large, diverse datasets, e.g. declarative, behavioral, and textual, that were previously difficult to analyze using conventional methods.

From a methodological perspective, the application of AI opens new opportunities for data triangulation and result validation, as well as for detecting hidden relationships and patterns in user behavior. Such an approach supports a more in-depth diagnosis of service quality and the dynamic monitoring of changes in customers' perceived value. Consequently, AI can be seen not only as an analytical tool but also as a methodological partner for researchers, supporting the cognitive and decision-making processes.

At the same time, integrating AI into e-service quality research involves several challenges. Data quality and reliability are critical, as they form the foundation for machine learning algorithms. Incomplete, inconsistent, or contaminated data may lead to erroneous conclusions, even when using advanced models. Ethical and legal issues are also crucial, including user privacy protection, transparency of analytical processes, and compliance with regulations such as GDPR.

Equally important is the role of researcher competencies, as interpreting results generated by AI models requires not only knowledge of IT tools but also the ability to critically analyze and understand the socio-organizational context. Without this, there is a risk of overreliance on algorithmic outputs and potential misinterpretations.

The proposed model has several notable research limitations:

- Conceptual nature of the methodological framework – the model requires empirical validation across different e-service contexts to confirm its practical effectiveness.
- Data quality and standardization – data from various sources may be inconsistent, incomplete, or difficult to compare.
- Ethical considerations – ensuring privacy, anonymity, and compliance with legal regulations, such as GDPR, is essential.
- Expert interpretation of results – analyzing AI-generated outcomes requires researcher expertise to avoid erroneous conclusions due to algorithmic bias.

From the perspective of future research, the following directions appear particularly important:

- Testing the proposed data integration model across different e-service sectors (e.g., e-health, e-finance, e-government).
- Developing AI tools tailored to the needs of management and quality sciences.
- Advancing the concept of AI-driven quality research, in which artificial intelligence supports the research process at all stages, from data collection to result interpretation.

In summary, the use of artificial intelligence in e-service quality research does not replace traditional methods but serves as their natural extension. Integrating both approaches enables the creation of modern, adaptive research models that better reflect the complexity of contemporary digital environments and evolving user needs.

6. Conclusions

This paper critically reviewed existing approaches to e-service quality research and demonstrated their methodological limitations, particularly their reliance on subjective, declarative data, static measurement results, and limited ability to capture the dynamic nature of digital service interactions. The analysis showed that traditional models, although still valuable, are insufficient when used independently in contemporary, data-intensive digital environments.

Based on the results of the conceptual analysis and sectoral examples presented in the study, new knowledge is provided in the form of an integrated, AI-supported methodological framework for e-service quality research. The proposed model combines declarative, behavioral, and textual data and illustrates how artificial intelligence techniques such as

machine learning and natural language processing can enhance data triangulation, pattern detection, and predictive analysis of user satisfaction and behavior.

From a theoretical perspective, the study contributes to the development of management and quality sciences by extending existing e-service quality research paradigms toward a more holistic and dynamic, data-driven approach. It supports the emerging concept of AI-driven quality research, in which artificial intelligence complements classical methods throughout the research process, from data collection to interpretation.

From a practical perspective, the results indicate that the proposed framework can be used by organizations to monitor e-service quality in real time, identify critical service weaknesses, and support evidence-based decision-making. The integration of AI tools enables faster response to changing user expectations and facilitates the design of adaptive, user-centered digital services across sectors such as e-commerce, e-education, and e-government.

The study is methodological and conceptual in nature, which constitutes its main limitation. The proposed framework requires empirical validation using real-world data from different digital service contexts. Nevertheless, the results provide a solid foundation for future research aimed at operationalizing the model, testing its effectiveness, and developing dedicated AI tools for quality management practice.

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THE IMPLEMENTATION GAP IN THE DIGITAL MATURITY OF POLISH ENTERPRISES – MEASUREMENT AND IDENTIFICATION

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Purpose: The purpose of article is to define and empirically measure the implementation gap in enterprises' digital maturity, understood as the difference between the declarative–narrative and operational–implementation levels of digital transformation.

Design/methodology/approach: A quantitative survey was conducted on a sample of 697 enterprises in Poland, using the CAWI technique. A modified version of the “Digitalcheck Mittelstand” tool was employed. Two indices were constructed: the declaration index (ID) and the implementation index (IR), as well as the gap indicator $L = ID - IR$.

Findings: The implementation gap proved to be a structural phenomenon: only 10.3% of the enterprises achieve a relative alignment between the level of declarations and the implementation of digital technologies, 40.7% display overestimation, and 48.9% underestimation. The results confirm that the narrative–strategic and operational–implementation layers of digital maturity often develop asynchronously.

Research limitations/implications: The study is cross-sectional, based on self-report data and conducted in a single country, which limits the possibility of causal inference and generalizing the results to other economies.

Practical implications: The results indicate the need to design digital-maturity measurement tools that separate the level of declarations and the level of implementation of digital technologies and report at least two indices (ID, IR) and their difference. Diagnosing the implementation gap enables managers to identify situations in which strategy and narrative run ahead of operational capabilities ($L > 0$), or conversely, where implementation capabilities are not supported by a coherent vision, leadership, and communication ($L < 0$). The structure of the gap, differentiated by sector and firm size, suggests the necessity of designing individualized transformation programs.

Social implications: The implementation gap distorts the diagnosis of the state of digital transformation at the system level and may lead to errors in public policy, including supporting entities that are narratively skilled at the expense of those that actually possess advanced digital capabilities. Introducing an explicit gap indicator into measurement tools improves the quality of information used in designing support programs, economy-wide digitalization strategies, and initiatives related to social responsibility and sustainable development.

Originality/value: The article proposes a coherent Resource-Based View based concept of the implementation gap in digital maturity. It demonstrates empirically that this gap is not “measurement noise” but a dominant feature of contemporary enterprises.

Keywords: digital maturity, economic entities, Poland.

Category of the paper: research paper.

1. Introduction

Digital maturity of enterprises is a widely discussed concept, approached in the literature through numerous, partially overlapping ideas of how to define and measure it. The starting point for conceptualizing digital maturity is the process of digital transformation. Digital transformation is understood as the implementation of advanced technologies in order to optimize economic and social processes (Pricopoaia et al., 2025). Many authors define digital transformation as the implementation of technologies across all areas of an organization (Babaçoğlu et al., 2025). They treat this process as evolutionary, oriented toward leveraging digital opportunities and technologies to create value propositions within existing business models. Enterprises that invest resources in digital transformation usually experience growth and are more likely to achieve their intended outcomes (Kotiranta et al., 2024; Rossmann, 2018). Digital transformation can therefore be seen as a development path aimed at accomplishing goals and identifying ways of solving or preventing problems (da Costa et al., 2022; Nikkhou et al., 2016).

One of the most frequently cited definitions of digital maturity comes from Chanas and Hess (2016), who describe it as “the state of a firm’s digital transformation” and as a measure of “what the firm has already achieved in terms of transformation activities”. In this sense, digital maturity functions as an indicator of an organization’s current position and as a tool for identifying subsequent steps in the digital transformation process. At the same time, measuring it remains difficult, mainly due to the multitude of interpretations of digital transformation itself (Zaoui, Souissi, 2022). Ka et al. (2023) emphasize that digital transformation is a continuous process; accordingly, digital maturity supports the assessment of an organization’s current level of digitalization and provides ongoing feedback on its progress (Berghaus, Back, 2016).

Models used to assess levels of digital maturity offer a detailed description of the current state of enterprises and their strategies for implementing the Industry 4.0 concept (Gajdzik et al., 2025). They are research-oriented in nature, providing structured methods for assessing enterprises and the actions they have taken to reach a given maturity level.

The architecture and areas of application of digital maturity models vary considerably (Laaber et al., 2024; Hizam-Hanafiah et al., 2020). Nonetheless, important similarities can be identified: these models delineate analogous stages that guide organizations toward higher levels of digital maturity (Ochoa-Urrego, Pena, 2021). They usually assume that a clearly formulated digital strategy, aligned with the corporate strategy, is the starting point for any digitally oriented organization. In the initial phases, these models stress strategic prioritization, work flexibility, and managerial engagement in the transformation process. At this stage, they highlight the strategic importance of innovation, as well as the need to consciously develop digital innovation capabilities, support collaboration, and systematically explore the potential of new technologies. The next step is to develop digital innovations and collaboration aimed at

implementing digital business models, which translates into new products, services, and channels of operation. In parallel, a digital culture is shaped, organizational structures, leadership style, and change management are modified so that values, norms, and work practices foster experimentation and learning. In the later phase, digital progress is sustained through specific initiatives, flexible work arrangements, and continuous support from management, which reinforce the development of digital solutions. As a result, the organization attains digital maturity, understood as the ability to continuously anticipate changes in the digital environment, critically monitor its own performance, and rapidly adapt strategies, processes, and business models to a dynamically changing reality (van Tonder et al., 2024).

In the last decade, research on digital maturity of enterprises has focused primarily on identifying factors conducive to transformation and on mapping the stages of moving from an “analog” to a “digital” organization (Kane et al., 2015; Vial, 2019). In typical measurement approaches, a single scale is used to measure simultaneously: (a) the existence of a digital strategy, (b) leadership and culture supportive of change, and (c) the extent of use of technologies, data, and automation. The implicit assumption is that the strategic and cultural layer is a sufficient predictor of the operational layer. Empirically, this does not have to be true: an organization may have a strategy, financial resources, and communication, but lack integrated systems, unified data dictionaries, security procedures, and mechanisms for financing IT investments (Ross et al., 2019). The opposite situation is also possible: the enterprise has systems, procedures, and data but is unable to communicate the digital transformation process and the successes it achieves in this area. Thus, classical models, by combining intention and execution, may overestimate the level of digital maturity in organizations that “speak well about digitalization” but “implement it poorly”, or underestimate maturity in organizations that “implement it excellently” but “speak about it insufficiently”.

The problem is important because in classical measurements of digital maturity both types of variables “we want to, we have a strategy” and “we are able to, we have data and integration” are aggregated into a single index, which smooths over real infrastructural and competence gaps. As a result, an enterprise may be classified as “advanced” solely because it fulfills the narrative–strategic layer of transformation, even though it lacks the technical and procedural conditions to reach higher levels of digital maturity (Warner, Wäger, 2019), or as “non-advanced” solely because it does not fulfill the narrative–strategic layer, despite having the technical and organizational conditions for digital maturity. This leads to a flawed diagnosis of the state of digital transformation both at the organizational level and at the level of the entire economic system.

A precondition for effective digital transformation of an enterprise is its IT capability and process-based data management. In line with Resource-Based View (RBV) theory in the context of IT capability, a strategic orientation toward digitalization alone is insufficient if the enterprise does not possess IT capabilities that enable fast and reliable implementation of solutions. IT capability is understood here as a bundle of technical resources (infrastructure,

system integration, architecture), human resources (development competencies, project management, security), and relational resources (business–IT collaboration), which together form the basis for translating strategy into working services and processes (Ross et al., 2019). A modular, well-documented architecture and the ability to quickly integrate new components distinguish firms that merely talk about transformation from those that exploit it economically (Ross et al., 2019).

The second pillar of effective digital transformation is process-based data management and data governance. Khatri and Brown (2010) argue that organizations without clearly defined decision roles concerning data quality, standards, security, and access end up with fragmented, inconsistent data sets that cannot serve as a basis for advanced analytics or process automation. Otto (2011) adds that maturity in data management requires a process perspective: data must be embedded in process flows rather than treated as a “by-product” of transactional systems. In this light, indicators such as “we have an AI strategy” or “management supports digitalization” do not yet reveal whether the organization is actually able to fuel these ambitions with high-quality, integrated data.

The perspective of dynamic capabilities (Teece, 2007) provides a theoretical framework to explain why organizations are able to recognize the importance of digitalization (sensing) and even communicate it (partial seizing), but fail to carry out deep resource reconfiguration (reconfiguration). In Teece’s view, real transformation requires not only recognizing a technological opportunity but also launching costly and often politically difficult processes: standardization, decommissioning of legacy systems, investments in infrastructure, retraining employees, and changing IT budgeting rules. If the enterprise lacks sufficient reconfiguration capability because it does not have enough capital, operational-level managerial determination, or IT competences, a typical pattern emerges: high awareness, low operationalization.

Applying this perspective to research on digital maturity allows the implementation gap to be interpreted not as a “measurement error” but as a real characteristic of many contemporary enterprises: they are exposed to technological and regulatory pressures, so they learn to speak the language of digital strategy, but do not have a parallel capability to reconfigure their operational core. The gap is thus a manifestation of an asymmetry between sensing/seizing and reconfiguration.

The gap between the narrative–strategic layer and the operational layer in the measurement of digital maturity leads to systematic distortion of results: organizations that “loudly talk about digitalization” are overestimated, while those that “quietly implement it” are underestimated, which reduces the validity of indices and their ability to provide a reliable diagnosis of the state of transformation. Aggregating the variables “we want to, we have a strategy” and “we are able to, we have data and integration” into a single indicator masks real deficits or advantages in the area of IT capability and data governance, makes it difficult to distinguish strategic–cultural problems from infrastructural–process ones, and distorts the classification of maturity stages in “stage-based” models. Consequently, the observed relationships between digital maturity and

outcomes (business, operational, ESG) are weakened, which may lead to erroneous theoretical conclusions (within RBV, IT capability, dynamic capabilities) and misguided public policy decisions and support programs that reward entities skilled in narrative at the expense of those that actually possess advanced digital capabilities.

The aim of this article is to define and empirically measure the gap between the declarative–narrative level and the operational–implementation level of digital maturity within a single survey-based measurement on a sample of 697 Polish enterprises. For the purposes of this article, the following research questions are posed:

1. Does an implementation gap in digital transformation occur in Polish enterprises?
2. What is the direction of the implementation gap: overestimation or underestimation?

The remainder of the article presents the theoretical framework and operationalization of the implementation gap, the research methodology applied, the results of the empirical analyses, and the implications for the design of digital maturity measurement tools and for the practice of managing digital transformation.

2. Methods

2.1. Digital Maturity Measurement Tool

There is a wide range of models for assessing digital maturity. Thordsen and Bick (2023) conducted a systematic literature review of solutions developed between 2011 and 2022 and showed that existing models differ substantially in terms of quality and content, which makes them difficult to compare. Most of them do not meet standard academic criteria, as they are often created by business consultants outside the scientific context. The choice of model for this study was driven by the availability of the measurement scale (e.g., Deloitte and PwC models are not accessible without a paid license), its reliability, and the universality of the model (preference was given to tools not restricted to a single sector, such as manufacturing). Another important criterion was the range of dimensions included in the scale, with priority given to tools covering the broadest possible spectrum of digital maturity dimensions.

The measurement instrument used in this study was based on the “Digitalcheck Mittelstand” model (<https://digitalzentrum-berlin.de/digitalcheck-mittelstand>, accessed on 16 November 2025). This model distinguishes seven core dimensions of digital maturity, which were adopted as the framework for the assessment tool. The questionnaire was translated from German into Polish, preserving the structure of the maturity dimensions: strategy, customers, products and services, processes, organization, IT infrastructure, and external environment. An additional dimension, integrated digital leadership, was introduced to extend the measurement of digital maturity to the area of skillfully combining strategy, human capital, and communication into

a single stream of actions aimed at digital transformation. The final instrument consisted of 73 items rated on a 7-point Likert scale (1 – strongly disagree, 7 – strongly agree). The version tested in Poland demonstrated very high internal consistency (Cronbach's $\alpha = 0.99$) (Jaciow et al., 2025).

2.2. Theoretical framework of the implementation gap

The theoretical framework of the implementation gap is based on the assumption that digital maturity is a multidimensional construct encompassing both the declarative–strategic layer and the operational–implementation layer. The scale used measures eight dimensions: strategy (10 variables), customers (7 variables), products and services (8 variables), processes (12 variables), organization (21 variables), IT infrastructure/technology (10 variables), environment (2 variables), and integrated digital leadership (3 variables). On this basis, the implementation gap is conceptualized as an asymmetry between two levels of maturity: (1) the declarative–narrative level, covering strategy, organization, and integrated digital leadership (vision, transformation plans, communication, culture, leadership), and (2) the operational–implementation level, covering customers, products and services, processes, IT infrastructure/technology, and environment (the actual use of digital technologies to collect and analyze data, digital channels of customer reach, data-driven offer development, digitalization and automation of processes, data quality, scalability and flexibility of IT architecture, financing of digitalization processes from external sources).

The implementation gap is not treated here as “measurement noise” but as a structural feature of the organization: positive when the level of declarations, vision, culture, and leadership is ahead of the level of IT capabilities, data quality, and digital processes; negative when operational capabilities are more developed than the narrative–strategic layer. In this way, the scale anchors the implementation gap in the paradigms of RBV and IT capability (the distinction between strategic orientation and actual technological resources and capabilities) and dynamic capabilities (sensing/seizing – mainly in the dimensions of strategy and leadership – versus reconfiguration, reflected in processes, products/services, the customer area, and IT infrastructure).

2.3. Reliability of both sets forming two levels of maturity

The high reliability of both maturity levels, the declarative–narrative level (1) of 0.91 and the operational–implementation level (2) of 0.92, is confirmed by the very high reliability of their constituent subscales (Table 1). Level (1) is based on the dimensions strategy, organization, and integrated digital leadership, whose Cronbach's α coefficients range from 0.88 to 0.96, indicating high internal consistency of the items describing vision, culture, leadership, and the use of external-environment instruments in the context of digitalization. Level (2) is built from the dimensions customers, products and services, processes, and IT infrastructure/technology, environment, for which Cronbach's α ranges from 0.92 to

0.95, confirming the reliable measurement of the actual use of digital technologies in customer relationships, the offering, processes, and IT architecture.

Table 1.

Cronbach's α coefficient values for the constructs under study

Declarative-narrative level (1)	Cronbach's α	Operational-implementation level (2)	Cronbach's α
For all variables at the (1)	0.91	For all variables at the (2)	0.92
In the dimension:		In the dimension:	
- Strategy	0.94	- Customers	0.92
- Organization	0.96	- Products and services	0.93
- Integrated digital leadership	0.88	- Processes	0.95
		- IT infrastructure	0.95
		- Environment	0.94

Source: own study.

Such values of reliability factors mean that both the declarative-narrative and operational-implementation components are stable, coherent constructs, and the observed gap between them is substantive in nature, and not an artifact resulting from poor measurement quality.

2.4. Operationalize the implementation gap

Based on the two levels of digital maturity established as separate theoretical constructs, they were subsequently operationalized. The operationalization of the implementation gap consisted in constructing two separate indices: the declaration index (ID) and the implementation index (IR). Items describing the declarative-narrative level of transformation (1) were assigned to ID, whereas items describing the operational-implementation level (2) were assigned to IR.

For each unit of analysis, the arithmetic mean of the items assigned to a given level (separately for ID and IR) was calculated and then rescaled to a 0-100 scale using a linear transformation. Since the study employed a 7-point Likert scale, the rescaling was performed using the formula (1):

$$(M - 1) / 6 \times 100 \quad (1)$$

A value of 0 indicates the minimum level of maturity in a given dimension, and 100 the maximum level. In the next step, the implementation gap (L) (2) was defined as the difference between the declaration index (ID) and the implementation index (IR), i.e.:

$$L = ID - IR \quad (2)$$

Positive values of L indicate that the narrative-strategic layer outweighs the operational layer (overestimation), negative values indicate that operational-implementation capabilities exceed the level of declarations (underestimation), while values close to zero are interpreted as a relative alignment between “what we say” and “what we do” in terms of digital maturity.

2.5. Data collection and sample

The survey was conducted by the Research and Development Center of the University of Economics in Katowice using the SurveyMonkey platform. Drawing on an extensive database of enterprises, the research team constructed a sample that included firms from the main sectors of the economy (manufacturing, trade, and services), which enabled the collection of cross-sectional data capturing the diversity of business activity in Poland. Access to this database also allowed for the inclusion of enterprises with different legal forms (limited liability companies, civil law partnerships, sole proprietorships, and joint-stock companies). This sampling strategy ensured that the results reflect the specific characteristics of both corporate-type organizations and individual entrepreneurs, thereby enhancing the generalizability of conclusions regarding business operations in the Polish market.

Using the available information, the sample was balanced across the three primary types of business activity: manufacturing, trade, and services. These proportions were chosen to mirror the actual sectoral structure at the national level, enabling comparisons of firm characteristics and behaviors across different segments of the economy. To maximize response rates and reach a broad pool of respondents, a mixed-mode survey design was applied, combining three channels: CAWI (Computer-Assisted Web Interviewing), telephone-supported CAWI, and CATI (Computer-Assisted Telephone Interviewing). The use of these methods was motivated by their broad coverage and the possibility of targeting respondents according to predefined criteria. Additionally, CAWI is a widely used technique in business research (Kocot et al., 2024; Pawłowska et al., 2025; Andruszkiewicz et al., 2024). Fieldwork took place in January 2025. In total, 697 fully completed questionnaires were obtained, including 69 via CAWI, 501 via telephone-supported CAWI, and 127 via CATI.

The research sample consisted of 697 enterprises: 230 manufacturing firms, 216 trading firms, and 251 service enterprises. In legal terms, the largest group were limited liability companies (37.9%), followed by civil law partnerships (21.4%) and sole proprietorships (18.8%). Registered partnerships represented 9.2% and joint stock companies 8.5%, while other partnership forms (including limited and professional partnerships) accounted for 4.4%. The legal structure varies by sector: manufacturing is clearly more “corporate” (58.7% limited liability companies and 12.6% joint stock companies, with virtually no sole proprietorships), whereas trading and service activities show higher shares of sole proprietors (28.2% and 27.9%) and civil law partnerships (19.0% and 27.9%).

With respect to size, the sample is dominated by small and medium-sized enterprises. Across the whole sample, 29.7% of firms employ up to 9 people, 12.2% have 10-49 employees, 28.7% have 50-249 employees, 23.4% employ 250-499 people, and 6.0% have 500 or more employees. Manufacturing companies are concentrated in the medium and large size classes (50-249 employees: 50.9%; 250-499: 36.1%; 500 and more: 13.0%). Trading and service firms are more often micro and small entities: in trade, 41.2% of enterprises have up to 9 employees,

while in services the share of micro firms reaches 47.0%, and a further 32.3% employ 10-49 people.

The enterprises covered by the survey are also heterogeneous in terms of age. In the overall sample, the oldest firm was established in 1932 and the youngest in 2022, with a median year of establishment of 2005. Manufacturing firms include relatively older entities (median 2000), trading firms have a median founding year of 2005, and service firms are on average the youngest group (median 2007). This structure means the sample captures both long-established companies and newer market entrants across key sectors of the Polish economy.

Analysis conducted for another article indicated that the surveyed Polish enterprises are characterized by a moderate level of digital maturity – the average global score was 4.65 (median 5.08) on a 7-point Likert scale, which classifies them at the "Moderate Digital Advancement" stage (Level 4). The highest-rated dimensions of digital maturity were organization (average 4.94) and processes (average 4.85). The lowest-rated dimension was environment (average 4.04). The remaining scores for the surveyed dimensions were relatively similar (ranging from 4.74 to 4.63) (Jaciow et al., 2025).

3. Results

For the purposes of the analysis, two indices were constructed – the declaration index (ID) and the implementation index (IR) – as well as an implementation gap indicator $L = ID - IR$. On this basis, each firm was classified into one of three categories: overestimation ($L > 0$), underestimation ($L < 0$), and relative alignment between the level of declarations and the level of implementation ($L \approx 0$).

In the total sample, only 10.3% of enterprises are characterized by a relative alignment of the narrative–strategic and operational–implementation levels of digital maturity. The vast majority of organizations exhibit a significant implementation gap: in 40.7% the declarative layer prevails (overestimation), whereas in 48.9% the level of actual technological and process capabilities is higher than the level of declarations (underestimation) (Fig. 1). These results confirm that the asymmetry between “what we say” and “what we do” is structural rather than marginal.

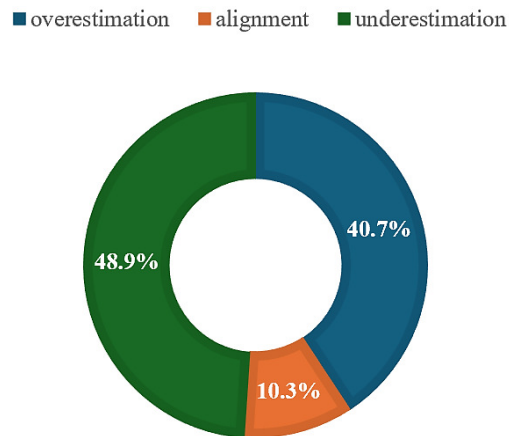


Figure 1. Distribution of enterprises by implementation gap.

Source: own research.

The structure of the gap varies according to business profile (Fig. 2). In manufacturing, underestimation dominates – more than half of producers operate at a higher level of implementation than of declaration, with a relatively lower share of firms displaying overestimation. In trade, the relationship between overestimation and underestimation is more balanced, although underestimation still prevails. In services, the share of enterprises with overestimation increases, while the share of underestimation is somewhat lower than in manufacturing and trade. This means that service firms more often develop a digital transformation narrative that outpaces actual actions, whereas in manufacturing we more frequently observe “silent digitalization” – advanced processes and infrastructure accompanied by a less articulated vision.

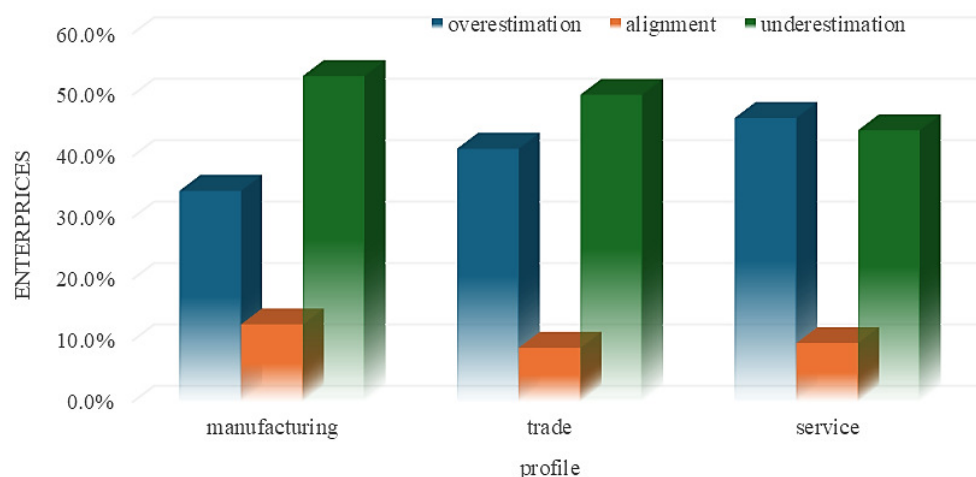


Figure 2. Implementation gap by profile of enterprises.

Source: own research.

Equally clear differentiation is visible with respect to firm size. In all size classes, the share of firms with a substantial gap is very high, while the share of alignment remains low and usually does not exceed a dozen or so percent. Micro-enterprises (up to 9 employees) more often show overestimation, with a relatively lower scale of underestimation, which can be

interpreted as the dominance of an aspirational narrative over actual capabilities. Among small and medium-sized firms (10-249 employees), the structure shifts towards increasing underestimation – these organizations develop digital solutions faster than they are able to describe and embed them in a coherent strategy. In large enterprises (250-499 and 500 or more employees), the dominance of underestimation is even stronger: actual technological and process capabilities clearly exceed the level of declarations, while the share of firms with alignment falls to a marginal level (Fig. 3). This points to a deficit of integrated digital leadership and weak internalization of the transformation vision in the largest organizations.

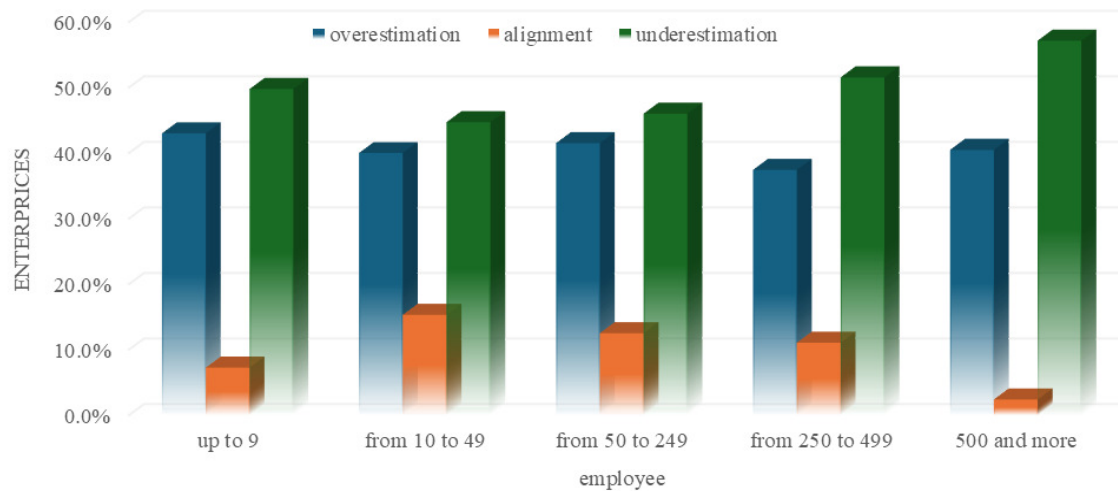


Figure 3. Implementation gap by size of enterprises.

Source: own research.

The pattern of the gap is most strongly differentiated by the level of digital maturity. At the lowest level (1), the vast majority of enterprises underestimate their maturity: the share of underestimation reaches around 70%, whereas overestimation and alignment are relatively rare (Fig. 4). This means that some organizations assigning themselves a very low level of maturity in fact possess more advanced digital processes and infrastructure than their self-description suggests. At levels 2-5, the share of both overestimation and underestimation remains high (around 40-55% each), with only a very small proportion of firms showing alignment. This indicates that in the “middle” phases of digital transformation enterprises are particularly exposed to a mismatch between the strategic and operational layers – some of them assess their preparedness too optimistically, while others underestimate their actual resources and capabilities. Only at the highest level of digital maturity (6) does the share of firms with alignment clearly increase – reaching about one third of the sample. At the same time, the proportions of both overestimation and underestimation decline, although cases with an existing implementation gap still predominate. This means that a high level of digital maturity favors the synchronization of the narrative–strategic and operational layers, but does not guarantee their full convergence.

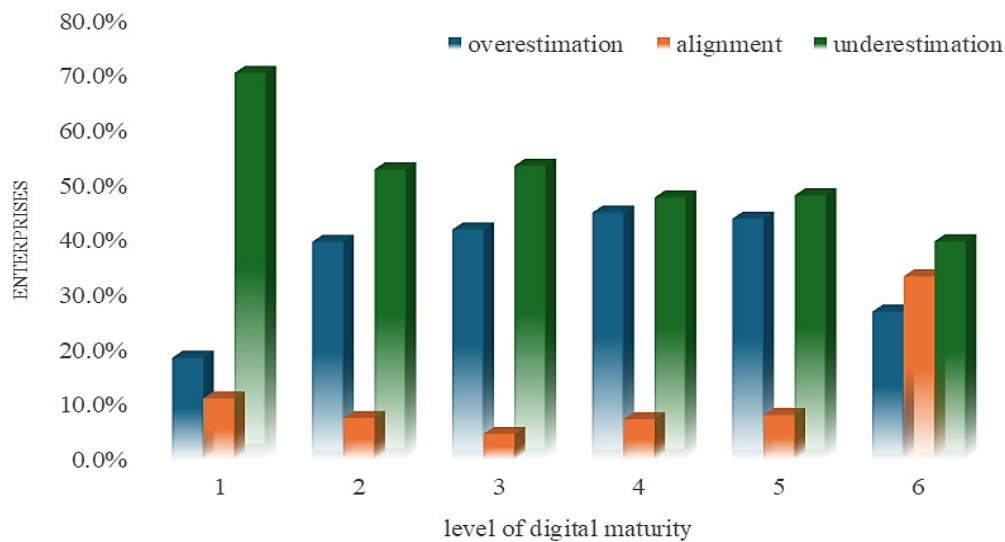


Figure 4. Implementation gap by level of digital maturity of enterprises.

Source: own research.

Taken together, the results indicate that the implementation of the digital transformation in Polish enterprises progresses in a highly asymmetric manner. Regardless of sector and firm size, there is a pronounced gap between declared and actually implemented digital maturity, while the direction and magnitude of this gap depend on the firm's profile, scale of operations, and maturity level.

4. Discussion

4.1. Research questions and interpretation of results

The research questions formulated in the introduction concerned the existence and direction of the implementation gap in the digital transformation of Polish enterprises. The distribution of the declaration–implementation index clearly confirmed that such a gap exists and is rather the norm than an exception. Only about one in ten surveyed enterprises is located at a level interpreted as alignment between what they implement and what they communicate within the analyzed dimensions of digital maturity. The vast majority of firms display either overestimation or underestimation of their level of digital maturity. This means that the declarative–narrative level of digital transformation and the operational–implementation level systematically diverge, which justifies (at least for the 697 Polish enterprises studied) treating the implementation gap as a structural property of organizations rather than a measurement artefact.

The second question concerned the direction of the identified gap. At the aggregated level, underestimation (48.9%) occurs slightly more often than overestimation (40.7%). This pattern is consistent with the observation that many enterprises develop operational digital capabilities in a fragmented and bottom-up manner and only later embed them in strategy, leadership narratives or formal transformation plans (Hortovanyi et al., 2023). At the same time, the high share of overestimation shows that digital visions and the strategic narrative of digitalization may run ahead of data quality, IT infrastructure and the level of process digitalization in the enterprise.

Sectoral differences complement this picture of the studied reality. In manufacturing and trade, underestimation dominates: operational capabilities (automation, data collection, digital channels) grow faster than the narrative layer, which remains anchored in a more traditional understanding of the business model. This is consistent with research indicating that in manufacturing firms digital transformation usually starts from technology and production, while organizational culture and customer-oriented capabilities lag behind (Hortovanyi et al., 2023). In the service sector, the structure is more balanced: the high share of both overestimation and underestimation means that some service firms aggressively experiment with digital narratives and customer-facing innovations, while others quietly build a digital core without reframing their strategy.

Firm size also differentiates the direction of the gap. Micro-enterprises and the largest entities (500+ employees) most often underestimate their level of digital maturity. In the smallest firms, digitalization is often informal and embedded in everyday practices. Managers do not necessarily label these improvements as “digital transformation”, thereby downplaying the maturity level of their organization. In large enterprises, the opposite holds: dispersed digital initiatives and strong operational capabilities in individual departments may not be fully visible at the top-management narrative level, which generates a negative implementation gap. Medium-sized firms display somewhat more balanced patterns, but alignment still remains rare.

The relationship between the implementation gap and the overall level of digital maturity of the surveyed enterprises is non-linear. At the lowest level (1), underestimation clearly dominates: the share of firms underestimating their digital maturity reaches about 70%, whereas overestimation and alignment are rare. This means that some organizations assigning themselves a very low level of maturity in fact possess more advanced digital processes and infrastructure than their self-description suggests. At levels 2-5, the shares of both overestimation and underestimation remain high (around 40-55% each), with only a very small group of aligned firms. This indicates that in the “middle” phases of digital transformation enterprises are particularly exposed to a discrepancy between the strategic and operational layers. Some of them assess their preparedness too optimistically, while others underestimate their resources and capabilities. Only at the highest level of digital maturity does the share of aligned enterprises clearly increase, reaching around one third of the sample, while the

proportions of both overestimation and underestimation decline. This means that high maturity favors the synchronization of the declarative–narrative and operational–implementation layers, although it does not guarantee full convergence. This is consistent with stage-based models that treat digital transformation as a process of gradual capability-building, culminating in a configuration in which strategy, structure, processes and technology are coherently integrated (Hortovanyi et al., 2023; Kane et al., 2017).

Taken together, the results show that the implementation gap is widespread, directionally differentiated and sensitive to sector, firm size and stage of digital transformation.

4.2. Theoretical implications

The findings contribute to the debate on digital maturity models in several respects. First, they support the claim that digital maturity is multidimensional and internally uneven. Most existing models present maturity as a single trajectory or aggregated index and implicitly assume that higher maturity directly translates into better firm performance (Laouar, Boukerch, 2025; Hortovanyi et al., 2023). The overestimations and underestimations identified in the study show that strategic narratives and operational capabilities often develop along partly independent paths. Digital transformation should therefore be conceptualized as the co-evolution of at least two layers: the declarative–narrative layer (vision, culture, leadership, formal strategy) and the operational–implementation layer (processes, IT infrastructure, customer interfaces, data practices).

Furthermore, the results empirically reinforce the argument, present in more recent work, that digital maturity models often fail to explain how digital capabilities actually translate into competitive advantage (Laouar, Boukerch, 2025). The implementation gap provides the missing mechanism: even high scores in narrative dimensions do not generate benefits if they are not accompanied by investments in processes, technologies and data. Conversely, strong operational capabilities may remain underexploited if they are not embedded in a strategic narrative that guides resource allocation, organizational learning and market positioning. This is consistent with the resource-based view and dynamic capabilities theory, which distinguish between sensing and seizing opportunities on the one hand and reconfiguring processes and assets on the other. Additionally, studies on value creation for the digital consumer demonstrate that digital transformation must be understood not only as a technological and organizational process but also as a strategic response to evolving consumer expectations regarding convenience, personalization and speed. These findings (Gajdzik et al., 2025) reinforce the multidimensional nature of maturity and support the argument that narrative and operational layers co-evolve rather than develop uniformly.

It is also worth emphasizing that the study extends multidimensional digital-maturity frameworks, including organizational and process levels (Tubis, 2023). By operationalizing two maturity indices (ID and IR) and calculating their difference, it shows that misalignment between levels is not an incidental anomaly but a statistically dominant pattern. This strengthens

calls for maturity models that explicitly account for asymmetries between strategy and operations and for disproportionate development of individual organizational subsystems. It also complements comparative studies showing the heterogeneity of existing models and their limited comparability (Cognet et al., 2023). The implementation-gap perspective introduces a new axis of interpretation: models can be compared not only in terms of the dimensions they cover, but also in terms of whether they allow the identification of positive and negative asymmetries between narrative and implementation.

4.3. Implications for the design of digital-maturity measurement tools

The empirical data presented in the article may also have consequences for the design and use of digital-maturity assessment tools. First, such tools should explicitly distinguish between declarative–narrative and operational–implementation items and report at least two separate indices instead of a single aggregated score. The approach used here, based on ID, IR and their difference L , shows that the direction and magnitude of misalignment carry important information that would be completely lost in a one-dimensional indicator. This is consistent with models that propose separate organizational and process dimensions and point to the risk of drawing conclusions from global averages in the presence of strong variation in the level of digitalization across departments (Tubis, 2023).

Second, the design of digital-maturity measurement tools should go beyond a static snapshot of the firm and include mechanisms that link diagnostic results to concrete improvement paths. The literature on maturity models criticizes their prescriptive limitations and static character, emphasizing that they often fail to provide practical guidance on how to translate digital capabilities into competitive advantage (Laouar, Boukerch, 2025). The implementation-gap perspective can be embedded into such frameworks: maturity tools should not only assess the level but also diagnose whether the priority is to strengthen operations ($L > 0$, overestimation) or to raise the level of strategy and leadership to match existing capabilities ($L < 0$, underestimation).

Third, the revealed patterns of overestimation and underestimation highlight the need for measurement rigor and multi-perspective data collection. Comparative studies of maturity models point to their heterogeneity in terms of structure, dimensions, KPIs and scoring algorithms and call for more systematic, quantitative validation (Cognet et al., 2023; Hortovanyi et al., 2023). The high reliability of both maturity levels in this study shows that carefully constructed scales can achieve very good internal consistency, which is a prerequisite for treating the implementation gap as a substantive construct rather than a measurement error. Future tools should build on validated scales, use consistent Likert-type formats and, where possible, triangulate managerial self-assessments with data from operational employees or system logs in order to reduce social desirability bias in the declarative layer.

Fourth, maturity tools must transparently disclose their dimensional coverage and be interoperable. Comparative frameworks based on keyword matrices and KPI mapping show that existing models differ greatly in the number and scope of dimensions, which hampers benchmarking and the use of results in public policy (Cognet et al., 2023). Introducing an explicit implementation-gap indicator would facilitate comparisons between models by adding a common measure describing the relationship between strategic declarations and operational reality, regardless of the detailed dimensional structure of a given tool.

4.4. Implications for the practice of managing digital transformation

From a management perspective, the results indicate that effective digital transformation requires active management of the implementation gap. The very low share of enterprises located at a level of relative balance between declaration and implementation means that managers cannot treat digital-maturity self-assessments as a straightforward indicator. Organizations with overestimation are in a situation where ambitious digital strategies are not accompanied by adequate investments in data quality, IT architecture and process redesign. This imbalance is particularly visible when contrasted with the expectations of digital consumers, who require speed, reliability, seamless omnichannel experiences and personalized interactions - capabilities that depend directly on robust operational processes, high-quality data and integrated IT architectures (Jaciow, Wolny, 2011; Jaciow et al., 2013; Jaciow, Wolny, 2022). Such a configuration entails the risk of stalled projects, employee cynicism and “digital fatigue”. Studies of digitally maturing firms emphasize that real progress depends on cross-functional collaboration, investment in digital talent and a long-term orientation, elements that connect narrative ambitions with concrete organizational changes (Kane et al., 2017).

Enterprises that underestimate their level are also not in a comfortable position. When operational capabilities outpace the narrative and leadership attention, organizations risk underutilizing their digital assets, missing opportunities for new business models and underinvesting in complementary capabilities such as data-driven customer orientation or building ecosystem partnerships. Research on capability maturity indicates that digital capabilities are complementary and should be developed in a balanced way. Excessive or insufficient development of particular capabilities at a given stage leads to predictable “transformation pains” (Hortovanyi et al., 2023). An explicit diagnosis of the implementation gap helps managers see where the imbalance lies and target their actions accordingly.

The patterns differentiated by sector and firm size identified in the study suggest the need for an individualized approach to digital-transformation programs. In manufacturing, where underestimation dominates, managers should focus on making existing digital practices visible, codifying them in strategy and investing in integrated digital leadership that links production-level innovations with the narrative at the level of the entire enterprise. In services, where overestimation is more common, the priority is to translate promises made to customers in the digital domain into a robust operational backbone, reliable data infrastructure and redesigned

processes. Large firms, characterized by strong underestimation, need governance mechanisms—steering committees, enterprise architects, digital-transformation offices—that consolidate dispersed operational progress into a coherent strategic perspective. Micro and small firms need simple, practice-oriented frameworks that prevent both complacency resulting from overestimation and self-limiting underestimation and that link digital initiatives to concrete value creation in their context (Laouar, Boukerch, 2025; Tubis, 2023).

The findings also strengthen the call for a practice-based approach to managing digital transformation. The literature emphasizes that maturity models are useful for diagnosis and benchmarking but insufficient for steering day-to-day transformation work. Organizations must translate assessment results into concrete practices and routines that yield measurable effects (Laouar, Boukerch, 2025). Managing the implementation gap is a specific way of operationalizing such an approach: instead of asking only “how mature are we?”, managers monitor “where does our narrative run ahead of implementation and where do implementation capabilities run ahead of the narrative?” and design targeted interventions in leadership, culture, process design and technology deployment.

Finally, the higher share of enterprises at the highest maturity level that do not fall into the implementation gap indicates that digital mastery requires not only advanced technologies and sophisticated use of data, but also the ability to continuously recalibrate narratives and operations. This is consistent with the view of digital transformation in terms of dynamic capabilities and with research showing that digitally mature organizations treat transformation as an ongoing organizational competence rather than a one-off project (Hortovanyi et al., 2023; Kane et al., 2017).

5. Summary

The article analyzes the digital maturity of Polish enterprises from the perspective of the implementation gap between what organizations declare about digital transformation and what they actually implement in the areas of processes, technologies, and data. Drawing on a modified version of the “Digitalcheck Mittelstand” tool, two levels of maturity were distinguished: the declarative–narrative level (strategy, organization, integrated digital leadership) and the operational–implementation level (customers, products and services, processes, IT infrastructure, environment). For 697 enterprises, a declaration index (ID), an implementation index (IR), and the gap $L = ID - IR$ were calculated and rescaled to a 0-100 range. The high Cronbach’s alpha coefficients for both levels indicate strong internal consistency, which makes it possible to treat the observed gap as a substantive effect rather than a measurement error.

The results show that the implementation gap is a widespread phenomenon: only about 10% of firms exhibit a relative alignment between the narrative and implementation layers, while the remaining enterprises either overestimate or underestimate their level of digital maturity. The direction and magnitude of this gap vary by sector, firm size, and maturity level. In manufacturing and trade, underestimation occurs more frequently, which can be interpreted as “silent digitalization”, whereas in services narratives that outpace actual operational capabilities are observed more often. Micro-enterprises tend to overestimate, while large firms tend to underestimate their digital maturity. The relationship between the gap and the level of maturity is non-linear: at the lowest maturity level, underestimation dominates; at intermediate levels, both types of gap are frequent; and only at the highest maturity level does the share of firms with relative alignment increase.

The interpretation of the results is grounded in the Resource-Based View and dynamic capabilities theory. The implementation gap reflects an asymmetry between the “sensing/seizing” layer (strategy, leadership, culture, communication) and the ability to deeply reconfigure resources (processes, data, IT infrastructure). The article shows that traditional, one-dimensional digital-maturity indices mask this asymmetry, leading to distorted diagnoses at both the organizational and economic-system levels. The authors argue that digital-maturity measurement tools should separate the level of declarations from the level of implementation and report a gap indicator as a standard diagnostic element. This has implications both for the practice of managing digital transformation (more precise identification of areas where the narrative or operational capabilities need to be strengthened) and for the design of public policies and support programs, which should be based on a robust diagnosis of actual digital capabilities rather than on declarations alone.

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A TAXONOMIC ANALYSIS OF SMART CITIES AND SUSTAINABLE DEVELOPMENT IN POLAND AND SELECTED EUROPEAN COUNTRIES: A DYNAMIC APPROACH

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Purpose: The primary objective of this study is to conduct a taxonomic analysis of smart city implementations within the framework of sustainable development in Poland and selected European countries. By adopting a dynamic approach, the research tracks evolutionary trajectories and temporal shifts, with particular emphasis on the comparative periods preceding and following the COVID-19 pandemic.

Design/methodology/approach: This paper examines the implementation of smart city solutions and their impact on sustainable development in Poland and selected European countries, with a specific focus on the pre- and post-COVID-19 pandemic periods. The data were sourced from the Eurostat database, in accordance with the thematic scope of the study and data availability, covering the years 2017, 2020, and 2024. The analysis employs selected Multidimensional Comparative Analysis (MCA) tools to, on the one hand, establish a ranking of development levels across the surveyed nations—thereby facilitating a comparative assessment of the units—and, on the other hand, apply a clustering method to identify groups of countries characterized by homogeneous dynamic development of the phenomenon.

Findings: The study evaluates the implementation of smart city solutions within the framework of sustainable development across selected European countries, with a specific focus on the COVID-19 pandemic period. Taxonomic analysis facilitates the effective measurement of how various factors influence the trajectory of this phenomenon

Research limitations/implications: A significant limitation of this study is the lack of longitudinal, comparable statistical data spanning an extended timeframe. Nevertheless, the proposed methodology facilitates cross-national and regional comparisons and serves as a robust foundation for future scholarly inquiry.

Originality/value: The taxonomic analysis of the investigated phenomenon is applicable for benchmarking diverse spatial units—ranging from nation-states to regional and local administrations—as well as for examining various multifaceted dimensions of the issue. The findings constitute a substantial contribution to the advancement of empirical research in this field.

Keywords: taxonomic analysis, Smart City, ICT adoption, sustainable development, COVID-19 pandemic.

Category of the paper: Research paper.

1. Introduction

Contemporary nation-states and urban environments are undergoing profound technological, social, and environmental transformations. These shifts are precipitated, *inter alia*, by globalization, urbanization, and the increasing integration of advanced technologies into the daily functioning of society. Furthermore, rapid urban expansion, demographic shifts, the depletion of natural resources, as well as the imperative of environmental preservation and climate change mitigation, compel us to confront an array of increasingly multifaceted challenges. These developments fundamentally influence the spatial organization of cities, the provision of public services, the accessibility of innovative solutions, and the level of social well-being. A pivotal strategic response to these issues is the Smart City concept, which is gaining prominence globally, including in Poland. The information society, by leveraging Information and Communication Technologies (ICT), plays an essential role in the realization of sustainable development goals. Digital tools facilitate the efficient analysis of environmental data, support the formulation of urban management strategies, and enable the rigorous monitoring of urbanization processes.

The evolution of the Smart City concept represents a primary trajectory for the transformation of contemporary urban centers, which must address challenges associated with globalization, urbanization, and the implementation of sustainable development principles. The digitalization of public services, the deployment of the Internet of Things (IoT), energy management systems, and intelligent transportation have become integral components of modern urban infrastructure. Notable implementations include, among others, the intelligent public transport system in Warsaw and the energy management platform in Barcelona. Their significance extends beyond improving the quality of life for residents; it also encompasses enhancing economic efficiency, mitigating environmental impact, strengthening social cohesion, and increasing urban resilience to crises, such as the COVID-19 pandemic.

The implementation of smart solutions facilitates enhanced responsiveness to citizen needs and fosters social engagement. It is essential to emphasize that the Smart City encompasses not only technological advancements but also a management philosophy rooted in social dialogue, innovation, and the pursuit of harmonious development across all dimensions of urban life.

Within the European context, there is a pronounced diversity in the implementation of smart city solutions, stemming from distinct economic, institutional, and cultural conditions. Individual countries and cities exhibit various models of smart technology adoption, resulting in disparities in digital infrastructure maturity, the quality of public services, and the degree of civic involvement. Poland, mirroring other nations in the Central and Eastern European region, is currently undergoing an intensive search for smart technology implementation models that support urban modernization while addressing the specific needs of local communities.

The integration of smart city solutions enables efficient resource management, the reduction of the anthropogenic impact on the environment, and the promotion of civic activity, which concurrently enhances urban competitiveness and attractiveness. A significant challenge remains the provision of equitable access to modern technologies for all social groups and the elimination of both infrastructural and social barriers (Bibri, Krogstie, 2017; Komninos, 2013; Makowski, Kidyba, 2018; Stawasz, Sikora-Fernandez, 2016; Szewczyk, 2020). A society that leverages technological resources while concurrently pursuing harmonious development—underpinned by ecological, social, and economic values—constitutes a cornerstone of contemporary urban policy. Consequently, the successful implementation of smart city solutions in Poland and other European nations is contingent upon a multitude of factors, including the degree of digitalization within public administration, the receptivity of local authorities to innovation, the engagement of the private sector, and the level of civic awareness and education. The operationalization of the smart city concept necessitates a thorough consideration of local contingencies, economic specificities, and social traditions. Such initiatives foster the development of robust, modern, and resilient urban centers capable of competing effectively in the international arena and addressing the challenges of the future. The article proposes an analysis utilizing Multidimensional Comparative Analysis (MCA) tools to, on one hand, establish a ranking of the developmental state of the investigated phenomenon, thereby facilitating a comparative analysis of the objects, and on the other hand, to apply a method for identifying clusters of homogeneous development among the studied entities.

In conclusion, it can be asserted that the urban transformation toward the smart city model represents one of the most significant trends of the 21st century. The implementation of intelligent solutions serves as a mechanism for enhancing the quality of life and remains a fundamental prerequisite for sustainable development. Furthermore, the COVID-19 pandemic accelerated the digitalization of urban services and shifted urban development priorities. The pre- and post-pandemic periods are critical for analyzing transformations in the adoption of smart city technologies.

This paper proposes a taxonomic analysis of smart city implementations against the backdrop of sustainable development in Poland and selected European countries, adopting a dynamic approach that accounts for the periods before and after the COVID-19 pandemic.

This framework enables, *inter alia*, an assessment of urban development levels and the formulation of future research trajectories and urban policy recommendations. The proposed comparative analysis encompasses multiple countries and employs a dynamic approach to track the evolution of the phenomenon over time. It presents a study that evaluates smart city initiatives and sustainable development through taxonomic instruments, while accounting for the structural changes induced by the COVID-19 pandemic.

The study consists of an introduction to the subject matter, an overview of the research methods employed, the presentation and discussion of empirical results, and the conclusions.

2. Methodology

2.1. Linear ordering method for the analyzed phenomenon

The selection of an appropriate methodology is contingent upon the nature of the data, the objectives of the analysis, and the required interpretability of the findings. In the field of smart cities and sustainable development, taxonomic methods facilitate not only the classification of countries based on their level of smart city implementation but also the identification of leaders and laggards. This identification provides a robust foundation for subsequent causal analyses and the formulation of policy recommendations. This study proposes the application of a taxonomic approach designed for the linear ordering of spatial units (entities). To rank these entities, a relative synthetic development index was employed, calculated according to the following formula (Pociecha, Podolec et al., 1988):

$$W_i = \frac{\sum_{j=1}^k z_{ij}}{\sum_{j=1}^k \max_i \{z_{ij}\}} \quad (1)$$

where:

$$z_{ij} = x_{ij}^* + \left| \min_i \{x_{ij}^*\} \right| \quad (2)$$

where x_{ij}^* - standardised variable.

The index assumes values within the interval $[0, 1]$, where values approaching unity indicate a superior performance of the entity regarding the analyzed dimension (Pociecha et al., 1988). The application of this index facilitates a comparative assessment of development levels across entities, based on heterogeneous sets of diagnostic variables.

2.2. The centroid method

Numerical taxonomy, a branch of multivariate statistics, provides robust analytical tools for the simultaneous classification of entities based on multiple characteristics. This approach facilitates the formation of homogeneous clusters characterized by similar profiles (Pociecha et al., 1988). The specific hierarchical procedure employed in this study is an agglomerative technique, namely the centroid method (also referred to as the center of gravity method). The methodology commences with the derivation of a distance matrix. Initially, individual entities are treated as separate clusters; subsequently, clusters are merged based on the proximity of their centers of gravity. The cluster representative is the centroid, defined as the vector of mean values for all diagnostic features of the entities within that cluster. The merging criterion is typically the minimization of the distance between centroids, which is most frequently calculated using the Euclidean distance.

3. Data characteristics and source material

The smart city concept and sustainable development encompass a broad spectrum of diverse thematic dimensions. Due to the constraints regarding the availability of comprehensive statistical data, the empirical scope of this study was narrowed to three selected thematic groups. The analysis utilizes a final set of diagnostic variables covering the years 2017, 2020, and 2024, with a particular focus on the impact of the COVID-19 pandemic. The research data were sourced from the Eurostat database, ensuring that the selected indicators align with both the thematic framework and data availability requirements.

The diagnostic variables adopted for this study are measurable and provide a robust representation of the analyzed phenomenon. The final selection of diagnostic features was determined based on the calculated coefficients of variation and a formal verification through correlation analysis, utilizing the inverse correlation matrix (Chomątowski, Sokołowski, 1978; Grabiński et al., 1980; Janiga-Ćmiel, 2023, 2025; Malina, 2008; Młodak, 2006; Nowak, 1990; Panek, 2009; Pociecha et al., 1988; Strahl, 1990; Zeliaś, 2004). The study encompasses 25 European countries, categorized into the following thematic domains:

Thematic Domain I: Selected elements of ICT infrastructure:

X1 – Broadband internet coverage by technology [%].

X2 – Mobile broadband internet traffic (within the country) [%].

X3 – Level of internet access – households [%].

X4 – Number of individuals – frequency of internet use.

Thematic Domain II: Selected aspects of the quality of life:

Y1 – Gross domestic product (GDP) and main components (output, expenditure and income).

Y2 – Self-perceived health by sex, age and degree of urbanisation [%].

Y3 – Number of population change - Demographic balance and crude rates at national level.

Y4 – Self-reported unmet needs for medical examination by sex, age, main reason declared and degree of urbanisation.

Thematic Domain III: Investment areas in smart mobility and sustainability:

Z1 – Number of new zero-emission vehicles by type of vehicle and type of motor Energy.

Z2 – International trade in ICT goods.

Z3 – Share of energy from renewable sources [%].

Z4 – Number of climate related economic losses by type of event.

In the subsequent stage of the analysis, the variables will undergo standardisation to facilitate the derivation of a linear ordering of the countries regarding the investigated phenomenon.

4. Empirical results and discussion

4.1. Linear ordering within the three selected thematic domains

Utilizing the methodology delineated in Chapter 2, a ranking of the studied countries was established across three thematic domains. The results pertaining to the first domain—comprising selected elements of ICT infrastructure in European countries for the years 2017, 2021, and 2024—are summarized in Table 1.

Table 1.

Linear ordering of selected ICT infrastructure elements in European countries (2017, 2021, 2024).

2024	W	2020	W	2017	W
Netherlands	1	France	1	France	1
Spain	0.913	Spain	0.934	Germany	0.761
Denmark	0.890	Italy	0.910	Italy	0.707
Luxembourg	0.871	Netherlands	0.878	Finland	0.645
Italy	0.798	Germany	0.875	Poland	0.641
France	0.796	Luxembourg	0.856	Spain	0.568
Sweden	0.760	Denmark	0.853	Sweden	0.563
Austria	0.750	Finland	0.844	Austria	0.556
Finland	0.731	Austria	0.832	Netherlands	0.521
Malta	0.719	Poland	0.779	Denmark	0.510
Poland	0.718	Sweden	0.743	Luxembourg	0.366
Belgium	0.716	Cyprus	0.677	Belgium	0.359
Germany	0.716	Belgium	0.631	Estonia	0.311
Cyprus	0.708	Slovenia	0.547	Cyprus	0.297
Hungary	0.682	Hungary	0.542	Czechia	0.279
Romania	0.673	Estonia	0.524	Hungary	0.270
Czechia	0.607	Malta	0.501	Slovenia	0.270
Slovenia	0.551	Czechia	0.484	Romania	0.269
Estonia	0.526	Romania	0.482	Malta	0.262
Latvia	0.508	Latvia	0.448	Latvia	0.249
Portugal	0.375	Slovakia	0.441	Lithuania	0.205
Bulgaria	0.370	Lithuania	0.374	Croatia	0.199
Slovakia	0.313	Croatia	0.324	Slovakia	0.199
Lithuania	0.292	Portugal	0.322	Portugal	0.169
Croatia	0.194	Bulgaria	0.149	Bulgaria	0.086

Source: based on own research (<https://ec.europa.eu/eurostat>).

The linear ordering presented in Table 1 for the first thematic domain (2017, 2020, 2024) reveals significant disparities in digital development across the surveyed nations. These findings are intrinsically linked to the attainment of Sustainable Development Goals (SDGs), particularly those concerning resilient infrastructure and fostered innovation. Countries that have consistently prioritized ICT investment—most notably the Netherlands, France, Denmark, Luxembourg, and Germany—maintain superior positions. This reflects sustained efforts in digitizing public services, expanding broadband connectivity, and deploying innovative technological solutions. In these nations, advanced ICT infrastructure facilitates efficient resource management, mitigates environmental degradation (e.g., through the

proliferation of remote services), and enhances both the quality of life and equitable access to services across all social strata.

Conversely, several Central and Eastern European countries, including Bulgaria, Croatia, Lithuania, and Slovakia, occupy the lower echelons of the ranking, indicating a decelerated pace of innovation and constrained access to modern technologies. This divergence poses a risk of exacerbating socio-economic inequalities within Europe, potentially hindering the realization of global sustainable development objectives, specifically those regarding equal opportunity and the reduction of the digital divide.

Furthermore, the COVID-19 pandemic served as a catalyst, significantly accelerating digitalization processes post-2020. The crisis necessitated intensified investment in ICT infrastructure, resulting in a marked increase in indicator values for countries capable of rapid implementation of remote solutions in education, public administration, and commerce. While digitally advanced nations consolidated their positions through agile adaptation, those with lower baseline indicators continue to experience a developmental lag despite moderate improvements. This underscores the critical importance of long-term ICT strategic planning. Ultimately, the results suggest that while ICT infrastructure is a fundamental prerequisite for sustainable development in Europe, its uneven distribution may further entrench social and economic disparities.

The empirical findings for the second thematic domain—addressing selected aspects of the quality of life (2017, 2020, 2024)—are summarized in Table 2.

Table 2.

Linear ordering of selected quality-of-life aspects in European countries: 2017, 2021, and 2024

2024	W	2020	W	2017	W
Germany	1	Germany	1	Germany	1
France	0.822	France	0.814	France	0.811
Italy	0.708	Italy	0.717	Italy	0.727
Spain	0.588	Spain	0.572	Spain	0.566
Poland	0.442	Poland	0.455	Poland	0.462
Romania	0.233	Romania	0.236	Romania	0.241
Netherlands	0.221	Netherlands	0.215	Netherlands	0.212
Belgium	0.148	Belgium	0.144	Belgium	0.142
Czechia	0.136	Czechia	0.134	Czechia	0.133
Portugal	0.134	Portugal	0.130	Portugal	0.130
Sweden	0.132	Sweden	0.130	Sweden	0.127
Hungary	0.120	Hungary	0.122	Hungary	0.123
Austria	0.116	Austria	0.113	Austria	0.111
Bulgaria	0.083	Bulgaria	0.084	Bulgaria	0.087
Denmark	0.078	Denmark	0.076	Denmark	0.075
Finland	0.074	Finland	0.072	Finland	0.072
Slovakia	0.071	Slovakia	0.071	Slovakia	0.071
Croatia	0.053	Croatia	0.053	Croatia	0.054
Lithuania	0.041	Lithuania	0.040	Lithuania	0.040
Slovenia	0.032	Slovenia	0.031	Slovenia	0.030
Latvia	0.029	Latvia	0.029	Latvia	0.029
Estonia	0.023	Estonia	0.022	Estonia	0.021

Cont. table 2.

Cyprus	0.018	Cyprus	0.017	Cyprus	0.016
Luxembourg	0.015	Luxembourg	0.014	Luxembourg	0.013
Malta	0.014	Malta	0.012	Malta	0.011

Source: based on own research (<https://ec.europa.eu/eurostat>).

An analysis of the linear rankings for selected European countries regarding quality of life (2017, 2020, 2024) elucidates the factors determining national positions both preceding and following the COVID-19 pandemic. Indicators such as GDP per capita, self-perceived health status, demographic shifts, and the prevalence of unmet medical needs serve as both metrics of social well-being and integral components of sustainable development strategies.

Prior to the pandemic, economically resilient nations—most notably Germany and France—consistently occupied the top echelons of the ranking. This dominance was predicated on high GDP per capita, robust healthcare systems, and effective preventive care programs. Favorable self-assessments of health and positive demographic trends (e.g., increased life expectancy and lower emigration rates) resulted from long-term investments in health education and social infrastructure. Such outcomes align with the core principles of sustainable development: ensuring a high current quality of life while safeguarding the needs of future generations.

The COVID-19 pandemic induced profound shifts in several quality-of-life dimensions. During the 2020–2021 period, many nations experienced a decline in self-rated health and restricted access to medical services. For Central and Eastern European countries, such as Poland, Romania, and Bulgaria, the crisis exacerbated pre-existing structural challenges, including lower GDP per capita, overburdened healthcare systems, and less favorable demographic indicators. Consequently, the pandemic necessitated urgent investments in preventive healthcare, public education, and service accessibility—all of which are fundamental to achieving the Sustainable Development Goals (SDGs).

Conversely, highly developed countries that exhibited agility by integrating digital solutions into healthcare, education, and public administration either maintained or improved their standing. The efficacy of their crisis management—characterized by the rapid deployment of telemedicine and increased expenditure on preventive lifestyles—positively influenced citizen well-being. This underscores that institutional flexibility and crisis resilience are critical prerequisites for sustainable development.

The final stage of this study incorporates data from the third thematic domain, focusing on investment areas in smart mobility across European countries for the years 2017, 2020, and 2024. The results are presented in Table 3.

Table 3.

Thematic Domain III: Investment areas in smart mobility across European countries (2017, 2020, 2024)

2024	W	2020	W	2017	W
Germany	1	Germany	1	Germany	1
France	0.584	France	0.482	France	0.510
Spain	0.378	Poland	0.330	Poland	0.311
Poland	0.320	Italy	0.253	Italy	0.305
Italy	0.312	Spain	0.243	Spain	0.296
Netherlands	0.260	Sweden	0.240	Netherlands	0.226
Sweden	0.259	Netherlands	0.232	Sweden	0.212
Austria	0.162	Czechia	0.176	Slovakia	0.157
Czechia	0.158	Belgium	0.154	Czechia	0.149
Slovakia	0.152	Slovakia	0.145	Denmark	0.129
Belgium	0.145	Austria	0.122	Austria	0.123
Romania	0.116	Denmark	0.118	Belgium	0.119
Denmark	0.103	Hungary	0.112	Hungary	0.090
Hungary	0.089	Romania	0.083	Romania	0.068
Portugal	0.080	Finland	0.073	Finland	0.066
Finland	0.070	Portugal	0.058	Portugal	0.059
Lithuania	0.052	Latvia	0.039	Lithuania	0.035
Croatia	0.047	Lithuania	0.035	Latvia	0.031
Latvia	0.045	Bulgaria	0.030	Croatia	0.028
Bulgaria	0.043	Croatia	0.029	Bulgaria	0.026
Slovenia	0.031	Slovenia	0.022	Slovenia	0.024
Estonia	0.024	Estonia	0.016	Estonia	0.020
Luxembourg	0.013	Luxembourg	0.016	Luxembourg	0.015
Cyprus	0.011	Cyprus	0.007	Cyprus	0.007
Malta	0.005	Malta	0.004	Malta	0.004

Source: based on own research (<https://ec.europa.eu/eurostat>).

The ranking of European countries regarding smart mobility investments for the years 2017, 2020, and 2024 is determined by the interplay of four diagnostic variables: the adoption of new zero-emission vehicles, climate-related economic losses, the volume of international trade in ICT goods, and the share of renewable energy in the total energy mix. Prior to the COVID-19 pandemic, the leading positions were occupied by nations characterized by high innovation indices and proactive climate policies, most notably Germany and France. These countries prioritized the development of electric and hybrid vehicle fleets while simultaneously implementing strategies to mitigate greenhouse gas emissions and minimize potential economic losses stemming from adverse climate impacts.

In these leading nations, international trade in ICT-related goods—particularly within the modern transport technology sector—remained substantial. Furthermore, the high proportion of renewable energy in the energy mix, specifically in Scandinavian countries such as Sweden, Denmark, and Finland, provided a robust framework for smart mobility and facilitated further reductions in \$CO_2\$ emissions.

The COVID-19 pandemic necessitated a temporary reallocation of fiscal resources to address the immediate health and economic crises, which initially constrained investments in transport infrastructure and renewable energy across many European jurisdictions.

In the post-pandemic era, sustainable development has emerged as a cornerstone of national investment strategies. Countries that demonstrated agility by increasing expenditure on zero-emission vehicles, charging infrastructure, and renewable energy sources have either consolidated or enhanced their ranking positions. Effectively mitigating the economic repercussions of climate change and pursuing a sustainable energy transition have become pivotal elements in fostering socio-economic resilience.

4.2. Identification of homogeneous country clusters based on developmental levels

The initial phase of the analysis utilized Multidimensional Comparative Analysis (MCA) tools to rank European countries across selected dimensions of the smart city concept within the framework of sustainable development, accounting for the impact of the COVID-19 pandemic. The second phase involves identifying clusters of countries characterized by homogeneous development trajectories within the addressed thematic scopes. To identify groups of countries with comparable levels of the investigated phenomenon, the previously established set of diagnostic variables was employed. The classification results for the analyzed countries across selected years are presented below. Domain I: Selected Elements of ICT Infrastructure in European Countries (2017, 2021, 2024).

Cluster analysis of surveyed countries (2024):

Gr 1 = {Bulgaria}

Gr 2 = {Italy}

Gr 3 = {Poland, Latvia}

Gr 4 = {Slovakia, Portugal, Croatia, Lithuania}

Gr 5 = {Sweden}

Gr 6 = {Czechia, Estonia, Slovenia}

Gr 7 = {Denmark, Luxembourg, Netherlands, Austria}

Gr 8 = {Hungary, Malta, Romania, Germany, Spain}

Gr 9 = {Finland}

Gr 10 = {Cyprus, Belgium}

Gr 11 = {France}

Cluster analysis of surveyed countries (2020):

Gr 1 = {Bulgaria}

Gr 2 = {France, Poland}

Gr 3 = {Italy}

Gr 4 = {Malta}

Gr 5 = {Latvia}

Gr 6 = {Sweden, Finland}

Gr 7 = {Czechia, Germany, Estonia, Spain, Croatia, Lithuania, Hungary, Austria, Portugal, Romania, Slovenia}

Gr 8 = {Belgium, Denmark, Cyprus, Luxembourg, Netherlands}

Cluster analysis of surveyed countries (2017):

G1 = {Sweden}

G2 = {Finland, Austria}

G3 = {Slovakia, Poland, Lithuania}

G4 = {Romania, Portugal, Italy, Croatia, Bulgaria}

G5 = {Slovenia, Hungary, Spain, Estonia, Czechia, Latvia}

G6 = {France}

G7 = {Belgium, Denmark, Germany, Luxembourg, Netherlands}

G 8 = {Cyprus, Malta}

The cluster compositions identified for the years 2017, 2020, and 2024 reflect the heterogeneous levels of ICT infrastructure development across Europe, as well as the profound impact of external catalysts, such as the COVID-19 pandemic and the strategic shift toward sustainable development. In 2024, the analysis identified several single-element clusters (including Bulgaria, Italy, Sweden, Finland, and France), which signifies idiosyncratic developmental trajectories. These nations may be characterized by unique investment strategies, varying rates of ICT implementation, or distinct levels of resilience to post-pandemic economic shifts. Conversely, the more populous clusters represent countries with comparable developmental levels and similar adaptive responses to recent challenges, such as accelerated digitalization and network infrastructure expansion. In 2020, amidst the peak of the COVID-19 pandemic, a greater number of clusters was observed. This fragmentation may be attributed to divergent national responses to the crisis and fiscal constraints; many nations were compelled to reallocate resources toward healthcare, thereby decelerating digital infrastructure projects. Simultaneously, the emergence of single-element clusters (e.g., Malta, Latvia) highlights individualized survival and adaptation strategies during the crisis. In 2017, preceding the pandemic, the clusters were generally larger and more integrated, suggesting a more synchronized pace of ICT development across Europe. During this period, technological advancement was more evenly distributed among nations. The isolation of specific countries, such as Sweden and France, underscores their preeminent position as digital leaders.

Domain II: Selected aspects of quality of life in European countries (2017, 2021, 2024)

Identified homogeneous clusters in 2024:

G1 = {Belgium, Czechia, Austria, Hungary, Portugal, Sweden}

G2 = {Estonia, Cyprus, Latvia, Lithuania, Luxembourg, Malta, Slovenia}

G2 = {Bulgaria, Denmark, Slovakia, Finland}

G3 = {Germany}

G4 = {Spain}

G5 = {Netherlands}

G6 = {France}

G7 = {Croatia}

G8 = {Poland}

G9 = {Romania}

G10 = {Italy}

Identified homogeneous clusters in 2020:

G1 = {Belgium, Sweden, Portugal, Austria, Hungary, Czechia}

G2 = {Finland, Slovakia, Denmark, Bulgaria}

G3 = {Slovenia, Malta, Luxembourg, Lithuania, Latvia, Cyprus, Estonia}

G4 = {Germany}

G5 = {Spain, Poland}

G6 = {Romania, Netherlands}

G7 = {France, Italy}

G8 = {Croatia}

Identified homogeneous clusters in 2017:

G1 = {Estonia, Cyprus, Latvia, Lithuania, Luxembourg Malta, Slovenia}

G2 = {Sweden, Portugal, Austria, Hungary, Czechia, Belgium}

G3 = {Bulgaria, Denmark Slovakia Finland}

G4 = {Poland}

G5 = {Germany}

G6 = {Spain}

G7 = {Romania}

G8 = {Netherlands}

G9 = {Italy}

G10 = {France}

G11 = {Croatia}

In 2024, the analysis reveals a distinct fragmentation into numerous, often single-element clusters. This suggests a divergence in national strategies regarding quality-of-life enhancements and varying degrees of implementation for pro-ecological and digital initiatives. Countries such as Germany, France, Spain, and Italy constitute single-element clusters, indicating idiosyncratic developmental trajectories and individualized responses to the challenges of sustainable development and post-pandemic recovery. Conversely, more populous clusters, such as Cluster 1 (comprising Belgium, the Czech Republic, Austria, Hungary, Portugal, and Sweden), signify a synchronized pace of adaptation and a shared approach to implementing solutions aimed at elevating social well-being.

In 2020, amidst the acute phase of the COVID-19 pandemic, the identified clusters were more numerous and exhibited greater internal consistency regarding their developmental levels. This phenomenon was driven by the urgent necessity for rapid crisis management, which dictated standardized interventions in public health, social security, and public infrastructure investment. Simultaneously, the emergence of single-element clusters (e.g., Germany, Croatia) reflects the adoption of unique national crisis-mitigation strategies.

In 2017, preceding the pandemic, the clusters were characterized by greater size and higher levels of integration, suggesting more equitable developmental progress and narrower disparities in quality of life across the surveyed nations. The isolation of specific countries, such as Germany, France, and Italy, underscores their role as pioneers of innovative solutions for enhancing citizen well-being. The absence of pandemic-induced pressures during this period allowed for a more harmonious developmental trajectory and fostered international cooperation within the framework of sustainable development.

Domain III: Areas of investment in smart mobility in European countries (2017, 2020, 2024)

Identified homogeneous clusters for the year 2024:

G1 = {Germany}

G2 = {Spain}

G3 = {France}

G4 = {Sweden, Netherlands}

G5 = {Lithuania, Latvia, Croatia, Bulgaria}

G6 = {Poland, Italy}

G7 = {Slovakia, Austria, Belgium, Czechia}

G8 = {Finland, Portugal, Hungary}

G9 = {Romania, Denmark}

G10 = {Slovenia, Malta, Luxembourg, Cyprus, Estonia}

Received groups of uniform development for the year 2020:

G1 = {Germany}

G2 = {Spain}

G3 = {France}

G4 = {Sweden, Netherlands}

G5 = {Bulgaria, Lithuania, Croatia, Latvia,

G6 = {Italy, Poland,

G7 = {Slovakia, Austria, Czechia, Belgium}

G8 = {Finland, Portugal Hungary

G9 = {Denmark, Romania}

G10 = {Estonia, Slovenia, Malta, Luxembourg, Cyprus}

Received groups of uniform development for the year 2017:

G1 = {Germany}

G2 = {France}

G3 = {Hungary}

G4 = {Malta, Cyprus}

G5 = {Austria, Belgium, Denmark}

G6 = {Finland, Romania, Portugal}

G7 = {Slovakia, Czechia}

G8 = {Bulgaria, Slovenia, Luxembourg, Lithuania, Latvia, Croatia, Estonia}

G9 = {Poland, Italy, Spain}

G10 = {Sweden, Netherlands}

The cluster compositions of nations exhibiting comparable levels of investment in smart mobility across 2017, 2020, and 2024 reflect both long-term developmental trends and the transformative impact of significant external catalysts. In 2017, preceding the COVID-19 pandemic, the analysis revealed a higher number of clusters, suggesting a more balanced rate of development and narrower disparities among the surveyed countries. During this period, the technological gap between nations was less pronounced, allowing for more integrated groupings.

In 2020, however, the clusters exhibited greater internal cohesion. This consolidation was a direct consequence of the pandemic, which necessitated rapid, synchronized responses to the public health crisis. During this phase, nations were compelled to implement standardized solutions in transportation, safety, and critical infrastructure to maintain essential mobility.

By 2024, a distinct fragmentation is observable, characterized by the emergence of smaller, frequently single-element clusters. This shift reflects divergent national strategies regarding smart mobility investments, varying degrees of technological implementation, and individualized paces of adaptation to the stringent requirements of sustainable development. This increasing heterogeneity suggests that while some nations have accelerated their green transition, others are following distinct, often non-linear, developmental trajectories in the post-pandemic landscape.

5. Conclusion

The primary objective of this study was to conduct a taxonomic analysis of smart city implementations in Poland and selected European countries, utilizing a dynamic approach to track evolutionary changes over time, with a specific focus on the pre- and post-COVID-19 pandemic periods. The research employs Multidimensional Comparative Analysis (MCA) tools to, on the one hand, establish a hierarchical ranking of the development levels—enabling a comparative assessment of the entities—and, on the other hand, apply clustering techniques to identify groups of countries characterized by homogeneous development trajectories.

A significant limitation of this research was the availability of statistical data, which dictated the selection of diagnostic variables. Given that smart city concepts and sustainable development encompass a vast array of thematic dimensions, the data scope was narrowed to three primary thematic domains for the years 2017, 2020, and 2024. This focus ensured an emphasis on the most relevant and accessible aspects of the phenomenon while allowing for a robust longitudinal comparison across the pandemic threshold.

The application of taxonomic linear ordering and clustering methods facilitated the identification of countries with similar developmental profiles, distinguishing leaders from laggards in the fields of digitalization, quality of life, and smart mobility investments. The comparative analysis reveals that the COVID-19 pandemic served as a catalyst for digital transformation, yet simultaneously widened the disparities in ICT infrastructure between high-adaptation and low-adaptation nations.

These findings allow for a nuanced analysis of the pace and specificity of technological adaptation within the context of globalization, urbanization, and environmental challenges. The proposed methodology is versatile, offering applicability not only for international comparisons but also for regional and local assessments. The study underscores the necessity of long-term investment strategies in digital infrastructure as a prerequisite for achieving Sustainable Development Goals (SDGs) and mitigating digital exclusion.

From a policy perspective, the results provide decision-makers with a tool to identify areas requiring intervention, design policies to reduce inequalities in service access, and implement solutions that enhance urban resilience to health or climate crises. For practitioners and urban experts, this research offers a framework for evaluating the efficacy of smart city initiatives and monitoring progress toward sustainability.

Despite its limitations, this study provides a significant contribution to both the theoretical and practical discourse on the future of smart cities in Europe. Future research will focus on expanding the temporal and spatial scope, including regional and municipal-level comparative analyses, while incorporating social participation and innovative governance models.

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ASSESSMENT OF THE RELATIONSHIP BETWEEN LOGISTICS CAPABILITIES INFLUENCING THE SUCCESS OF THE FIRMS

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Purpose: The aim of this article is to present the results of research conducted on the relationships between logistics capabilities in the context of achieving a firm's success

Design/methodology/approach: The research results presented were obtained through a literature review and structural analysis using the MIC-MAC program.

Findings: An assessment was conducted on the direct and indirect relationships between logistics capabilities affecting the determinants of a firm's success.

Research limitations/implications: Further research in the field of firm logistics capabilities should focus on identifying variations in the relationships between capabilities based on the firm's profile, as well as examining the interrelationships among logistics capabilities themselves.

Practical implications: The research findings offer guidance to firms seeking to attain success by developing their logistics capabilities and the interrelationships among them.

Originality/value: The findings reveal novel analyses that assess the extent of the relationship between logistics capabilities and the key determinants of firm success.

Keywords: Logistic capabilities, success, capabilities.

Category of the paper: Research paper.

1. Introduction

In the face of intense competition, rapid technological development, and changing conditions of business operations—including instability and the short-lived nature of competitive advantage—firms continuously seek new strategies to achieve success. A crucial role in attaining firm success is played by the firm's capabilities, which constitute a significant component of success potentials. Within the management context, logistics represents one of the key domains; therefore, logistics capabilities—understood as a specific set of competencies related to the efficient utilization of logistics resources—hold a prominent position in building organizational success. Sets of logistics capabilities influence the realization of desired market and economic outcomes that serve as indicators of firm success. Moreover, relationships of

varying degrees of dependency and intensity exist among different sets of logistics capabilities, which formed the basis for the empirical research conducted.

The aim of this article is to present the results of empirical research on the relationships between logistics capabilities have an impact on expected market and economic outcomes as determinants of firm's success. The article presents (1) an overview of firm and success logistics capabilities, (2) the research assumptions, and (3) the findings of the empirical study conducted.

2. Overview of firm success and logistics capabilities

Success can be understood both in social and economic dimensions. In the context of social life, success constitutes a fundamental social value, widely recognized and motivating the pursuit of specific actions. It is associated with the fulfillment of dreams and the achievement of goals, providing a sense of happiness (Paszenda, 2017). In the economic sphere, success pertains to the success of an firm, which is considered as the effective accomplishment of objectives. The success of a firm is linked to the completion of assigned tasks with the involvement of relatively fewer resources and means (Littler, Leverick, Wilson, 1993).

In this article, the success of a firm is identified with the achievement of expected success indicators, which result from the execution of specific activities aimed at accomplishing planned tasks (Matwiejczuk, 2014). These indicators manifest as market and economic outcomes identified through a literature review. Market outcomes include customer satisfaction, customer loyalty, trust, and market share, while economic outcomes encompass profit, profitability, and return on invested capital.

The indicated success outcomes are the result of leveraging the firm's success factors in the form of resources, capabilities, and competencies within the framework of defined success potentials of the enterprise (Matwiejczuk, 2014). Success potentials of a firm are a set of necessary conditions that must be fulfilled for the firm to achieve success, understood as attaining profit, fulfilling strategic objectives, and ensuring customer satisfaction (Gälweiler, 1987), as well as achieving positive results in the context of competition (Pümpin, 1986). These success potentials represent capabilities that serve as premises for strengthening the competitive position of the firm (Göpfert, 2000).

Given the significant role of logistics in the functioning of a firm, it is essential to distinguish logistics success potentials, which are specific resources and capabilities in the logistics domain, utilized and developed by firm to achieve favorable outcomes (Sennheiser, Schnetzler, 2008). Logistics success potentials are prerequisites for achieving profit, the expected level of customer service, and the strategic goals of the company (Blaik, 2001). Furthermore, they are critical in performing activities aimed at securing competitive advantages superior to those of

rivals (Pfohl, 1994). One of the key success factors within the logistics success potentials is the logistics capabilities of the firm, which form the basis of the empirical research conducted in this article.

Analyzing logistics capabilities, it is important to consider two fundamental interpretative perspectives that help to better understand their role and significance in the functioning of enterprises. The first perspective views logistics capabilities as a type of resource that enables more efficient utilization of other resources; in this sense, logistics capabilities are considered a subset of resources that allow a company to use its remaining assets more effectively and distinguish itself from competitors (Fernandes, Moori, Filho, 2018) or as a collection of firm resources supporting the achievement of strategic logistics objectives (Mathien, 2020). The second perspective regards logistics capabilities as complex bundles of skills resulting from possessed knowledge (Gligor, Holcomb, 2012) or as unique abilities that are acquired, maintained, and enhanced in competition based on time and quality (Mentzer, Min, Bobbitt, 2004).

The process of developing and enhancing logistics capabilities is intricate and time-consuming, occurring in a context of market competition where enterprises must efficiently leverage their logistics resources (Hofer, Jin, Knemeyer, 2021). From a resource-based view, logistics capabilities are characterized by a high degree of uniqueness and difficulty of replication by competitors (Olavarrieta, Ellinger, 2018). Moreover, they must exhibit rarity and significant value (Gligor, Holcomb, 2014). These capabilities encompass both internal and external aspects — the internal dimension pertains to functions such as planning, coordination, and integration of activities within the enterprise, especially through synchronization among various departments; the external dimension relates to relationships and collaboration with customers and suppliers. The integration of both dimensions enables comprehensive coordination of tasks both within the firm and in its broader business environment (Gligor, Holcomb, 2014). Certain characteristics of logistics capabilities may cause them to become key logistics capabilities within the framework of logistical success potentials.

3. Methods

The research process, which involved the assessment of relationships among logistics capabilities influencing market and economic outcomes—key indicators of a company's success—was divided into two stages. The first stage consisted of conducting expert surveys using a questionnaire, in which experts evaluated whether and to what extent individual logistics capabilities affect each other. To study the relationships between specific logistics capabilities impacting the firm's success, logistics capabilities identified through literature review and the author's own empirical research were utilized.

Based on the conducted research, six market outcomes were identified, including: customer satisfaction, customer loyalty, customer trust, absolute market share, relative market share, and served market share. The research also enabled the identification of seven economic outcomes: sales revenues, profit, net profit margin, return on assets, return on invested capital, return on equity, and return on investment. The study included eleven capabilities influencing market outcomes and fourteen capabilities affecting economic outcomes. The capabilities affecting market outcomes were: post-sales customer service, flexibility capabilities, supplier evaluation capabilities, process and activity assessment capabilities, organizational capabilities, learning capabilities, collaboration capabilities, transport reliability capabilities, responsiveness capabilities, supply chain management capabilities, and customer orientation capabilities. The logistics capabilities affecting economic outcomes included: cost management capabilities, supply chain management capabilities, demand management capabilities, distribution service efficiency, collaboration capabilities, transport reliability capabilities, quality assurance capabilities, broad distribution coverage capabilities, target market responsiveness capabilities, delivery management capabilities, learning capabilities, information management capabilities, standardization capabilities, and risk management capabilities.

The second stage of the research involved conducting a structural analysis (Impact Matrix Cross-Reference Multiplication Applied to a Classification) using the MIC-MAC program. The choice of structural analysis as the research method for assessing relationships among capabilities was justified by the fact that structural analysis allows for the organization and examination of mutually influencing factors, thereby enabling the identification of dependencies and relationships. Moreover, this method facilitates the study of interdependencies between variables whose relationships are not directly observable or evident (Wójcicki, Ładyżyński, 2008).

The structural analysis enabled the identification of relationships between logistics capabilities influencing both economic and market outcomes, as well as the classification of variables into groups according to their significance within the studied area. The groups of variables in structural analysis include: key factors, target factors, result factors, auxiliary factors, driving factors, regulating factors, external factors, and autonomous factors (Nazarko, Wnorowski, Kononiuk, 2011). Key factors are characterized by both a significant strength of influence and a high degree of dependence on other elements within the system. Target factors tend to exhibit greater variability under the influence of other factors than they exert on other variables themselves. In contrast, result factors demonstrate a limited capacity to exert influence while simultaneously showing a high level of dependence on other factors. Driving factors serve as important motors of influence, exerting strong effects on other system elements with a relatively low level of subordination. Regulating and auxiliary factors have minimal impact on other factors but play a crucial supportive role in the process of achieving objectives. External factors possess an influence strength lower than that of driving factors but display

greater activity compared to autonomous factors. Finally, autonomous factors are characterized by the lowest intensity of influence on the rest of the system (Ejdys, 2013).

The second stage of the structural analysis involved the preparation of two direct influence matrices: one for logistics capabilities impacting market outcomes and another for logistics capabilities affecting economic outcomes. To create the matrices necessary for the structural analysis, individual logistics capabilities were assigned acronyms. Subsequently, after developing the templates of the direct influence matrices, an expert survey was conducted to assess the mutual interactions among the logistics capabilities. Experts evaluated the strength of influences using a five-point scale, where 0 indicated no influence, 1 – weak influence, 2 – moderate influence, 3 – strong influence, and P – potential influence. The study involved 17 experts representing both the academic environment and the manufacturing sector. The experts were selected through purposive sampling in accordance with the selection principles adopted in the third stage of the research process, within the framework of the Delphi method.

4. Results

Based on the initial phase of the study, which involved the assessment of the degree of dependency among logistics capabilities, direct influence matrices were developed for the capabilities impacting market outcomes and economic outcomes. The values in the matrices were determined based on the dominant evaluations of the influence strengths of individual logistics capabilities as identified by experts, and are presented in Table 1.

Table 1.

The Degree of Mutual Interaction of Logistical Capabilities Affecting Market Outcomes – Direct Influence Matrix

	POK	ZE	ZOD	ZOPC	ZO	ZU	ZW	ZZNT	ZZSR	ZZLD	ZKK
POK	0	2	2	2	3	2	3	1	3	2	3
ZE	2	0	2	3	3	3	2	2	3	2	2
ZOD	2	2	0	2	2	3	3	2	0	2	2
ZOPC	2	1	2	0	3	3	1	1	2	3	2
ZO	2	2	2	3	0	3	3	2	2	2	1
ZU	3	3	1	2	2	0	2	2	1	2	2
ZW	2	3	3	2	3	2	0	1	1	2	3
ZZNT	2	2	2	2	3	3	2	0	1	2	2
ZZSR	2	3	1	2	2	3	3	2	0	3	2
ZZLD	3	3	2	2	3	3	3	2	3	0	2
ZKK	3	3	2	2	3	3	3	1	3	3	0

Source: Own elaboration based on the conducted studies.

Experts evaluating the relationships between logistics capabilities and market effects identified 109 relationships among individual capabilities. The conducted analysis revealed 12 instances of no dependency and 12 instances of weak connections. In 56 cases, a moderate level of dependency was observed, while in 41 cases, the relationships were characterized by a strong degree of linkage. The matrix also contains elements equal to zero, located along its diagonals, which intentionally symbolize the lack of dependency between the same logistics capabilities. This means that a given group of logistics capabilities does not exert influence on itself, i.e., it does not affect the same selected group of logistics capabilities.

Structural analysis enabled the determination of the total strengths of direct interactions among individual logistics capabilities, presented in Table 2. The total influence strength reflects the extent to which a given logistics capability impacts others, whereas the total dependency strength indicates the logistics capabilities on which a given capability depends. This assessment is based on the number of paths and loops of a specified length leading to the vertex in the graph representing the respective factor (Nazarko, Wnorowski, Kononiuk, 2011).

The results of the analysis indicated that the logistics capabilities exerting the strongest direct influence are customer focus capabilities, supply chain management capabilities, and flexibility capabilities. Conversely, the logistics capabilities with the least direct influence on other capabilities are learning capabilities, process and activity evaluation capabilities, and supplier evaluation capabilities. Notably, their influence is only slightly lower compared to those capabilities exhibiting the highest levels of impact. The structural analysis also revealed that the logistics capabilities demonstrating the greatest total dependency strength on other capabilities are learning capabilities, organizational capabilities, and collaboration capabilities. This means that these capabilities are the most dependent on other logistics capabilities within the system. In contrast, the capabilities exhibiting the smallest dependency strength, thus lower sensitivity to the influence of other capabilities, are transport reliability capabilities, supplier evaluation capabilities, and speed response capabilities.

Table 2

Total strengths of direct interactions occurring between logistics capabilities influencing market effects in structural analysis

Logistic capabilities affecting market outcomes	Overall strength of influence	Overall strength of dependence
Post-sale customer service	23	23
Flexibility capabilities	24	24
Supplier evaluation capabilities	20	19
Capabilities for process and activity evaluation	20	22
Organizational capabilities	22	27
Learning capabilities	20	28
Collaboration capabilities	22	25
Transport reliability capabilities	21	16
Capabilities ensuring response speed	23	19
Supply chain management capabilities	26	23
Customer focus capabilities	26	21

Source: Own elaboration based on the conducted studies.

The conducted research enabled the creation of a graph illustrating the direct interactions among logistics capabilities affecting market outcomes presented on Figure 1. Very strong dependencies between logistics capabilities, exhibiting highly significant relationships, are marked in red. Strong dependencies are indicated in blue, while dependencies shown in gray represent weak influences between logistics capabilities. Weak relationships between logistics capabilities are denoted by dashed lines.

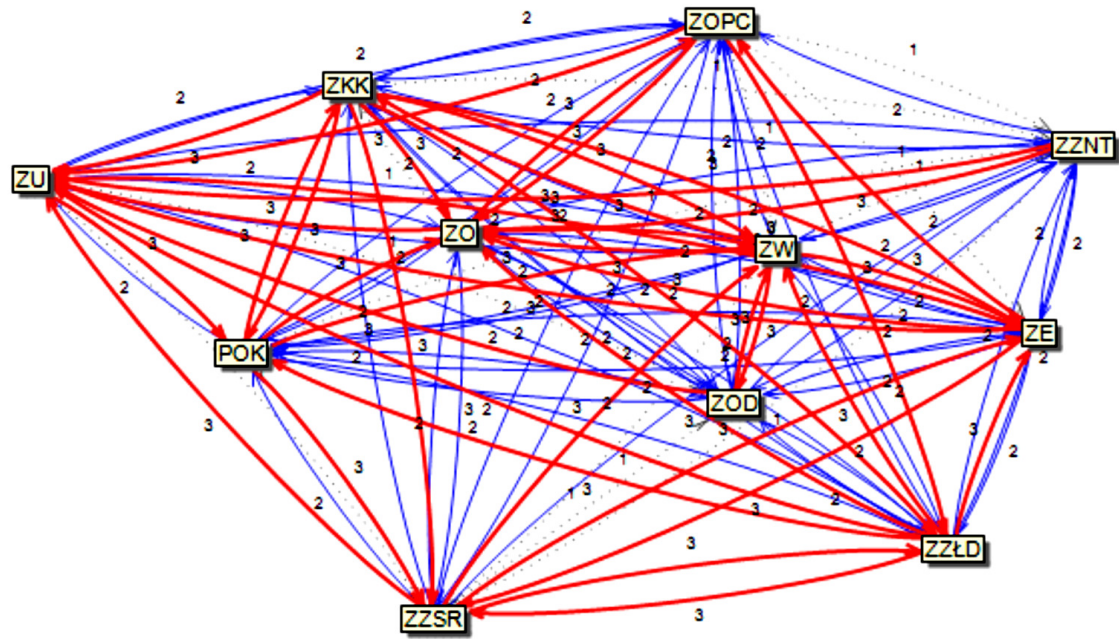


Figure 1. Graph of direct influences between logistic capabilities impacting market effects.

Source: Own elaboration based on the conducted studies.

The graph of direct influences between logistics capabilities demonstrates that there are very strong connections between all the analyzed capabilities, emphasizing their mutual dependence and interaction. Capabilities such as flexibility (ZE), learning (ZU), supply chain management (ZZLD), ensuring response speed (ZZSR), and customer focus (ZKK) are characterized by the highest number of relationships with very high intensity, indicated in red. Strong connections, marked in blue, are present between all capabilities; however, particularly intense relationships are observed for supplier evaluation (ZOD), ensuring transport reliability (ZZNT), and process and activity evaluation (ZOPC). The least intense relationships involve capabilities related to ensuring transport reliability (ZZNT) in relation to after-sales customer service (POK), process and activity evaluation (ZOPC), collaboration (ZW), customer focus (ZKK), and ensuring response speed (ZZSR). This confirms that the ZZNT group of capabilities exhibits the weakest connections with the remaining logistics capabilities, which may indicate their relative autonomy. In summary, the graph clearly indicates a significant network of mutual dependencies among logistics capabilities influencing market outcomes. The interactions between these capabilities can serve as a foundation for their synergistic utilization, leading to improved business performance and enhanced efficiency of the logistics system.

Structural analysis using the MIC-MAC method also enabled the creation of a distribution of logistics capabilities in terms of influence and dependence. The classification of logistics capabilities affecting market outcomes based on direct influences allowed for the identification of six groups of capabilities: (1) key factors, (2) regulating factors, (3) determining factors, (4) outcome factors, (5) external factors, and (6) autonomous factors.

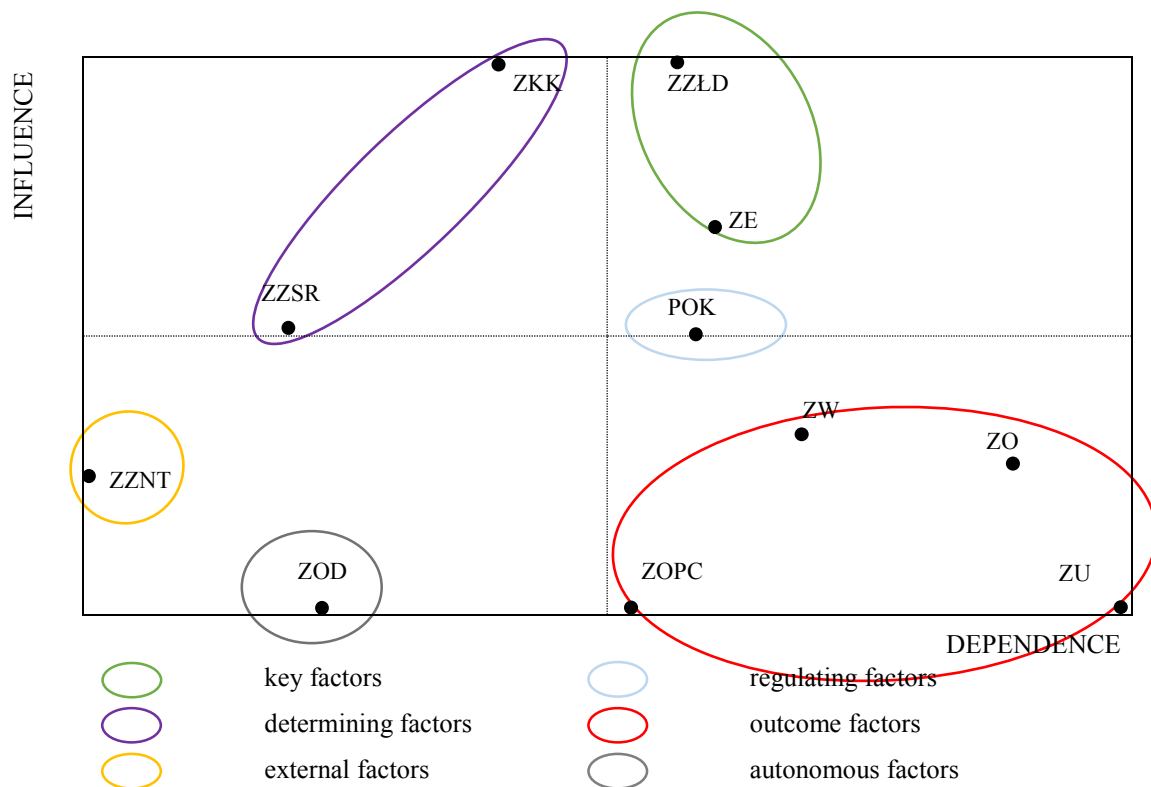


Figure 2. Classification of logistics capabilities influencing market outcomes based on direct interactions.

Source: Own elaboration based on the conducted studies.

Based on the conducted structural analysis, five groups of logistics capabilities can be distinguished, differing in their roles and the nature of mutual dependencies. Key factors include capabilities that combine a strong influence with a high degree of dependence on other capabilities, such as supply chain management (ZZLD) and flexibility capabilities (ZE). Determining factors are logistics capabilities that exert a strong influence on others while exhibiting relatively low susceptibility to control by other capabilities. This group includes customer focus capabilities (ZKK) and capabilities ensuring response speed (ZZSR). Regulating factors encompass auxiliary capabilities characterized by a low level of influence on other capabilities—in this system, after-sales customer service (POK) plays a significant supporting role despite its limited influence. Outcome factors include capabilities that show minimal impact on others but are significantly dependent on other factors; these include collaboration capabilities (ZW), organizational capabilities (ZO), learning capabilities (ZU), and capabilities for process and activity evaluation (ZOPC). They represent the result of mutual interactions within the logistics system. Finally, the group of external factors consists of

capabilities with minimal influence on others—namely, transport reliability capabilities (ZZNT) and supplier evaluation capabilities (ZOD), which exhibit the least influence on other capabilities, suggesting their relative autonomy or specific role. In summary, the dependency structure among logistics capabilities indicates the need for a differentiated management approach that considers both strong determining and integrating factors, as well as the role of auxiliary, outcome, and external elements. Such an analysis enables more effective targeting of efforts toward the development and optimization of individual components of the logistics system in the context of achieving improved market outcomes.

Within the conducted research, experts also assessed the dependencies among logistics capabilities influencing economic outcomes. Similarly to the logistics capabilities affecting market outcomes, an influence strength matrix was created. In the direct influence matrix, zeros were placed on the diagonal, indicating the absence of influence between the same logistics capabilities. Detailed results showing the degree of mutual interaction among logistics capabilities affecting economic outcomes, according to the direct influence matrix, are presented in Table 3.

Table 3

The Degree of Mutual Interaction of Logistical Capabilities Affecting Economic Outcomes – Direct Influence Matrix

	ZZK	ZZLD	ZZP	EUD	ZW	ZZNT	ZZSD	ZRRD	ZZD	ZU	ZZI	ZS	ZZR
ZZK	0	3	3	2	3	2	3	2	1	3	3	1	3
ZZLD	3	0	2	2	3	2	2	3	3	3	3	1	2
ZZP	1	3	0	3	2	2	2	3	3	3	3	1	2
EUD	2	3	2	0	2	2	2	3	3	2	3	1	2
ZW	1	2	1	2	0	1	2	3	3	2	3	2	1
ZZNT	2	2	1	2	2	0	1	2	2	1	3	2	2
ZZSD	2	2	1	2	3	2	0	2	2	1	1	2	1
ZRRD	2	2	3	3	2	2	1	0	2	1	2	1	2
ZZD	2	3	3	3	3	2	2	3	0	3	3	2	2
ZU	2	2	2	2	3	2	3	1	2	0	3	1	2
ZZI	2	2	2	2	3	2	3	3	3	3	0	2	2
ZS	2	1	1	2	2	1	3	1	1	1	2	0	1
ZZR	2	3	3	2	1	1	1	2	1	2	3	1	0

Source: Own elaboration based on the conducted studies.

Based on the assessment conducted by experts regarding the dependencies among logistics capabilities influencing economic outcomes, a total of 109 relationships between these capabilities were identified. The analysis revealed 13 cases of no dependency and 34 cases of weak dependence. Among the remaining relationships, 73 exhibited a moderate degree of connection, while 49 instances showed strong dependencies. Structural analysis also made it possible to determine the cumulative strengths of direct influences among logistics capabilities impacting economic outcomes, which are presented in Table 4.

Table 4

Total strengths of direct interactions occurring between logistics capabilities influencing market effects in structural analysis

Logistic capabilities affecting economic outcomes	Overall strength of influence	Overall strength of dependence
Cost management capabilities	29	23
Supply chain management capabilities	29	28
Demand management capabilities	28	24
Distribution service efficiency	27	27
Collaboration capabilities	23	29
Transport reliability capabilities	22	21
Providing wide distribution coverage	21	25
Capabilities for responding to target markets	23	28
Supply management capabilities	31	26
Learning capabilities	25	25
Information management capabilities	29	32
Standardization capabilities	18	17
Risk management capabilities	22	22

Source: Own elaboration based on the conducted studies.

The analysis indicates that the logistics capabilities with the strongest direct influence on other capabilities are supply management capabilities, information management, cost management capabilities, and supply chain management. In contrast, the capabilities associated with standardization and providing wide distribution coverage exhibit the lowest total influence strength. Regarding dependence strength, information management and collaboration capabilities demonstrate the highest levels of dependence, indicating that these elements are most reliant on other logistics capabilities affecting economic outcomes. In contrast, standardization capabilities constitute the group with the lowest dependence on other capabilities, suggesting their relative autonomy within the logistics system.

Structural analysis using the MIC-MAC program enabled the creation of a graph illustrating strong direct interactions among logistics capabilities affecting economic outcomes, which is presented in Figure 3.

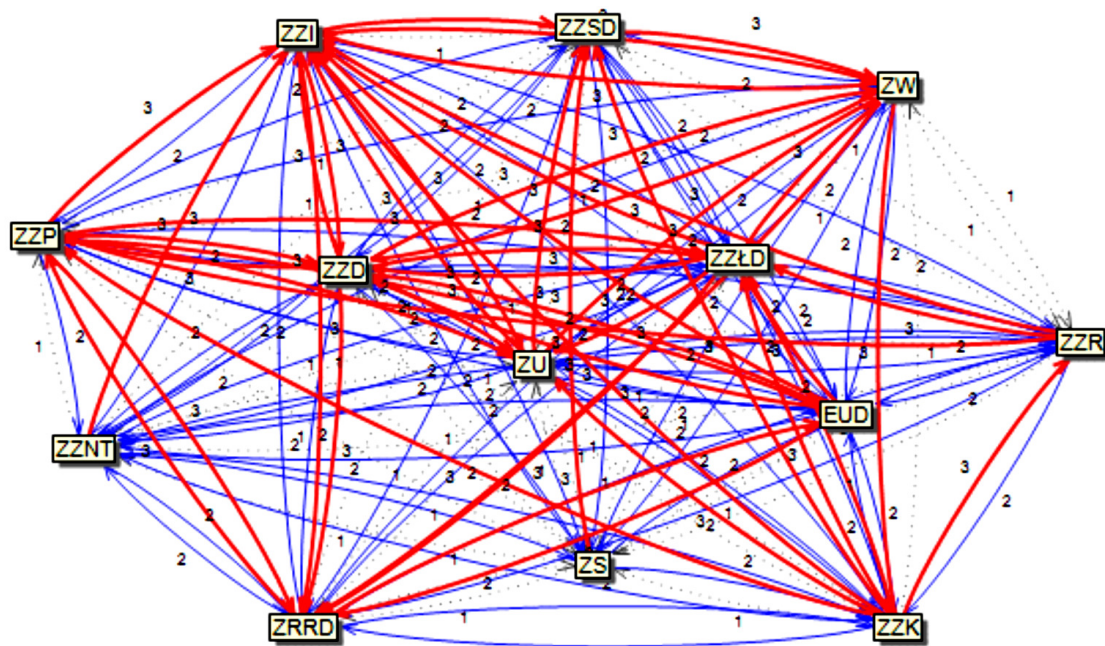


Figure 3. Graph of direct influences between logistic capabilities impacting economic effects.

Source: Own elaboration based on the conducted studies.

The analysis of the direct influence graph revealed that all logistics capabilities impacting the expected economic outcomes exhibit very strong relationships. The capabilities demonstrating the highest number of strong connections with other logistics capabilities are supply management (ZZD), learning capabilities (ZU), supply chain management (ZZLD), information management (ZZI), capabilities ensuring wide distribution coverage (ZZSD), and demand management (ZZP). Strong dependencies, marked in blue, occur in relation to transport reliability capabilities (ZZNT), risk management capabilities (ZZR), distribution service efficiency (EUD), and capabilities for quick response to target markets (ZRRD). Weak relationships between logistics capabilities, indicated by gray, are associated with learning capabilities (ZU) and standardization capabilities (ZS), which represent the group with the weakest links to other capabilities.

The analysis of the direct influence graph indicates that all logistics capabilities affecting economic outcomes are characterized by very strong or strong interdependencies. This confirms the mutual connections among these capabilities, forming a complex interaction network. Such strong relationships between logistics capabilities can both strengthen and weaken individual competencies within the system, ultimately influencing the achievement of positive economic outcomes by the firm. Therefore, managing and optimizing these interdependencies can be crucial for improving the economic performance of the firm.

Using the MIC-MAC program, logistics capabilities influencing economic outcomes were classified into groups based on the influence-dependence relationship, similarly to the logistics capabilities affecting market outcomes. Based on this, the logistics capabilities were divided into groups analogous to those impacting market outcomes.

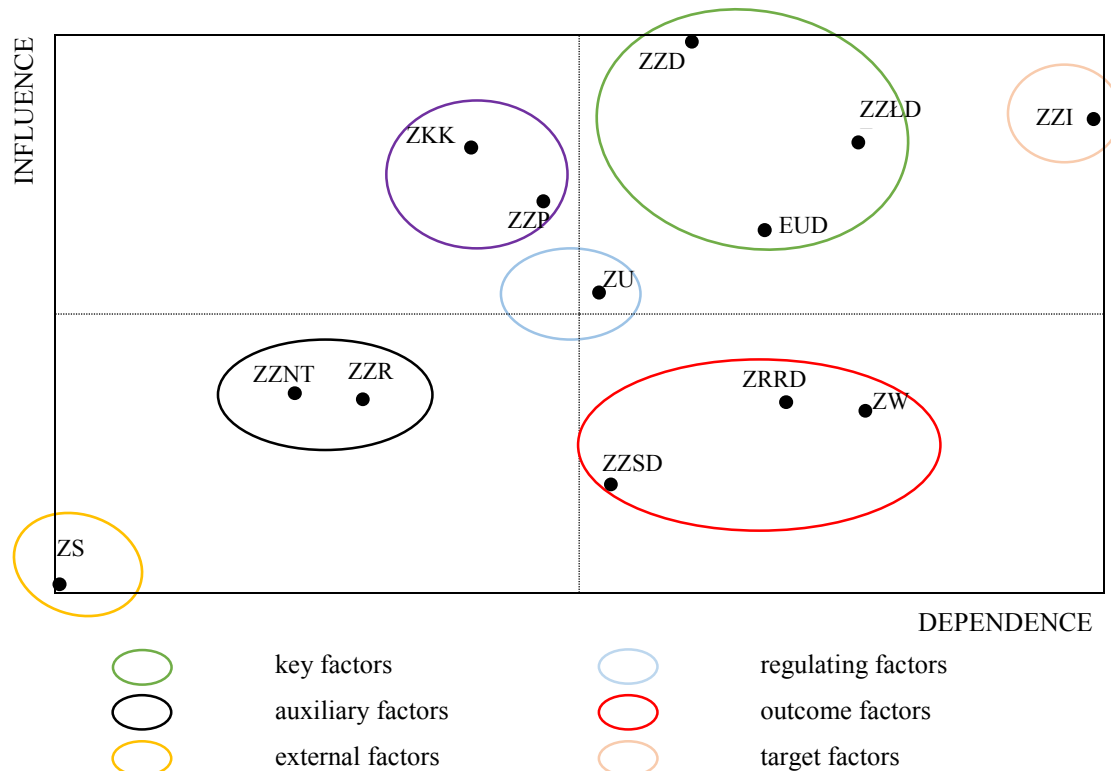


Figure 4. Classification of logistics capabilities influencing economic outcomes based on direct interactions.

Source: Own elaboration based on the conducted studies.

Key factors include supply management capabilities (ZZD), supply chain management capabilities (ZZLD), and distribution service efficiency (EUD), characterized by both a high degree of influence and dependence on other logistics capabilities. Within the goal factors group are information management capabilities (ZZI), which are more susceptible to influence by other capabilities than exerting influence themselves. Learning capabilities (ZU) are classified as regulating factors, possessing a low level of influence on other logistics capabilities but are important for achieving system objectives. Outcome factors include capabilities ensuring wide distribution coverage (ZZSD), collaboration capabilities (ZW), and capabilities ensuring response to target markets (ZRRD), which have limited impact on other capabilities but remain strongly dependent on their influence. Among the determining factors, acting as drivers of system influence, are demand management capabilities (ZZP) and customer focus capabilities (ZKK). Transport reliability capabilities (ZZNT) and risk management capabilities (ZZR) are classified as auxiliary factors, with moderate or low influence on other capabilities. Finally, the only group of capabilities with low influence classified as external factors comprises standardization capabilities (ZS), which exhibit limited interaction with other elements of the logistics system. This classification allows for a better understanding of the structure of mutual dependencies and indicates opportunities to direct developmental efforts in logistics, considering their role in the system and impact on the economic outcomes of the firm.

5. Summary

Firms continually strive to identify and implement strategies that enable the achievement of success. Within the resource-based view of strategic management, one of the key elements ensuring the success of a firm is its capabilities. Given the significant role of logistics in the functioning of firms, logistic capabilities warrant particular attention. The existing literature devoted to logistic capabilities indicates their substantial contribution to achieving success, nevertheless, a research gap persists concerning the interrelationships among specific logistic capabilities and their influence on the determinants of firm success.

In light of the above, research was conducted to assess the relationships occurring between specific logistic capabilities influencing market and economic outcomes. The study was carried out in two stages—first through expert surveys, and subsequently via structural analysis. In the initial stage, a questionnaire was administered to experts who evaluated the relationships among individual logistic capabilities. The collected data served as the basis for conducting a structural analysis of the relationships between these capabilities. The analysis revealed that the relationships among capabilities affecting economic outcomes exhibit a higher density compared to those among capabilities influencing market outcomes. This pattern of dependencies between logistic capabilities suggests a close interconnection between these groups of capabilities and indicates the need for a holistic approach to their development—considering the simultaneous cultivation of various groups of logistic capabilities rather than focusing solely on isolated aspects.

It should be noted that the conducted analysis concerned manufacturing firms, which limits the possibility of directly transferring the obtained results to other economic sectors. Differences arising from the specificity of production processes, distinct organizational structures, and varied material and immaterial resources indicate the necessity for further research on the adaptation of the proposed solutions in other industries. Moreover, logistic capabilities are characterized by the fact that they are developed internally within the firm and cannot be directly acquired from external sources, which means each firm possesses a unique set of capabilities contextually adapted to its own conditions and potential. This specificity restricts the universality of the presented analyses and underscores the importance of continuing research in the field of logistic capabilities.

The specific nature of a firm's capabilities, which cannot be acquired externally but must be developed internally, gives each entity unique potential. This limits the universality of the conducted research, while opening space for individual adaptation. For firms with limited resources, a privileged implementation path is recommended, consisting of the staged adaptation of the presented research results. It begins with the identification of logistic capabilities, proceeds through the assessment of relationships between them, and culminates in the monitoring of market and economic outcomes. Furthermore, the unique potential of each

firm's logistic capabilities underscores the necessity of individual adaptation; therefore, for entities with limited resources, a priority focus is proposed on key logistic capabilities constituting the firm's success factors, which lead to the distinguishing markers of success, namely market and economic outcomes.

In light of the above limitations, future research should focus on the identification and validation of sets of logistic capabilities in diverse types of firms, as well as on their practical application under real market conditions, which will enable the assessment of their effectiveness. Particular attention should be devoted to in-depth empirical studies concentrating on logistic capabilities that significantly influence the market and economic outcomes of firms, taking into account the sectoral aspect. It is especially important to verify and potentially expand the catalogue of logistic capabilities in firms operating in the service and trade sectors, where the characteristics of logistic processes differ from those in manufacturing firms.

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Appendix

Table 1.

List of logistical capacities with acronyms

Acronym	Name of logistic capabilities
ZSRR	Capabilities ensuring response speed
ZOPC	Capabilities for process and activity evaluation
ZRRD	Capabilities for responding to target markets
ZW	Collaboration capabilities
ZZK	Cost management capabilities
ZKK	Customer focus capabilities
ZZP	Demand management capabilities
EUD	Distribution service efficiency
ZE	Flexibility capabilities
ZZI	Information management capabilities
ZU	Learning capabilities
ZO	Organizational capabilities
POK	Post-sale customer service
ZZSD	Providing wide distribution coverage
ZZR	Risk management capabilities
ZS	Standardization capabilities
ZOD	Supplier evaluation capabilities
ZZŁD	Supply chain management capabilities
ZZD	Supply management capabilities
ZZNT	Transport reliability capabilities

Source: Own elaboration based on the conducted studies.

THE IMPACT OF ARTIFICIAL INTELLIGENCE ON CREATING INTELLECTUAL CAPITAL IN POLISH ORGANIZATIONS

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Purpose: The aim of the paper is to identify the components of the Intellectual Capital structure in the AI era and to indicate the mechanisms of AI technology's impact on the Human, Organizational, and Relational Capital of Polish enterprises, which will enable the development of a theoretical model for assessing this impact.

Design/methodology/approach: The study uses the method of critical analysis of the literature and a review of desk research results. The study area of the paper covers the issues of Intellectual Capital (IC) and AI. The paper is theoretical and conceptual in nature and represents the author's point of view. Employing a deductive approach, this study reinterprets established dimensions of IC for the era of AI.

Findings: The paper develops the components of the IC structure in the AI era, identifies the potential impact of AI on IC in Polish enterprises, and proposes a theoretical and conceptual model of the impact of AI on IC. The results obtained indicate that AI has a strong and diverse impact on the IC of organizations.

Research limitations/implications: The discussion explores a new direction for research and, above all, should be inspiration for further study of the impact of AI on IC in companies. The proposed model is general, but it could be a basis for further research.

Practical implications: Practical implications include the possibility of using the proposed model to choose and develop an appropriate strategy for the company's development and increase its market value.

Social implications: The article emphasizes the impact of AI in creating an organization's IC, especially in the area of shaping human-technology relationships, which determine the future dimension of people's social competencies. The proposed model generates greater awareness among management and employees regarding companies' responsibility for access to technology and the creation of IC. This may result in the development of a new strategy for responsible AI management.

Originality/value: The study brings new value by considering the impact of AI on Human, Organizational, and Relational Capital at the same time. Additionally, the article shows how and with what components the impact of AI on IC can be analyzed.

Keywords: Artificial Intelligence, Intellectual Capital, Impact AI on IC.

Category of the paper: Viewpoint and conceptual paper.

1. Introduction

In the era of globalization, Artificial Intelligence (AI) technology has become a key indicator of the development of an organization's potential and the achievement of market competitiveness for businesses and the economy. As a driving force behind industrial transformation, AI enhances productivity, increases efficiency, optimizes resource allocation (Fan, Chen, Yang, 2025), transforms the way people make decisions, changes the demand for labor by increasing the need for highly skilled workers, automates processes, and at the same time reduces the demand for repetitive tasks (Autor, 2024; Han, Mao, 2023; Ma et al., 2022; Noy, Zhang 2023; Wang, Chen, Chen, 2024), and also supports employee learning and enables the creation of new forms of relational value.

The dynamic development of AI contributes to the verification and re-discussion of many issues related to Human Resource Management (HRM) and the creating of an organization's IC. Therefore, the literature contains considerations regarding the nature of future relationships between human knowledge capital and AI (Gashenko et al., 2020; Popkova, Sergi, 2020; Gitling, 2024; PARP 2025), or the use of AI in Organizational and Relational Capital management processes (Kisielnicki et al., 2022; Chowdhury et al., 2023; Kabus, 2025). There are also considerations regarding the use of AI in responsible HRM (Chowdhury et al., 2023; Korkosz-Gębska, 2025), as well as analyses of the transformative impact of AI on IC development (Al-Romeedy, Alharethi, 2024; Popescu, Šebestová, 2024). However, the subject matter often focuses on selected industries and various correlations of this topic with other issues, e.g., studying the impact of AI and IC on the sustainable development of organizations in the tourism, hotel, or transport industries. The literature on the subject rarely shows how the implementation of AI in organizations affects changes in the Human, Organizational, and Relational Capital of specific market enterprises, transforming them.

There is also a lack of research (or very little) on the impact of AI on the structure, shape, and value of IC, which is now seen as a strategic resource for organizations (Wójcik, 2023). Consequently, this results in a lack of knowledge among decision-makers and the inappropriate use of AI in companies. Furthermore, traditional IC models (Jurczak, 2006; Mroziwski, 2008) do not consider AI technology as an element that contributes to the value of an organization. Therefore, there is also a great need to redefine the components of IC in the areas of Human, Organizational, and Relational Capital. This article attempts to answer the following questions: *What are the key components of Intellectual Capital in the age of AI? and How does Artificial Intelligence affect the structure of Human, Organizational, and Relational Capital in Polish enterprises?*

The aim of this work is to identify the components of the IC structure in the AI era and to indicate the possibilities and mechanisms of AI technology's impact on the Human Capital (HC), Organizational Capital (OC), and Relational Capital (RC) of Polish companies in the context of

building organizational value, which will enable the development of a theoretical model for assessing this impact.

2. Research methods

The author's considerations are based on literature studies and a review of source research results, together with a critique of the literature. The research methods included: a review of scientific literature, industry reports, and online sources related to the issue of IC in the AI era. The search was conducted using Google Scholar. Only works analyzing the impact of AI on IC (including HC, SC, RC) published in Polish and English between 2020 and 2025 were taken into account. In addition, analyses contained in source materials and reports of Polish companies published in 2022-2025 were used, and companies that are leaders in the implementation and use of AI in various areas of IC were analyzed. The research conducted in this way was used to analyze the results, propose an IC structure, and develop an original model of the mechanisms of artificial intelligence's impact on IC development in an enterprise, as well as to formulate final conclusions in this regard. This work is therefore theoretical and conceptual in nature and may inspire further research and exploration of this topic on a larger scale.

3. Results

In this paper, the author understands the intellectual capital of an organization within a holistic-dynamic concept as capital that changes over time as a result of interactions specific to social capital and under the influence of the strategies adopted by the organization. In this approach, IC consists of Human Capital, Organizational Capital, and Relational Capital. All elements of IC may change over time under the influence of transforming environmental conditions, the development of AI technology, and its implementation in the specific context of the organization. In this context, companies should constantly update and adapt IC components, adjusting them to the reality in which they operate. Table 1 presents the identification of IC structure elements in the AI era.

Table 1.
Identification of IC structure elements in the AI era

ELEMENTS OF IC STRUCTURE IN THE AGE OF AI		
LEVEL I	LEVEL II	LEVEL III
Human Capital supported by AI (skills developed through human interaction with AI tools)	Knowledge Capital	• digital knowledge (in the field of digital tools, algorithm and model creation), • specialized knowledge in a given area, enabling critical analysis of responses generated by AI.
	Skills Capital	• communication skills in the field of prompt engineering, • digital skills (ability to work with AI tools, understanding of the basics of algorithms), • analytical and synthetic skills (data analysis and interpretation of AI results), • social and cognitive skills allowing for effective human-AI collaboration, • ability to apply ethical principles in the field of AI and awareness of technological risks.
	Social Capital	• trust in AI, • norms, values, and relationships built in the digital world, • motivation to be active and make decisions based on cooperation with algorithms.
Organizational Capital supported by AI (organizational infrastructure that supports the collection, processing, and use of knowledge with the participation of AI)	Structural Capital	• data warehouses, algorithms, and AI models, • AI-supported decision-making processes, • recommendation and prediction systems, • human-AI collaboration procedures, • AI tools for work organization and automation (e.g., cloud computing, chatGPT, AI agents, chatbots), • intelligent work processes, process automation (RPA), • AI-based knowledge systems (generative document repositories, intelligent search engines, Knowledge Graph tools), • digital organizational culture (acceptance of algorithms, openness to technological experiments, resilience to change).
	Process Capital	• processes and procedures realized with the use of AI, • AI-based process mapping tools.
Relational Capital supported by AI (the organization's relationships with its environment, enriched by AI)	Capital of Distinction	• the organization's reputation in the context of the ethical use of AI.
	Market Capital	• stronger relationships with customers, suppliers, competitors, and strategic partners, • large-scale personalization of customer interactions (recommendation systems), • automated customer service (chatbots, voicebots), • real-time behavioral analytics, • collaboration with AI technology providers, • co-creation of products with AI partners, • platforms for sharing experiences.
	Customer Capital	• customer base, potential customers, • responsible management of customer data using AI tools.

Source: Own work.

AI contributes to strengthening the development of all three elements of intellectual capital. In the area of human capital, AI supports the development of individual and team competencies and creates human-machine collaboration by:

- stimulating new cognitive, digital, and adaptive competencies among employees (critical thinking, creative thinking, ability to collaborate with technologies). Generative AI systems do not eliminate the need for human input (Deloitte, 2024), but shift the emphasis from performing repetitive tasks to tasks requiring creativity, analysis, and quality control of the results generated by AI models,
- the creation of new professions and specializations, e.g., data analysts, technology ethics specialists, knowledge management experts, and prompt engineers,
- limiting routine operational activities, which necessitates the use of reskilling (learning completely new skills) and upskilling (deepening current skills) programs for employees (EY Poland, 2024),
- supporting learning processes in organizations and its personalization through Adaptive Learning, which involves tailoring the entire learning process to the needs, skills, and abilities of e-learning participants (Kołodziejczyk, 2019).

In the area of organizational capital, the impact of AI mainly concerns:

- intelligent automation of work and information processing. Knowledge Graph Systems and Large Language Models (LLMs) can analyze internal document repositories, reports, and emails, creating summaries, capturing key information, and answering questions. They can also translate texts and create creative content and recommendations. In this way, AI plays the role of a “knowledge assistant” that supports employees in accessing the data they need (Cognity.pl, 2025);
- supporting the automation and optimization of business processes (RPA – Robotic Process Automation), which enhances operational efficiency and reduces the risk of human error;
- creating real-time learning organizations by continuously monitoring process efficiency and recommending necessary improvements (Pańkowska, Sołtysik-Piorunkiewicz, 2025), which allows for reducing losses, better inventory planning, and responding to market changes;
- enabling better intellectual property management (Zancan, Rodrigues, 2025), e.g., algorithms analyze patent markets, identify similar solutions, and help develop strategies to protect innovations.

The impact of AI on relational capital can be observed through:

- personalization of communication and better understanding of the needs of customers and business partners, e.g., recommendation systems used in e-commerce analyze the purchase history and behavior of users to offer them products that match their individual preferences (Ślusarz, 2024). As a result of such activities, customer satisfaction increases, and thus the relational value of the organization also increases,

- strengthening communication and cooperation within teams through the use of sentiment analysis (tools for analyzing content and emotions in emails or chats that help leaders recognize employee moods and respond to potential conflicts), which help create a more empathetic and balanced work environment (PIRIOS, 2025).

The results of the above analyses indicate that improvements in corporate AI innovation significantly contributes to technological progress, reduces the percentage of employees with low levels of education, and facilitates the structural modernization of human, organizational, and relational capital (Fan, Chen, Yang, 2025).

The analysis of practical applications of AI in Polish companies presented below: PKO BP, InPost, CD Project, and Allegro also shows how AI technology affects the development of IC in real economic conditions. Detailed information on the characteristics of the impact of AI on IC in selected Polish companies is presented in Table 2.

Table 2.

The impact of AI on Human, Organizational, and Relational Capital in Polish companies

PKO Bank Polski		
a leader in the digitization of the financial sector in Central and Eastern Europe, which uses AI in various areas, from customer service to risk management.		
The impact of AI on HC	The impact of AI on OC	The impact of AI on RC
AI affects HC by appropriately improving the skills of bank employees. PKO BP has created internal training programs in data management, analytics, and AI ethics. In addition, the AI assistant also supports programmers in writing code, correcting errors, and creating test scenarios, as well as other employees in searching for documents.	AI improves structural capital (better processes and a solid knowledge base) by using a virtual voice assistant in the IKO mobile app, which answers questions and carries out basic instructions.	AI increases relational capital by improving customer service efficiency, generating knowledge about customer needs and behaviors, and educating customers about online banking security. AI also assists in soft debt collection (reminding customers of payment deadlines, verifying the authenticity of ID cards, and analyzing the opinions of IKO app users).
InPost		
a logistics company that delivers parcels and operates Europe's largest network of parcel lockers. InPost uses AI to predict demand, optimize routes, and manage resources in real time.		
The impact of AI on HC	The impact of AI on OC	The impact of AI on RC
Thanks to AI, employees learn to interpret data, work with predictive models, and make fact-based decisions. The company has thus created a work environment based on organizational learning, where experiences are collected and used in real time.	AI helps to forecast resource demand, plan courier routes, and manage parcel locker locations. Predictive systems analyze weather data, seasonal trends, and customer behavior, which help avoid delays, better plan operations, increase delivery predictability, and manage staff and vehicle fleets more effectively. Algorithms analyze data on traffic, location, time of day, weather, and order history. Based on this, they forecast the load on individual points and optimize the delivery plan. This makes it possible to reduce transportation costs and CO ₂ emissions, as well as shorten delivery times.	Predictive systems analyze customer data and behavior, allowing company to better plan their operations, avoid delays, and manage customer relationships more effectively.

Cont. table 2.

CD Projekt		
a company in the computer games sector that conducts research and development in the field of AI applications in game testing processes, generating realistic behaviors of independent characters, and supporting the work of creative teams.		
The impact of AI on HC	The impact of AI on OC	The impact of AI on RC
In the area of HC, the company cares about developing technological skills among its employees and creates interdisciplinary teams in which programmers, psychologists, artists, and data analysts work together.	The team responsible for AI is exploring the possibilities of using existing AI-based tools and developing its own AI-based tools for the development of future products, particularly in the areas of prototyping process improvement, testing automation, and the creation of realistic non-playable character (NPC) behavior.	The AI team manages research projects on the use of machine learning for automatic scenario testing and player behavior analysis. These activities enable faster error detection and the creation of more refined game worlds for users, which improves customer relations.
Allegro		
an e-commerce platform that is a pioneer in the use of AI in data and customer behavior analysis and the personalization of their activities		
The impact of AI on HC	The impact of AI on OC	The impact of AI on RC
Recommendation systems support people in increasing sales by analyzing purchase history, searches, time spent browsing offers, and price preferences. Based on this, they create personalized product recommendations and dynamically adjust the order of search results.	The use of AI tools to create offers, generate product descriptions, automatically fill in product parameters, as well as optimize photos, set prices, and categorize products. In addition, AI systems collect knowledge about user behavior, which becomes a strategic resource for the company. Furthermore, the company has introduced an AI assistant that helps search for products on Allegro and inspires customers to make purchases (e.g., the assistant suggests what the user may need).	AI helps in responding to customer inquiries and assists consultants in efficient communication, which improves the user experience. Thanks to natural language analysis in customer inquiries, the company better understands their intentions and can match results more accurately. Automatic response systems reduce response times and enable the handling of thousands of queries per day. AI also ensures the security of purchases by detecting potential fraud.

Source: Own work based on: (Wardziak, 2025; MCIT.PL, 2025; CD Projekt, 2025; Business Insider 2022).

All of the companies described show that the key factor for success is not AI-based technology itself, but how it is implemented and how it can be used for the organization's purposes. Companies that treat AI as part of their knowledge and competence development strategy gain a competitive advantage. PKO BP invests in digital education for its employees, InPost creates a data-driven organizational culture, CD Projekt uses AI as a tool to support creativity, and Allegro proves that AI can improve customer relationships. In addition, in all companies, the implementation of AI results in faster development of Human, Organizational, and Relational Capital.

The results of the above analysis allow us to develop a theoretical model of the mechanisms of AI's impact on an organization's IC (Figure 1), which can stimulate the development of Human, Organizational, and Relational Capital.

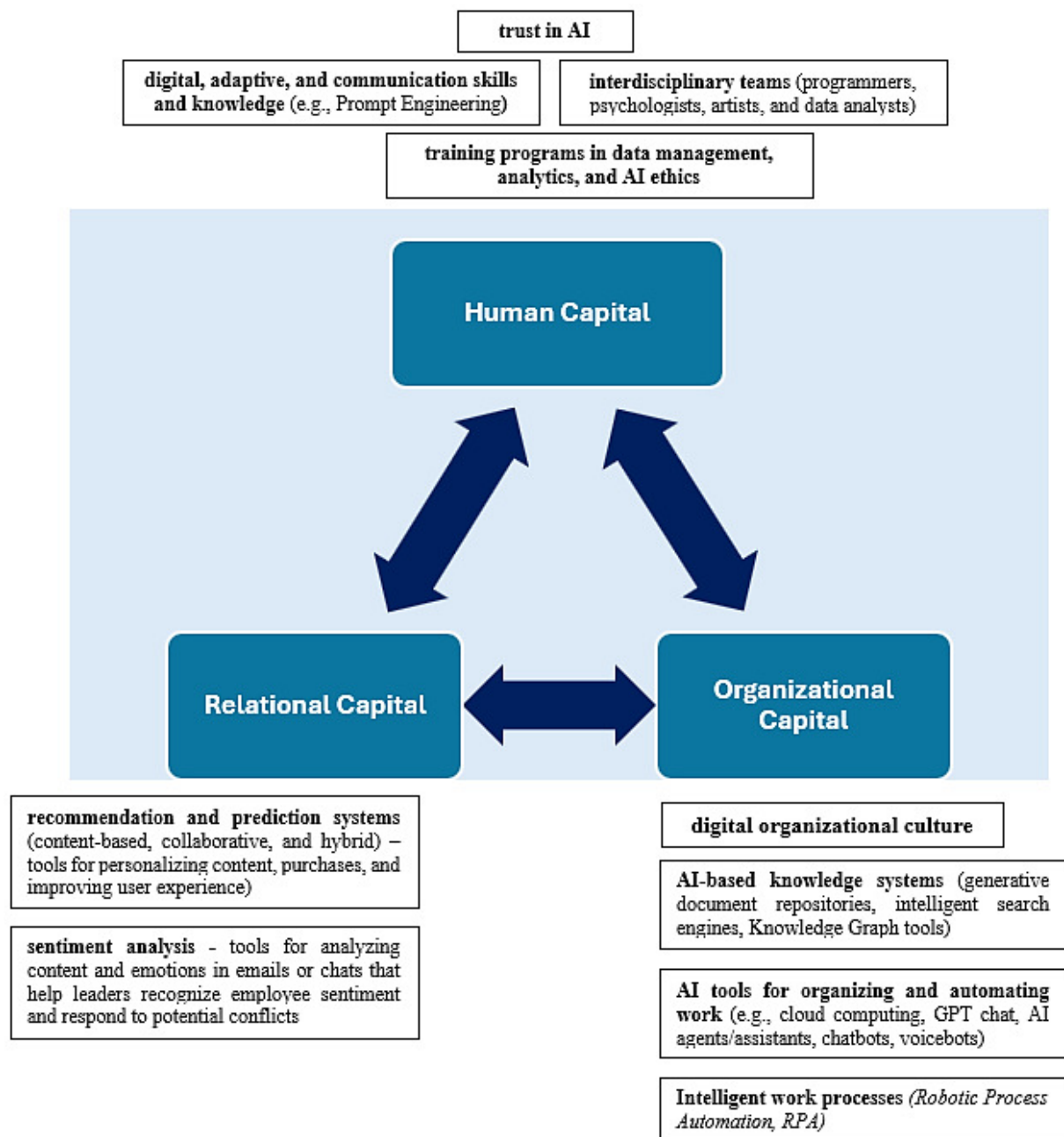


Figure 1. The theoretical model of AI mechanisms influencing IC in creating organizational value.

Source: Own work.

4. Conclusions

An analysis of the literature and existing research lead to the conclusion that the speed of implementation and use of innovative AI-based technologies has a significant impact on the formation and development of an organization's IC. Proper implementation and use of AI in a company develop the knowledge and skills of employees, contribute to the development of

infrastructure and organizational processes, and generate stronger and more valuable relationships with the organization's stakeholders, increasing the company's market competitiveness.

However, the effect of AI on IC is not the same for every organization and depends on the specifics and context of the company's operations - its size, technological maturity, or business model, as well as the level of identification and engagement of IC. Therefore, it is worth considering the key mechanisms of AI's impact on IC presented in the theoretical model and analyzing them according to the specifics and context of the organization's operations.

The proposed model generates greater awareness among management and employees of the possibilities and mechanisms of AI technology's impact on an organization's IC, which can contribute to the creation of a thoughtful strategy for the organization's development, focused on the conscious and responsible use of AI in the context of stimulating people's competencies and knowledge, enriching organizational solutions, and building relationships based on mutual trust and cooperation.

The discussion explores a new direction for research and, above all, should inspire further reflection. Future research should take into account empirical data on the impact of AI on the structure, shape, and value of IC (including HC, SC and RC). In the future, it will also be worthwhile to conduct longitudinal studies that monitor how IC evolves over time with the increasing adoption and integration of AI. It is also worth considering the possibilities of measuring the impact of AI on the development of IC in an organization and developing appropriate measurement tools.

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THE FORM AND CONTENT OF ECOLABELS IN IMPROVING THEIR EFFECTIVENESS

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Purpose: The research objective of this thesis is to review the latest research in order to determine the form and content of ecolabels that will increase their effectiveness in environmental.

Design/methodology/approach: A qualitative literature review was used in this study. It served to identify, evaluate and synthesise research relevant to the problem under consideration. The study adopted a systematic literature review methodology in accordance with the guidelines set out by Moher et al. (2009).

Findings: The analysis of the research results identified during the systematic literature review process allowed us to identify elements related to the form and content of the ecolabel design. They were grouped into the following categories: visual design, scope of environmental information, accuracy of environmental information, adaptation to consumer segments, information relevant to the product, and presentation in online retail. These results indicate that designing an effective ecolabelling system requires treating it as a complex communication system. The effectiveness of ecolabels depends on many aspects and requires an integrated approach. However, any actions taken to achieve this are worth the maximum commitment of all market parties.

Research limitations/implications: A limitation of the study is that the literature review is based on only one database, Scopus.

Practical implications: The results of this study provide a valuable source of knowledge about the desired graphic and informational elements of ecolabels. This data may be relevant for regulatory bodies and certification bodies. This work has identified and described the components of ecolabels that are most desired by consumers, the practical implementation of which will contribute to increasing the effectiveness of environmental labelling.

Originality/value: The paper presents an original and unique approach to the problem of research on the effectiveness of ecolabels. Based on a well-established and described method of systematic literature review, the latest research on ecolabels was identified and analysed.

Keywords: ecolabels, effectiveness, sustainability, environment, systematic literature review.

Category of the paper: Literature review.

1. Introduction

For better health, wellbeing, and biodiversity, many social and political movements seek to promote and activate actions that will reduce the negative impact on global resources (Kuhlman, Farrington, 2010). However, these actions are insufficient, and there is a lack of conviction and commitment on many levels. The last decade has been characterised by the highest average temperature in the history of measurements. As a result of climate change, extreme weather events are becoming more frequent (Statistics Poland, 2022). These changes are generating significant financial losses. The European Environment Agency estimates that between 2010 and 2020, Poland incurred costs exceeding EUR 3 billion.

These circumstances are prompting governments to take action to protect the planet from degradation, mainly through sustainable consumption and production (Resolution..., 2015). Among the various concepts and tools for achieving these goals, many industry groups and social organizations identify the economic and environmental opportunities offered by environmental labelling systems (Aitken et al., 2024). However, despite the large number of labelling systems implemented, it appears that this effort is not producing proportional results.

Existing research on this topic is highly fragmented and scattered. It concerns various labelling and ecolabelling systems. Very often, individual research projects analyze and conduct experiments separately with, for example, colours, content or the location of ecolabels. There is a lack of studies that simultaneously take into account a combination of the elements mentioned above in their assumptions. There are many studies that analyse premises, trust, or pro-environmental attitudes. However, there is a lack of comprehensive studies that collect the most recent scientific research and provide concrete and solid evidence as to what form and content of ecolabels increase the effectiveness of environmental communication. Therefore, the objective of this thesis is to review the latest research in order to determine the form and content of ecolabels that will increase their effectiveness in environmental communication.

The study poses the research question RQ1: What form and content of ecolabels increase the effectiveness of environmental communication? The article consists of an introduction, literature review, methods, results, discussion, and summary.

2. Literature review

Ecolabelling is designed to generate significant economic incentives in the consumer decision-making process. It allows for more environmentally friendly decisions and creates sensitivity to pro-environmental aspects. An organised labelling system is an important tool in the pursuit of environmental commitments (Wessells et al., 2021). Above all, it communicates value and gives consumers a choice.

Environmental labelling programmes take into account: rules, minimum requirements, criteria, and procedures that must be applied to all interested market players (Guidelines..., 2009). The participation of countries in this process is required and should be implemented. This aspect is particularly important in the context of internationalisation of markets and the need to strengthen labelling systems at the international level (Prakash et al., 2020). The effectiveness of this action requires close dialogue, mutual recognition, and supporting measures within the framework of international cooperation.

However, studies highlight the limited effectiveness of environmental labelling. They point to a lack of sufficient awareness among consumers and little recognition from producers on the market (Prakash et al., 2020). When these results are combined with system barriers such as lack of recognition in public policy and compliance and verification costs, they have resulted in a low level of acceptance of environmental labelling (EU Commission, 2017). An important challenge in increasing the impact of labels on market participants is the creation of a system for their monitoring and evaluation. However, as many researchers point out, creating such a system that would be effective and efficient is no small challenge (Thidell, Leire, Lindhqvist, 2015). Significant difficulties include: lack of access to data on the market share of ecolabelled products, confidentiality of sales data, and the location of these documents in companies' internal resources. Due to these limitations, it is difficult to estimate the actual environmental benefits of this labelling.

Many studies show that ecolabelling has the potential to influence consumer behaviour, but this is conditional on consumers understanding and attaching importance to this information (Taufique et al., 2014; Prieto-Sandoval et al., 2016). For some time now, there have been calls for the standardisation of ecolabels in discussions on the labelling system. Standardizing labelling reduces confusion among buyers and builds trust (Nes, Antonioli, Ciaian, 2023; Policarpo et al., 2023). There could also be benefits for producers. For market participants responsible for product supply, standardizing labels could bring many benefits. Among other things, it would reduce legal requirements if the rules were implemented in all markets and geographical areas (Hay et al., 2024). This could have the additional effect of increasing the market capacity for certified products. If labelling systems are improved in line with consumer requirements and producer demands, future benefits may prove to be significantly higher than the costs incurred.

High-quality ecolabelling opens up access to new, developed markets and potential buyers with high purchasing power. In an era of ever-increasing market competition, the use of a reliable ecolabelling system provides an opportunity to maintain and strengthen market share (UNCTAD, 1994).

Ecolabelling systems provide consumers with important information so that they can make more environmentally friendly purchasing decisions (Potter et al., 2021). However, the state of research on best practices regarding the form and scope of ecolabels is not clear (Hay et al.,

2024). Another problem is determining which ecolabels are most effective and even which of their elements and components determine the best performance of the label (Potter et al., 2021).

For effective communication, environmental labelling should ensure product visibility and distinction. The clarity and accessibility of the information consumers need to make decisions is an essential element of an effective labelling system (Thogersen, Haugaard, Olesen, 2010). Research by Meis-Harris et al. (2021) indicate that more comprehensive and multiinformative environmental labels, despite a certain level of complexity, are also effective and important in consumer decision-making.

Research on the use of colors in presenting the environmental characteristics of a product is also very interesting. Colours enable quick visual communication. Their range of use, for example, the colour palette of traffic lights, can facilitate the interpretation of presented data on the extent of environmental impact (Feucht, Zander, 2018). There is also research that confirms that QR codes on packaging can be easily used by consumers to obtain additional information on the sustainability of a product (Nes, Antonioli, Ciaian, 2023). However, there is still no complete understanding of how effective individual elements of ecolabels are. Some researchers measure effectiveness in terms of consumer recognition. There is also no consistent approach to measuring the effectiveness of information delivery, which confirms that the subject matter is difficult. Despite these uncertainties, the objective of this study is to review the latest research to determine the form and content of ecolabels that will increase their effectiveness.

3. Methods

A qualitative literature review was used to achieve the research objective of this study. It serves as a method to identify, evaluate, and synthesize all studies relevant to a specific research question, topic, or phenomenon (Van Dinter, Tekinerdogan, Catal, 2021). This study adopted a systematic literature review methodology in accordance with the guidelines of Moher et al. (2009). This approach is preferred to classical reviews. The methodology of a systematic literature review, with its specific framework and guidelines, ensures a high level of repeatability, is transparent and well established (Cook et al., 1997). Therefore, it is a very good strategy for identifying studies related to the objective of this work.

The first step of the study focused on identifying manuscripts that addressed the impact of ecolabels and their form and content on their broadly understood effectiveness. The PRISMA procedure was used to select publications, in accordance with the guidelines proposed by Moher et al. (2009).

The search strategy involved using the Scopus database and searching for the term 'ecolabel'. The term was searched for in titles, keywords, and abstracts. The study was conducted in November 2025. To ensure that the review was up to date, publications from 2024 and 2025 were analysed.

The following standards were adopted to ensure transparency:

- inclusion criteria: studies concern ecolabels, the article presents the results of empirical research, the article is available in full text and peer-reviewed,
- Exclusion criteria: ecolabels are not the main subject of the study, studies that are reviews or meta-analyses, non-English language literature, paid content without institutional access.

A total of 61 publications were identified in the first step. After reviewing them, eight unrelated studies were excluded. The abstracts and, where necessary, the full texts were subjected to a detailed evaluation. In the next stage, the following were rejected: publications in languages other than English, reviews, and those that did not focus on the form and content of the ecolabels. Ultimately, 11 studies met all the criteria. The procedure adopted and its individual stages are presented in Figure 1.

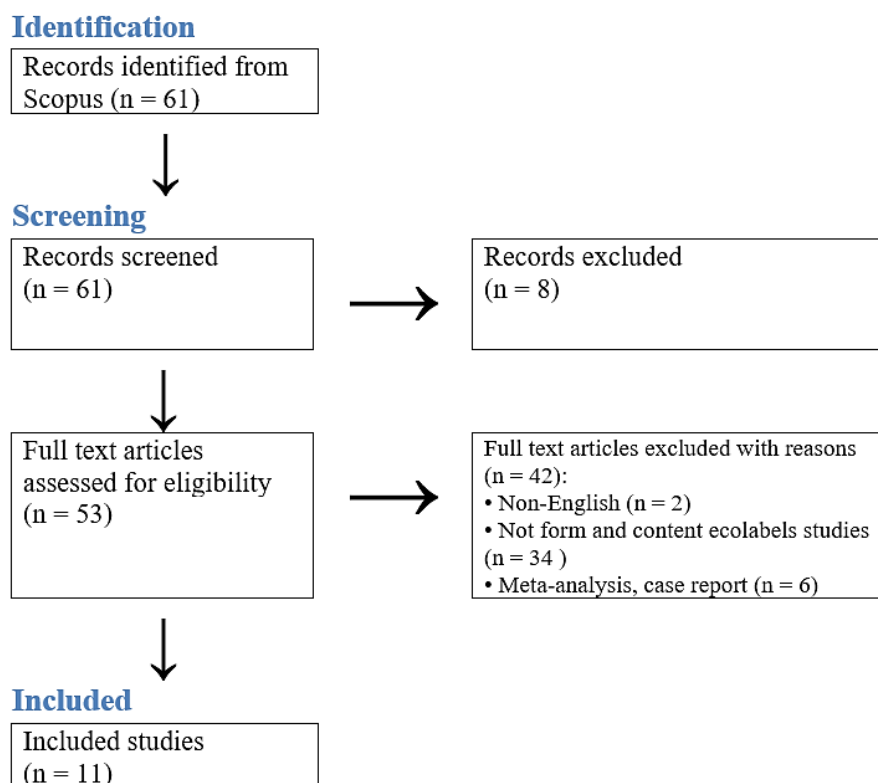


Figure 1. The procedure used to select manuscripts.

Source: own study based on (Moher et al., 2009).

Key empirical conclusions from the studied area were extracted from selected publications according to the adopted procedure. Subsequently, a qualitative content analysis and thematic categorisation were performed (Indulska, Hovorka, Recker, 2012). The results obtained were subjected to open coding, followed by division and grouping. In this way, a systematic review of the latest literature and a qualitative thematic analysis of its results allowed for the collection, identification and presentation of the most current and relevant research on the effectiveness of ecolabels. As a result of the adopted procedure, 11 high-quality manuscripts were selected, which were analyzed in detail, and the most important conclusions were synthesised according to the adopted objective of the study.

4. Results

The qualitative analysis of the research results identified during the literature review process allowed us to focus primarily on the following elements related to the form and content of the ecolabel design. Research findings were grouped into the following categories:

- visual design,
- scope of environmental information,
- accuracy of environmental information,
- adaptation to consumer segments,
- information relevant to the product,
- presentation in online retail.

Research by Hay et al. (2024) showed that the most effective graphic form to distinguish and promote products with a reduced environmental impact is an image of planet Earth. The analyses also took into account label forms such as dashboards, bar graphs, NIPS panels, star ratings, and carbon footprints. However, the scale that illustrates the strength of impact has the greatest effect when represented by colors. Traffic light colours proved to be the best for this purpose (Hay et al., 2024), as they are already sufficiently well coded and embedded in human existence. An example of such a label is shown in Figure 2. Empirical research by Hay et al. (2024) confirmed the high effectiveness of labels with this visual design. This research seems to reveal a very promising direction for future research and improvements in the effectiveness of ecolabels.

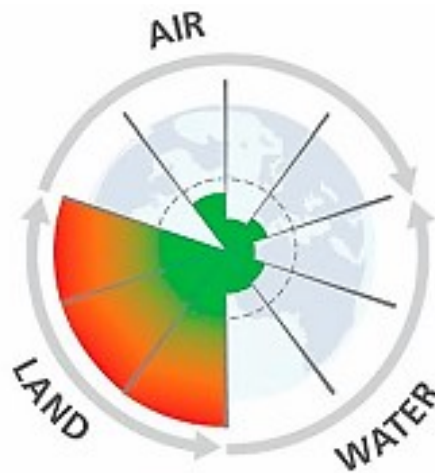


Figure 2. An example of an environmental label in the Earth project.

Source: own study based on (Hay et al., 2024).

The review of the form and content of ecolabels also identified studies on the scope of environmental information presented. It turns out that the effectiveness of ecolabels is also influenced by additional information related to the broadly understood sustainability of the product. The results of the review allowed us to determine that such examples of information include: region of origin and water management certification (Pablo-Cano et al., 2024), products not tested on animals (Völker et al., 2024), and the fishing method used (Fang, Gao, Zhanget, 2024).

Another category of research identified as important in the process of improving the effectiveness of ecolabels is the precision of the environmental information presented. The work of Tanaka, Dente and Hashimoto (2024) shows that the effectiveness of environmental communication can be increased by supplementing the ecolabel graphics with additional information, e.g. the percentage of recycled products. Examples of such labels, which include a planet in the graphics and additional percentage information about recycling, are presented in Figure 3. According to the results of Tanaka, Dente and Hashimoto (2024), this form of ecolabelling promotes eco-friendly purchasing behaviour to the greatest extent and improves the effectiveness of this communication tool.



Figure 3. An ecolabel showcasing the Earth and its share of recycled raw materials.

Source: own study based on (Tanaka, Dente, Hashimoto, 2024).

Another advantage of presenting environmental data in numerical form is the ability to compare the impact of different products. This is another identified benefit of improving the form and content of ecolabels, which increases their effectiveness. Consumers want to be able to refer to and compare specific values for a given environmental characteristic. This allows the presented value to be compared to the average product in the same category or to a set threshold or limit (Meyerding, Schaffmann, Lehberger, 2019). This enables consumers to see and understand the difference between products in terms of their environmental impact (Hay et al., 2024).

The latest literature also devotes considerable attention to the adequacy of the scope of information presented in the context of the effectiveness of the ecolabel. A study by Tanaka, Dente and Hashimoto (2024) suggests that the type of labelling may vary depending on the type and complexity of the product. If products are used for longer periods and have a greater impact on the environment, more information should be provided. In the case of simple and less complex products, such as disposable cups, the scope of information accompanying the ecolabel may be basic (Hay et al., 2024). Aitken et al. (2024) in their research. Comparing the effectiveness of two ecolabels for seafood products (Figure 4), they found that both variants received high ratings from consumers. However, the label without detailed data received slightly higher preference ratings. It should be noted that the average scores for both labels were high and the difference was small (Aitken et al., 2024). This result confirms that the average response to simpler labels was greater but less strongly associated with purchase intentions than the information label (Aitken et al., 2024).



Figure 4. Two variants of the ecolabel have been subjected to detailed consumer research.

Source: own study based on (Aitken et al., 2024).

Another interesting conclusion related to improving the effectiveness of ecolabels is their connection, via a QR code, to more comprehensive data available online (Hay et al. 2024). This proposal stems from the desire to convey as much data as possible while taking into account the physical limitations of ecolabels. According to the proposals of Hay et al. (2024), an environmental label should consist of a basic layer and an in-depth layer in the form of

a reference to online information. The existence of a more detailed database of environmental information on certified products would increase the chances that discerning and interested customers would obtain satisfactory environmental data (Hay et al., 2024).

A very important conclusion from the literature review is the need to tailor the form and content of labels to consumer segments and their diverse needs. The results of many studies confirm that the same format of environmental information will not be equally effective in all cases. Tanaka, Dente and Hashimoto (2024) found that increasing the effectiveness of ecolabelling requires changes in the type of information provided, which should consist of information that supports and stimulates consumer behaviour in favour of sustainable products. Information and the way it is presented can vary depending on consumer characteristics and personality. Characteristics that are relevant to environmental labelling may include sensitivity, awareness, willingness to pay, trust, age, etc. (Völker et al., 2024; Recio-Román, Recio-Menéndez, Román-González, 2024).

In turn, Houf, Szymkowiak and Shepherd (2024) draw attention to the challenges arising from the constantly growing volume of online sales. The increase in trade volume prompts reflection on the conditions and circumstances of presenting environmental information in this channel, which is undoubtedly much more specific than the traditional one. Research shows that the label should be prominently displayed when the product is presented on the store's website. This is an essential element in supporting pro-environmental purchasing behavior in this relatively new and very specific market situation (Houf, Szymkowiak, Shepherd, 2024). Figure 5 shows an example of an effective presentation of ecolabels in online commerce.



Figure 5. An example of the possibility of presenting ecolabels in online stores to improve their efficiency.

Source: own study based on (Houf, Szymkowiak, Shepherd, 2024).

It seems that the direction of research on the presentation of ecolabels in online commerce is very promising and will certainly require further study to develop more precise guidelines and recommendations. Therefore, the undertaking of this research will contribute to increasing the effectiveness of ecolabels.

All identified recommendations on the form and content of the ecolabels are presented in the form of a diagram in Figure 6.

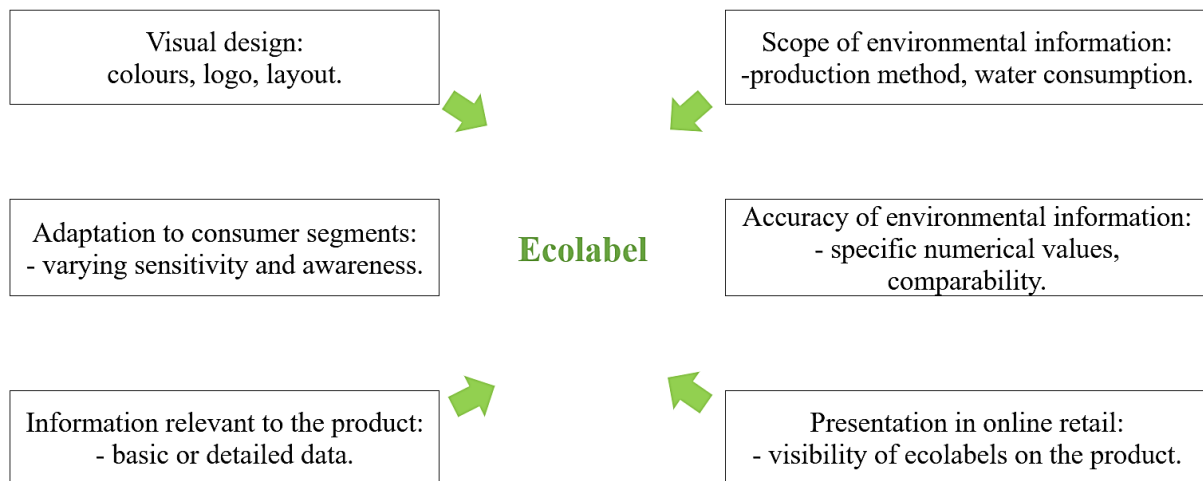


Figure 6. Identified recommendations regarding the form and content of the ecolabel.

Source: own study.

Figure 6 shows six groups of factors that influence the effectiveness of ecolabels. The research found that they contribute to and determine whether an ecolabel is noticeable, understood, and actually influences purchasing decisions.

5. Discussion

The high effectiveness of environmental environmental labeling systems and environmental communication poses a challenge for contemporary societies. Environmental labels are one of the central points of the policy to promote and increase the sales of products with a reduced negative impact on the environment. The study posed the research question RQ1: What form and content of ecolabels increase the effectiveness of environmental communication?

New knowledge in this area is very important. It can be useful for certification bodies, decision-makers, and policymakers. The study has filled a research gap in the highly fragmented and scattered research on ecolabels. In this study, the knowledge and research results of the latest literature have been collected and systematised in one place. The results obtained allowed us to conclude that the effectiveness of the labelling system is greatly influenced by factors grouped into the following analytical categories: visual design, scope of environmental information, accuracy of environmental information, adaptation to consumer segments, information relevant to the product and presentation in online retail.

There are few studies of this kind in the literature on the subject. Recently, reviews of the literature focusing on labels have been conducted by Ceballos-Santos et al. (2025), Rossi et al. (2024), Gonzalez-Torres et al. (2023), Bronnmann et al. (2023) and Garraud et al. (2023). However, the objectives of these publications varied. Ceballos-Santos et al. (2025) focused their research on ecolabels in the seafood sector, demonstrating that communication with consumers

is counterintuitive and that environmental impact assessments are incomplete. The specific issue of maritime sector labels was also the main topic of the work of Bronnmann et al. (2023) and Garraud et al. (2023). In turn, Rossi et al. (2024) focused their review on examining the socio-economic impact of ecolabels on biobased raw material producers. The research by Gonzalez-Torres et al. (2023) focused on energy efficiency. As can be seen, this review perfectly filled the gap by presenting the results of the latest research on ecolabels. This work has contributed to clarifying how the form and content of ecolabels can increase their effectiveness, which helps decision-makers and market participants to optimise the information message. The results presented seem very promising in the context of achieving sustainable development goals in the areas of environmental protection, the economy, and society.

6. Conclusions

A review of the latest research on the form and content of ecolabels, in the context of improving their effectiveness, has made it possible to collect, systematise, and standardise the most important recommendations in this area. The research area related to environmental behaviour is extremely difficult to explore. First and foremost, the main problem is the gap between consumers' intentions and their behaviour (Nguyen, Nguyen, Hoang, 2019).

The identified groups of factors related to the form and content that determine the effectiveness of ecolabels include visual design (graphics and use of colors), the scope of environmental information presented on the label, the accuracy of the environmental information presented, the adequacy of the scope of information to the nature of the product, the matching of labels to consumer segments and their diverse needs, and the specificity of the presentation of online retail labels. These results indicate that designing an effective ecolabelling system requires treating them as part of a more complex communication system. The presented recommendations will significantly facilitate the decoding of environmental messages and influence consumer decision-making processes. The effectiveness of ecolabels depends on many aspects and requires an integrated approach. However, any actions taken to this end are worth the maximum commitment of all parties.

The recommendations and directions for improving the effectiveness of ecolabels identified in this study are sufficiently relevant and effective that their widespread implementation in practice could influence consumer preferences in terms of sustainable behaviour.

It is also worth noting here the other elements of environmental communication strategies, which should include effective education (Iraldo, Barberio, 2017). Pro-environmental purchasing responses from consumers to labelled products can be achieved through information and targeted education of future buyers (Fang, Gao, Zhang, 2024). Kitano, Horie and Yamamoto (2025) focus on administrative bodies and industry entities, which very often

concentrate on supporting the production side through subsidies and financing. On the other hand, few of them focus their activities and provide support on the consumer side.

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THE ROLE OF RESOURCE SHARING IN BUILDING AMBIDEXTROUS SUPPLY CHAINS

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Purpose: This paper explores the relationship between supply chain ambidexterity (SCA) and resource sharing (RS). It also identifies the key enablers and barriers influencing successful resource-sharing practices.

Design/methodology/approach: The analysis was conducted on data from a survey study based on an original questionnaire, carried out among 150 Polish firms. Scale reliability was assessed using Cronbach's Alpha, and hypotheses were tested with Spearman's rank correlation.

Findings: Findings show a low-to-moderate level of RS ($M = 2.11$). Correlation analysis confirmed a strong, positive link between RS and perceived impact on both efficiency and adaptability/innovation. A key paradox emerged: firms' strategic ambidextrous orientation is neutral ($M < 3.0$), yet the perceived impact of sharing on ambidextrous outcomes is positive ($M > 3.1$). Relational factors, notably "Mutual trust" (enabler) and "Lack of trust" (barrier), were found to be paramount.

Research limitations/implications: Limitations include reliance on perceptual data, the low reliability of the "Exploration Level" scale, and a single-country sample, which limits generalizability. Future research should use objective KPIs and a validated exploration scale.

Practical implications: For practitioners, RS is a tool for both efficiency and innovation. Managerial priority should be building relational capital (trust, communication), which are the key enablers and barriers. The low overall RS engagement ($M = 2.11$) suggests a significant untapped opportunity for competitive advantage.

Originality/value: This paper fills a research gap by providing empirical evidence of the link between various RS types and both perceived dimensions of SCA (efficiency and adaptability). It also empirically reinforces the importance of the Relational View in SCM.

Keywords: ambidexterity, ambidextrous supply chain, sharing resources, supply chain ambidexterity, supply chain collaboration.

Category of the paper: Research paper.

1. Introduction

The current market environment is placing increasing demands on enterprises. To achieve a sustainable competitive advantage, organizations must not only ensure superior product and service quality but also significantly reduce order fulfillment times. Consequently, both individual firms and entire supply chains are actively seeking new development opportunities. In an era defined by globalization and dynamic market changes, organizations are increasingly turning to new solutions, such as resource sharing, to enhance their capabilities.

In this unpredictable context, supply chain ambidexterity is emerging as a critical factor for success. Defined as the organizational ability to simultaneously pursue contradictory objectives (Gibson, Birkinshaw, 2004), ambidexterity addresses an essential modern challenge: consumers demand increasing product variety delivered quickly and efficiently, while operational stability seeks to maintain low costs and high quality. Supply chain ambidexterity, therefore, is the capacity to achieve both efficiency (cost minimization and process optimization) and flexibility (rapid response to demand changes and capacity for innovation). In essence, it is the skill of balancing operational stability with innovation, enabling an organization to maintain and develop its current activities while simultaneously creating new solutions for long-term growth (Pelagio Rodriguez, Hechanova, 2014).

One potential strategy for fostering this dual capability is resource sharing, a practice in which physical or immaterial assets are shared among entities within the supply chain (Soosay et al., 2008). This can range from sharing physical infrastructure, such as warehouses or transport, to collaborating on equipment, training services, research and development, or co-developing new products. Such relationships may be established directly between participants or through a third party, such as a logistics service provider (LSP).

A review of the world literature reveals a significant research gap concerning the connection between these two concepts. Although resource sharing is known to offer benefits such as increased efficiency, flexibility, and innovation, it also presents challenges, such as trust, intellectual property protection, and coordination, and its specific impact on ambidexterity is poorly understood. Until now, resource sharing in supply chains and supply chain ambidexterity have been investigated mainly independently.

Therefore, this paper aims to recognize and explore the relationship between supply chain ambidexterity and the strategic implementation of resource sharing. In addition, it seeks to identify and analyze the key factors that decisively influence the success of resource sharing practices within complex supply chain networks. By addressing these objectives, this work provides crucial insight into how collaboration helps supply chains become both efficient and flexible.

To achieve these objectives and address the identified research gap, this study is guided by the following specific research questions:

RQ1: What is the observed relationship between the degree of resource sharing and the level of supply chain ambidexterity?

RQ2: What factors are perceived by supply chain professionals as critical for the successful implementation and operation of resource sharing practices in the supply chain?

RQ3: What are the main barriers that hinder or limit the adoption and development of resource sharing practices in supply chains?

The remainder of this article is structured as follows. Section 2 provides a comprehensive review of the literature, beginning with the initial concepts of organizational ambidexterity (2.1) and its specific application in the ambidextrous supply chain (2.2). This is followed by an analysis of resource sharing practices (2.3). Essentially, subsection 2.4 synthesizes these topics to explore the theoretical links between resource sharing and the ambidextrous supply chain, establishing the foundation for our empirical inquiry. Section 3 details the research methodology used in this study. Section 4 presents the core results of our investigation. These findings are then interpreted and contextualized in Section 5, the Discussion. Finally, Section 6 offers a summary of the entire study, highlighting key conclusions, implications, limitations, and avenues for future research.

2. Literature review

2.1. Ambidexterity

Ambidexterity is a recurring theme in organizational literature (Gibson, Birkinshaw, 2004) and is widely regarded as a necessary condition for sustained success (Kristal et al., 2010; Lin et al., 2013). At its core, ambidexterity refers to the capacity to pursue two seemingly contradictory objectives simultaneously (Chen et al., 2016; Lee, Rha, 2016; Gibson, Birkinshaw, 2004). The primary and most established contrast within this field concerns the challenge of merging exploitation and exploration (Lee, Rha, 2016; Aslam et al., 2020; Shams et al., 2021; Wamba et al., 2020)

Exploitation focuses on the use and refinement of existing resources, knowledge, processes, and competencies (Chen et al., 2016; Im, Rai, 2008; Kristal et al., 2010; Lee, Rha, 2016; Lee et al., 2020a). The objective of exploitation is operational efficiency, cost reduction, selection, and implementation, typically oriented towards ensuring short-term success (Aslam et al., 2020; Gu et al., 2021; Kristal et al., 2010).

In contrast, exploration centres on the search for new opportunities (Lee, Rha, 2016), the development of new competencies (Lee et al., 2020a), and the acquisition of new knowledge (Kristal et al., 2010) through experimentation, risk-taking, and innovation (Lee, Rha, 2016; Lee et al., 2020a; Gu et al., 2021). This aims to build future competitiveness and ensure long-term survival (Aslam et al., 2020; Kristal et al., 2010).

These two strategies essentially compete for limited organizational resources and require different mindsets and organizational procedures (Gu et al., 2021; Gupta et al., 2006; Lin et al., 2013). An exclusive focus on exploitation can lead the organization into a "competence trap," risking obsolescence as the market evolves. Conversely, excessive exploration, without sufficient exploitation to fund it, threatens operational efficiency and risks falling into a "failure trap" through costly, unsuccessful ventures (Kristal et al., 2010; Hadi et al., 2025; Gupta et al., 2006; Shams et al., 2021).

Organizational ambidexterity (OA) refers to a firm's capacity to balance exploitation and exploration throughout the entire business unit (Chen et al., 2016; Lee et al., 2020a). The pursuit of OA is widely considered a requirement for creating more sustainable operations, developing durable practices (Payán-Sánchez et al., 2022), and achieving superior business performance and competitive advantage (Chen et al., 2016; Lin et al., 2013).

In modelling OA, two main approaches dominate the literature: Structural Ambidexterity and Contextual Ambidexterity. Structural Ambidexterity involves creating dual structures or separate organizational units (subsystems). Under this model, each unit specializes in a different activity, one focused on exploitation and the other on exploration. Alternatively, structural ambidexterity can be achieved temporarily by sequentially switching the organization's focus between these activities (Shams et al., 2021; Chen et al., 2016; Gibson, Birkinshaw, 2004; Gupta et al., 2006). Simultaneously, Contextual Ambidexterity is defined as a behavioural capacity to simultaneously demonstrate alignment (exploitation) and adaptability (exploration) within the same business unit (Lee, Rha, 2016; Aslam et al., 2020; Gibson, Birkinshaw, 2004; Im, Rai, 2008). Contextual ambidexterity is achieved not by separating tasks but by building organizational systems and processes that encourage individual employees to make their own decisions about how to allocate their time across conflicting demands (Gibson, Birkinshaw, 2004; Lee et al., 2020b). This capability is shaped by an organizational context built on a combination of stretch, discipline, support, and trust (Lin et al., 2013; Gibson, Birkinshaw, 2004).

2.2. Ambidextrous Supply Chain

The concept of organizational ambidexterity has naturally been extended beyond the boundaries of a single firm to the broader context of the supply chain (SCM) (Aslam et al., 2018; Kristal et al., 2010). An ambidextrous supply chain (SCA) strategy represents a deliberate strategic choice, often by the focal firm, to simultaneously pursue exploitation and exploration practices across its network. This involves balancing SC exploitation (characterized by

efficiency, cost reduction, and reliability) with SC exploration (characterized by flexibility, innovation, and the search for new competencies) (Aslam et al., 2018; Kristal et al., 2010; Lee, Rha, 2016; Wamba et al., 2020).

SCA is increasingly viewed as a critical dynamic capability (Aslam et al., 2020; Lee, Rha, 2016). Firms that successfully implement an SCA strategy tend to perform better. This is attributed to their ability to achieve combinatory competitive capabilities, that is, the capacity to simultaneously reach high levels of quality, delivery speed, flexibility, and low cost, rather than being forced to trade one objective for another (Kristal et al., 2010). Furthermore, SCA is instrumental in building Supply Chain Resilience (SC-Resilience) by enabling the network to more effectively mitigate the negative impacts of disruptions (Aslam et al., 2020; Lee, Rha, 2016; Wamba et al., 2020).

Within the SCA framework, two capabilities are highlighted as particularly crucial: Supply Chain Agility (SC-Agility) and Supply Chain Adaptability (SC-Adaptability). SC-Agility is the ability to respond rapidly to short-term, temporary changes, such as volatile market demand or sudden supply-side disruptions (Aslam et al., 2018; Dubey et al., 2018; Wamba et al., 2020). In contrast, SC-Adaptability refers to the ability to adjust the fundamental design of the supply chain, including its structure and resource base, to meet long-term changes in the market environment (Aslam et al., 2018; Dubey et al., 2018; Wamba et al., 2020).

2.3. Resource Sharing

Resource sharing (RS) stands as a basic mechanism for inter-firm collaboration within the supply chain (Payán-Sánchez et al., 2022; Cao et al., 2010). It is broadly defined as the process of utilizing and jointly investing in capabilities and assets with supply chain partners. Firms engage in the sharing of both tangible (physical) and intangible resources. Physical resources typically include production equipment, facilities, and technology (Cao et al., 2010), while intangible resources encompass valuable assets such as knowledge, know-how, strategic information, and organizational capital (Cao et al., 2010; Payán-Sánchez et al., 2022; Brandon-Jones et al., 2014; Dubey et al., 2018; Klein, Rai, 2009).

Organizations gain competitive advantage not only from their internal assets, but from the synergetic combination of resources, knowledge, and capabilities developed in partnership with other firms (Klein, Rai, 2009; Payán-Sánchez et al., 2022; Cao et al., 2010; Im et al., 2019; Paulraj et al., 2008). Collaboration, therefore, provides access to partners' critical resources that might otherwise be unreachable (Payán-Sánchez et al., 2022; Cao et al., 2010; Klein, Rai, 2009).

Within this collaborative background, information sharing (IS) is a crucial intangible resource that must be timely, accurate, complete, and relevant to be effective (Brandon-Jones et al., 2014). Integration of high-quality information sharing with technological resources, such as IT infrastructure and connectivity, creates the essential capability of Supply Chain Visibility (SCV) (Brandon-Jones et al., 2014; Dubey et al., 2018), which is necessary for effective

coordination, alignment, and risk management across the network (Brandon-Jones et al., 2014; Patnayakuni et al., 2006).

2.4. Resource Sharing and Ambidextrous Supply Chain

Resource sharing (RS) functions as a key enabling mechanism for the ambidextrous supply chain (SCA) by directly addressing the challenge of resource shortage (Gupta et al., 2006). Access to external resources from partners, such as specialized teams, additional production capacity, or unique knowledge, serves to mitigate the internal resource constraints that firms typically face. This functionality is crucial for organizations seeking to pursue exploration and exploitation within their supply chain simultaneously (Gupta et al., 2006; Kristal et al., 2010).

The resources subject to sharing include both intangible and tangible assets. Although intangible assets are critical, the literature equally emphasizes physical assets (Cao et al., 2010). RS definitions explicitly include tangible assets such as manufacturing equipment, facilities, and technology (Cao et al., 2010). Effective collaboration often requires specific investments in complementary assets, creating "relational assets" that partners could not generate independently (Cao et al., 2010; Payán-Sánchez et al., 2022). This integration is also evident in logistics practices (Beske-Janssen et al., 2014), such as Vendor-Managed Inventory (VMI) or co-managed inventory, where the sharing of intangible data is essential for the co-management of tangible physical inventory (Cao et al., 2010).

A specific mechanism of resource sharing in inter-firm relationships is Knowledge-Sharing Ambidexterity (KSA), which involves the simultaneous engagement in both exploitative and exploratory knowledge sharing (Im, Rai, 2008; Im et al., 2019; Lee et al., 2020b). KSA, considered a form of resource-sharing ambidexterity, has been shown to lead to higher relationship benefits (Im et al., 2019). Joint use of both exploitative and exploratory knowledge enables partners to integrate their know-how, skills, and efforts (Im et al., 2019). This, in turn, promotes the development of combinative capabilities (Lee et al., 2020b), supporting both short-term and long-term value creation pursuits (Im et al., 2019).

Information technology (IT) represents another essential resource in this dynamic (Dubey et al., 2018). Ambidextrous use of IT is considered critical for achieving SC resilience (Gu et al., 2021). Exploitative IT use focuses on automation and efficiency within existing processes (Gu et al., 2021), while exploratory IT use facilitates more dynamic information sharing, enabling process reconfiguration and agile responses to disruptions (Gu et al., 2021). The complementary use of both forms supports both standardized, rapid responses (exploitation) and long-term knowledge acquisition (exploration) (Gu et al., 2021).

Furthermore, the link between resource sharing and SCA is strongly manifested through the dynamic capability of Supply Chain Adaptability (Aslam et al., 2020; Wamba et al., 2020). Defined as the ability to reconfigure the structure and resource base of the supply chain to meet long-term market shifts (Aslam et al., 2020; Wamba et al., 2020), adaptability inherently relies on the management of shared physical resources. This capability can be achieved by

reconfiguring assets (Lee, Rha, 2016; Aslam et al., 2018), such as identifying new supply bases (Wamba et al., 2020), or by shifting fixed costs to variable costs through outsourcing to 3PLs (Wamba et al., 2020). Practices such as establishing joint logistics systems or sharing warehouses are specific examples of leveraging RS to improve adaptability (Wamba et al., 2020).

Although the literature suggests strong theoretical links, particularly in the contexts of knowledge and IT, there remains a clear gap in empirically validating the relationship between the overall degree of resource sharing and the achieved level of supply chain ambidexterity. To address this gap, this study will test the following hypotheses:

- H1: A positive relationship exists between the degree of resource sharing in a supply chain and its level of ambidexterity, such that increased sharing leads to growth in both efficiency (exploitation) and flexibility (exploration) of the chain.
- H2: There is a positive relationship between the degree of resource sharing and the perceived impact of that sharing on the adaptability and innovation of the supply chain.

3. Methods

The analysis presented in this paper uses empirical data gathered through a diagnostic survey. The research was conducted between July 2025 and October 2025, employing a dual-mode survey that used both CAWI (Computer-Assisted Web Interview) and CATI (Computer-Assisted Telephone Interview) methods. The final sample comprised 150 respondents from 150 firms. The participating companies were segmented by size: 93 small, 27 medium, and 30 large enterprises.

The survey instrument captured responses using a 5-point Likert scale for each question (Table 1). To facilitate analysis, aggregated variables were constructed to represent the average response for the key aspects under study. A reliability analysis confirmed the internal consistency of these constructs, allowing them to be treated as composite indices (as detailed in Table 2). Thus, the following indices were developed:

Resource Sharing Indices (from Q1):

- Index 1: Physical Resources (Q1.1.1-Q1.1.5).
- Index 2: Human Resources (Q1.2.1-Q1.2.5).
- Index 3: Information Resources (Q1.3.1-Q1.3.5).
- Index 4: Financial Resources (Q1.4.1-Q1.4.5).
- Index 5: Knowledge and Know-how (Q1.5.1-Q1.5.5).

Ambidexterity Orientation Indices (from Q2):

- Index 6: Exploitation Level (Q2.1-Q2.4).
- Index 7: Exploration Level (Q2.5-Q2.8).

Perceived Impact Indices (from Q3 & Q4):

- Index 8: Impact of Sharing on Efficiency (Q3.1-Q3.4).
- Index 9: Impact of Sharing on Adaptability (Q4.1-Q4.4).

Table 1.

Questions from the survey questionnaire on the sharing of resources, ambidexterity orientation indices, and the impact of sharing resources on efficiency and adaptability

No.	Question					
Q1	To what extent does your company engage the following stakeholder groups in different areas of its operations?					
	Resources / Partners	With suppliers	With customers	With logistics providers	With companies within the same capital group	With competitors
	Physical Resources	1.1.1	1.1.2	1.1.3	1.1.4	1.1.5
	Human resources	1.2.1	1.2.2	1.2.3	1.2.4	1.2.5
	Information resources	1.3.1	1.3.2	1.3.3	1.3.4	1.3.5
	Financial resources	1.4.1	1.4.2	1.4.3	1.4.4	1.4.5
	Knowledge and know-how	1.5.1	1.5.2	1.5.3	1.5.4	1.5.5
Q2	To what extent does your company plan to:					
	2.1	implement improvements to current technologies, products, and services				
	2.2	strengthen cooperation with existing partners				
	2.3	focus on reducing operational costs				
	2.4	conduct efficiency analyses				
	2.5	increase the number of alternative suppliers				
	2.6	develop production in new geographical locations				
	2.7	modernize currently used technologies				
Q3	accept orders for products and services that go beyond the current offer					
	How resource sharing has affected current efficiency and operational optimization in the supply chain					
	3.1	Reduction of operational costs				
	3.2	Shortening of the total order fulfillment time				
	3.3	Reduction of inventory levels throughout the supply chain				
Q4	3.4	Better utilization of existing resources				
	How resource sharing has affected adaptability and innovation in the supply chain					
	4.1	Speed of response to market changes and demand fluctuations				
	4.2	Ability to cope with unexpected disruptions				
	4.3	Effectiveness and frequency of introduction of new solutions and innovations				
	4.4	Possibility of entering new markets or implementing new technologies				

Source: own calculations based on Author's research.

The analytical approach involved several statistical methods. Descriptive statistics, mainly mean and standard deviation, were calculated to determine the central tendency and the distribution of responses for key research indices. This descriptive approach, supplemented by frequency distribution analysis, was also used to identify critical success factors and barriers related to resource sharing, thus addressing RQ2 and RQ3. As detailed in Table 2, the reliability of these indices was assessed using Cronbach's Alpha prior to the main analysis.

Finally, to test the research hypotheses, a non-parametric correlation analysis was conducted, as detailed below. Given the ordinal nature of the data gained from these scales, Spearman's rank correlation coefficient (Spearman, 1904) was selected as the primary statistical method. This non-parametric approach was considered appropriate as it allows not only the identification of a statistically significant relationship but also the determination of its strength and direction.

Table 2.

Results of reliability analysis

Index	Combined questions	Cronbach's Alpha Value
Index 1	Q1.1.1, Q1.1.2, Q1.1.3, Q1.1.4, Q1.1.5	0.878
Index 2	Q1.2.1, Q1.2.2, Q1.2.3, Q1.2.4, Q1.2.5	0.856
Index 3	Q1.3.1, Q1.3.2, Q1.3.3, Q1.3.4, Q1.3.5	0.701
Index 4	Q1.4.1, Q1.4.2, Q1.4.3, Q1.4.4, Q1.4.5	0.763
Index 5	Q1.5.1, Q1.5.2, Q1.5.3, Q1.5.4, Q1.5.5	0.843
Index 6	Q2.1, Q2.2, Q2.3, Q2.4	0.742
Index 7	Q2.5, Q2.6, Q2.7, Q2.8	0.410
Index 8	Q3.1, Q3.2, Q3.3, Q3.4	0.784
Index 9	Q4.1, Q4.2, Q4.3, Q4.4	0.670

Source: own calculations based on Author's research.

4. Results

The analysis begins with a descriptive overview of the resource-sharing practices between the surveyed firms (Table 3). The overall mean across all resource-sharing activities is 2.11, indicating a generally low-to-moderate level of participation in the sample's sharing practices (on a 5-point scale). When analysed by resource type, Knowledge and know-how are the most commonly shared assets, with the highest total mean score (2.47). This is followed by Physical Resources (2.11). From the perspective of collaborative partners, companies share more strongly with their suppliers (2.36) and logistics providers (2.34). The highest-rated activity was sharing knowledge and know-how with suppliers (2.81).

Table 3.*Mean scores for the extent of resource sharing, by resource type and partner*

Resources / Partners	With suppliers	With customers	With logistics providers	With companies within the same capital group	With competitors	Total mean
Physical Resources	2.50	1.99	2.39	2.05	1.61	2.11
Human resources	2.36	1.91	2.39	1.82	1.65	2.03
Information resources	1.98	1.81	2.17	2.16	1.68	1.96
Financial resources	2.15	1.91	2.03	2.19	1.55	1.96
Knowledge and know-how	2.81	2.65	2.70	2.30	1.88	2.47
Total mean	2.36	2.06	2.34	2.10	1.67	2.11

Source: own calculations based on Author's research.

The mean scores (Table 4) for both the Exploitation Level (2.99) and the Exploration Level (2.87) are moderate. This indicates a slight lack of a strong, proactive orientation towards either ambidextrous dimension within the sampled firms.

Table 4.*Mean scores for ambidexterity orientation and perceived impact indices*

Index	Index 6: Exploitation Level	Index 7: Exploration Level
Mean	2.99	2.87

Source: own calculations based on Author's research.

In contrast, the perceived impact of resource sharing was rated more positively (Table 5). The Impact of Sharing on Efficiency achieved the highest mean score among these constructs (3.30). Similarly, the Impact of Sharing on Adaptability also scored highly (3.17). This suggests that while firms may be moderate in their ambidextrous orientation, they perceive a distinct positive contribution of resource sharing to both efficiency (exploitation) and adaptability (exploration).

Table 5.*Mean scores for ambidexterity orientation and perceived impact indices*

Index	Index 8: Impact of Sharing on Efficiency	Index 9: Impact of Sharing on Adaptability
Mean	3.30	3.17

Source: own calculations based on Author's research

To test the research hypotheses, a Spearman's rank correlation was performed. A strong, positive, and highly significant correlation was found between all five types of shared resources and the Exploitation Level (Table 6). The strongest relationships were observed for Financial Resources (0.571) and Knowledge and know-how (0.545).

In contrast, the relationship with the Exploration Level was notably weaker and less consistent, with only Financial Resources (0.367) and Knowledge and Know-how (0.376) showing a significant positive correlation. These mixed results, combined with the low reliability of the Exploration Level index (as shown in Table 2), led the analysis to focus on the perceived impact of sharing rather than on orientation.

Table 6.*Spearman's correlation coefficients showing the relationship between the exploitation level (Index 6), the exploration level (Index 7), and the type of shared resources (Index 1-5)*

	Index 6: Exploitation Level	Index 7: Exploration Level
Index 1: Physical Resources	0.468***	0.081
Index 2: Human resources	0.493***	0.059
Index 3: Information resources	0.477***	0.193*
Index 4: Financial resources	0.571***	0.367***
Index 5: Knowledge and know-how	0.545***	0.376***

p-value: $p < 0.001$, then ***; $0.001 \leq p < 0.01$, then **; $0.01 \leq p < 0.05$, then *.

Source: own calculations based on Author's research.

The results of correlating resource sharing with its perceived impacts (Table 7) show strong support for the research hypotheses. The efficiency (exploitation) component of Hypothesis 1 is strongly supported: all five resource-sharing indices are positively and highly significantly correlated with Impact on Efficiency. Knowledge and know-how (0.562) and Financial Resources (0.527) demonstrated the strongest links. Clear support was also found for

Hypothesis 2, which predicted a positive link between sharing and perceived impact on adaptability and innovation. All five types of resource-sharing are positively and significantly correlated with Impact on Adaptability. Again, Knowledge and know-how (0.502) and Financial Resources (0.404) achieved the highest correlation coefficients. In summary, the correlation analysis confirms that while the orientation towards exploration is weakly related to sharing, the perceived impact of sharing on both efficiency (H1) and adaptability/innovation (H2) is strong, positive, and statistically significant across all types of shared resources.

Table 7.

Spearman's correlation coefficients showing the relationship between the impact of sharing on efficiency (Index 8), the impact of sharing on adaptability (Index 9), and the type of shared resources (Index 1-5)

	Index 8: Impact of Sharing on Efficiency	Index 9: Impact of Sharing on Adaptability
Index 1: Physical Resources	0.441***	0.348***
Index 2: Human resources	0.472***	0.372***
Index 3: Information resources	0.408***	0.298***
Index 4: Financial resources	0.527***	0.404***
Index 5: Knowledge and know-how	0.562***	0.502***

p-value: $p < 0.001$, then ***; $0.001 \leq p < 0.01$, then **; $0.01 \leq p < 0.05$, then *.

Source: own calculations based on Author's research.

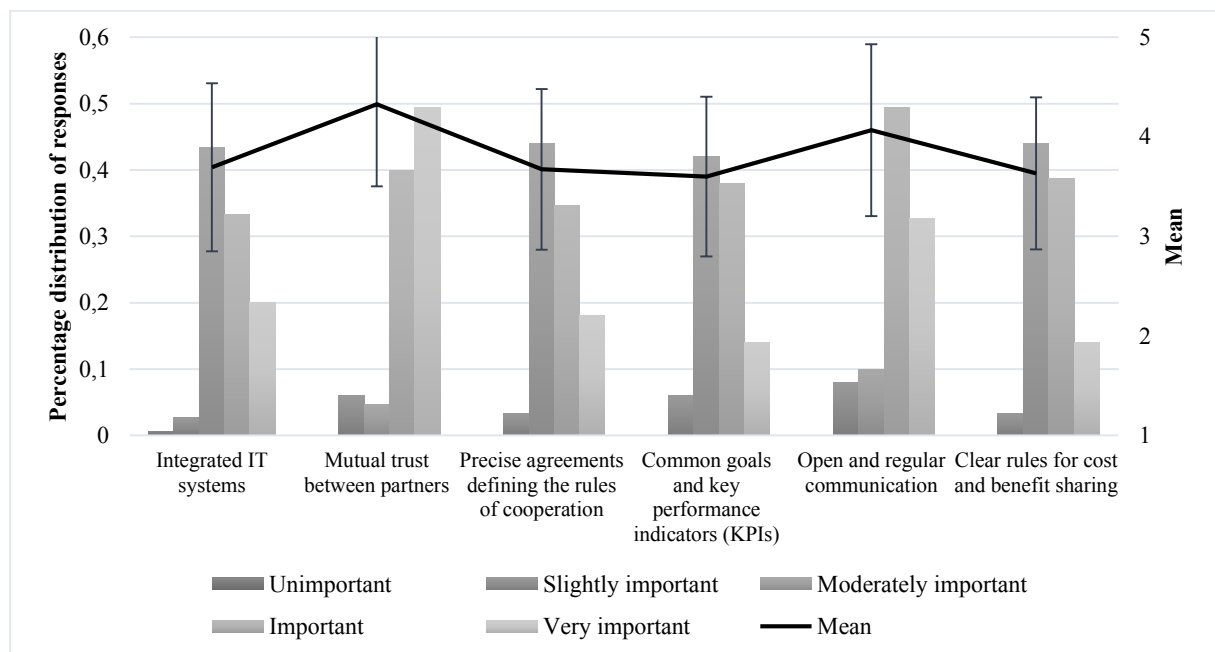


Figure 1. Percentage distribution of responses, mean, and standard deviation: Factors enabling effective resource sharing.

Source: own preparation based on Author's research.

The analysis of enabling factors (Figure 1) that address RQ2 reveals that relational factors are paramount. "Mutual trust between partners" was identified as the most critical enabler, achieving the highest mean score (4.33). The response distribution confirms this, with the vast

majority rating it as "Very important" or "Important". This is followed by "Open and regular communication" (4.07). However, the standard deviation bars for these relational factors are notably wide, indicating a diversity of opinion on their importance, despite the high mean.

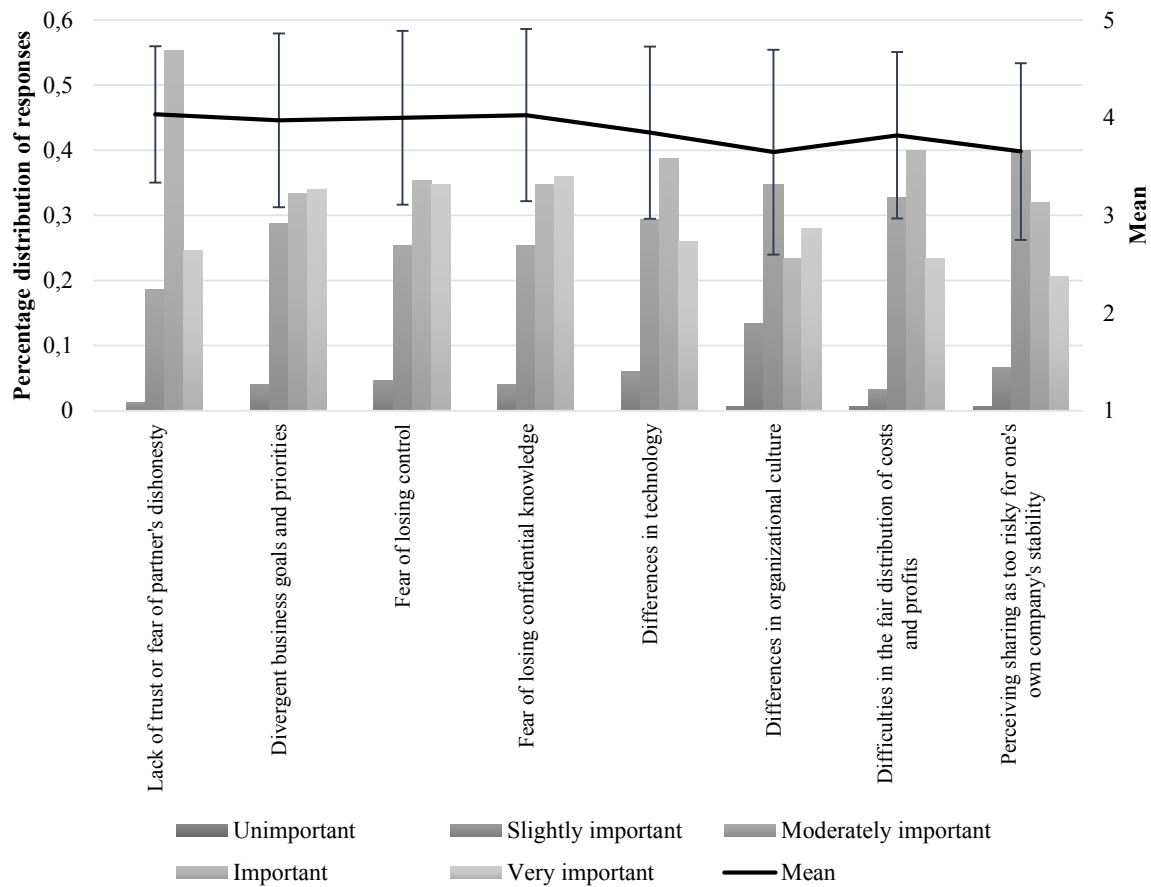


Figure 2. Percentage distribution of responses, mean, and standard deviation: Barriers to resource sharing.

Source: own preparation based on Author's research.

The barrier analysis (Figure 2) addressing RQ3 indicates that relational and knowledge-protection fears are the most significant obstacles. The most critical barriers identified by the respondents were "Lack of trust or fear of partner's dishonesty" (4.03), "Fear of losing confidential knowledge" (4.03), and "Fear of losing control" (4.00). Furthermore, the standard deviation data reveal a strong consensus (0.70) among respondents on the high importance of "Lack of trust".

5. Discussion

The primary objective of this study was to recognize the relationship between resource sharing (RS) and supply chain ambidexterity (SCA). The results provide strong empirical support for this connection.

The findings do not provide a basis for rejecting Hypothesis 1. A statistically significant, positive correlation was found between all five types of resource sharing and the Impact on Efficiency. This addresses the "exploitation" dimension of ambidexterity. The strongest links were observed with "Knowledge and know-how" and "Financial Resources". This aligns with traditional supply chain literature, where collaboration is primarily viewed as a mechanism for process optimization (Im, Rai, 2008; Im et al., 2019), cost reduction (Wamba et al., 2020; Im et al., 2019; Kristal et al., 2010; Aslam et al., 2020), and the use of partner assets to improve existing operations (Lee, Rha, 2016; Cao et al., 2010).

Similarly, no basis was found for rejecting Hypothesis 2. A positive and significant relationship was confirmed between all types of RS and the Impact on Adaptability, which directly measures perceived outcomes of flexibility and innovation. This finding addresses the exploration dimension and helps fill the identified research gap, providing empirical evidence that RS is not only an efficiency tool but also a critical mechanism for improving the supply chain's ability to adapt, innovate, and respond to market changes (Im et al., 2019). This supports the theoretical arguments that RS facilitates access to diverse knowledge and capabilities, thus fostering the dynamic capability of adaptability (Im et al., 2019; Wamba et al., 2020; Aslam et al., 2020; Lee, Rha, 2016).

Collectively, the inability to reject both H1 and H2 suggests that resource sharing serves as a key mechanism for supply chain ambidexterity, enabling firms to simultaneously pursue contradictory goals of exploitation (efficiency) and exploration (adaptability).

A particularly insightful finding appears from comparing the descriptive results for ambidextrous orientation (Table 4) and perceived impact (Table 5). The mean scores for the firms' strategic orientations towards Exploitation (2.99) and Exploration (2.87) were neutral. This suggests that ambidexterity may not be a conscious, formalized strategy for many of the sampled firms.

However, these same firms reported a clearly positive perceived impact of resource sharing on both Efficiency (3.30) and Adaptability (3.17). This paradox suggests that while managers may not be actively formulating a dual ambidextrous strategy, they are experiencing the dual benefits of ambidexterity (both efficiency and flexibility) as a positive outcome of collaborative resource sharing (Aslam et al., 2020; Gibson, Birkinshaw, 2004).

The analyses of enablers (Figure 1) and barriers (Figure 2) provide clear answers to RQ2 and RQ3, strongly validating the Relational View (Payán-Sánchez et al., 2022; Patnayakuni et al., 2006; Paulraj et al., 2008; Klein, Rai, 2009). The findings demonstrate that relational

factors are paramount, outweighing formal or technical ones. The most critical enabler identified by respondents was "Mutual trust between partners" (Klein, Rai, 2009; Patnayakuni et al., 2006; Beske-Janssen et al., 2014). Concurrently, the most significant barrier was "Lack of trust or fear of partner's dishonesty" (Payán-Sánchez et al., 2022; Patnayakuni et al., 2006; Klein, Rai, 2009). This dual finding places trust as a priority upon which the success or failure of resource-sharing centres depends. Although technical factors such as "Integrated IT systems" were believed to be important, they are secondary to the establishment of relational capital (Klein, Rai, 2009; Patnayakuni et al., 2006; Brandon-Jones et al., 2014; Paulraj et al., 2008; Gu et al., 2021). This explains the low overall level of resource sharing (Total mean 2.11) observed in Table 3, although the benefits are perceived as positive (Table 5). The difficulty in building the necessary trust (Figure 2) acts as a significant bottleneck, preventing firms from realizing this potential (Paulraj et al., 2008; Patnayakuni et al., 2006; Klein, Rai, 2009).

The interpretation of the strength of the correlation coefficients provides critical guidance for managerial resource allocation. While all forms of sharing are beneficial, the "Knowledge and know-how" category demonstrated the strongest link to both efficiency (0.562) and adaptability (0.502). From a decision-making perspective, this suggests that investments in intangible assets, such as inter-organizational training, joint R&D, and shared knowledge platforms, offer a higher "return" on ambidexterity than sharing physical infrastructure, which showed comparatively lower correlation values (e.g., 0.348 for adaptability). Consequently, managers facing budget constraints should prioritize the development of "relational capital" and IT systems that facilitate the flow of know-how. Furthermore, the high correlation between financial resource sharing and efficiency (0.527) indicates that joint investment mechanisms are key secondary priorities.

6. Summary

This study was motivated by the increasing demands of the modern market, which forces supply chains to seek new solutions, such as resource sharing (RS), to achieve a competitive advantage. While the literature has established supply chain ambidexterity (SCA), the ability to be simultaneously efficient (exploitative) and flexible (explorative), as a critical success factor, the empirical link between RS and SCA remains poorly understood. This paper aimed to address this gap by investigating the relationship between the degree of resource sharing and ambidextrous outcomes, and by identifying the key factors that enable and hinder such collaboration.

Based on a dual-mode survey of 150 supply chain professionals, the study employed descriptive statistics and Spearman's rank correlation to test the research hypotheses. The findings revealed that the overall level of resource sharing among firms is relatively low

($M = 2.11$), with "Knowledge and know-how" being the most shared asset and "Suppliers" the most common partners.

The correlation analysis provided no basis to reject the research hypotheses. A strong, positive relationship was confirmed between all types of resource sharing and the perceived impact on both Efficiency (H1) and Adaptability/Innovation (H2). This empirically confirms that resource sharing is a key function of ambidexterity, supporting both exploitation and exploration. Furthermore, the analysis of enablers and barriers (RQ2 and RQ3) confirmed the Relational View's priority. "Mutual trust" was identified as the most critical enabler. In contrast "Lack of trust" and "Fear of losing confidential knowledge" were the most significant barriers, suggesting that relational capital is the core for successful collaboration.

For supply chain professionals, this study provides key takeaways. Resource sharing should not be viewed only as a cost-saving tactic (exploitation). The data clearly show that it is an equally powerful tool for driving innovation and adaptability (exploration). Managers who collaborate build more flexible and innovative supply chains. Managerial efforts and investments should be prioritized. Although IT integration and contracts are necessary, the data suggest that resources are best spent on activities that build mutual trust and open communication, as these are the true enablers and most significant barriers to successful collaboration.

This research reveals a significant strategic paradox: firms report a clearly positive impact of resource sharing on ambidextrous outcomes ($M > 3.1$), but lack a conscious, formalized strategic orientation towards either exploitation or exploration ($M < 3.0$). This suggests that for many Polish firms, supply chain ambidexterity is currently an emerging or reactive property rather than a deliberate strategic choice. To move beyond accidental benefits, practitioners must transition to a proactive, ambidextrous strategy where resource sharing is treated as a core competency for long-term resilience.

Furthermore, the findings highlight a significant relational barrier that explains the relatively low overall engagement in resource sharing ($M = 2.11$). Although sharing knowledge and know-how is confirmed as the most effective driver of both efficiency and adaptability, it is also the domain where concerns regarding lack of trust and fear of losing control are most critical. This situation creates a collaborative dilemma, in which firms demonstrate the hesitation to engage in the very practices that offer the highest potential for competitive advantage. Therefore, the most critical managerial implication of this study is that the success of an ambidextrous supply chain depends less on technical or financial alignment and more on psychological and cultural capacity to establish mutual trust.

This study is subject to several limitations that offer opportunities for future research. First, the research is based on perceptual data from a single respondent per firm. Although this provides valuable managerial insight, it does not capture objective performance metrics. Future research should aim to correlate resource sharing with objective, financial, or operational KPIs. Second, a significant limitation was the low reliability of the Exploration Level scale

(Cronbach's Alpha = 0.410). This methodological issue prevented a reliable analysis of the orientation of exploration and required a turn to the H2 testing using the perceived impact scale. Future studies should focus on developing and validating a reliable scale for ambidextrous orientation specific to the SCM context. Finally, the sample of 150 firms from a single national context limits the generalizability of the findings. Future research could replicate this study in different countries or in specific industries.

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KNOWLEDGE MANAGEMENT PROCESS: A CONCEPTUAL REVIEW AND UNIFIED FRAMEWORK

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Purpose: This article critically examines and synthesizes the development of the knowledge management (KM) process over the past quarter-century, tracing its conceptual roots from Peter Drucker's foundational ideas to contemporary academic discourse. By mapping the evolution and highlighting the conceptual ambiguities surrounding the definition of KM, this article aims to provide conceptual clarity and a unified framework.

Design/methodology/approach: The purpose of this study is achieved through a comprehensive literature review, which serves as the primary research method. This approach enables a structured and in-depth examination of academic publications from the past 25 years related to knowledge management (KM) processes. This study conducts a comparative analysis of existing definitions, conceptual frameworks, and current discourse on KM. The paper adopts a conceptual and analytical approach, focusing on the theoretical foundations and evolution of KM.

Findings: Through a comprehensive review of scholarly literature, it identifies the fragmentation in KM interpretations and responds to this challenge by proposing a refined, four-part classification: knowledge creation, storage, sharing, and usage. This framework is intended to structure the complex dynamics of KM more coherently and to support researchers and practitioners in understanding how knowledge effectively circulates, evolves, and contributes to organizational value creation in a cyclical and integrated manner.

Research limitations/implications: The findings of this study are based on a narrative literature review and conceptual synthesis, which may not encompass all relevant sources and involve subjective judgment in process categorization. Additionally, the proposed framework has not yet been empirically tested.

Originality/value: Through a comprehensive review of scholarly literature, this paper identifies the fragmentation in KM interpretations and responds to this challenge by proposing a refined, four-part classification: knowledge creation, storage, sharing, and usage.

Keywords: knowledge management, knowledge management processes, knowledge creation, knowledge storage, knowledge sharing, knowledge usage.

Category of the paper: viewpoint.

1. Introduction

The history of knowledge management (KM) began in the 1970s with the work of Peter Drucker and others who recognized knowledge as a valuable organizational asset. In the 1980s, Peter Drucker introduced the term “knowledge worker” which after was used to create a term KM (Turriago-Hoyos et al., 2017). From the last two decades, knowledge has become one of the most important and valuable assets of organizations (Mohajan, 2017). In recent years KM has become an important success factor for enterprises (Staab, et. all. 2001). The formal concept of KM emerged in the early 1990s, as organizations began recognizing the value of knowledge as a strategic asset (Bennet and Bennet 2008). KM is integrating cognitive sciences, philosophy, sociology, psychology, information science, communication, document management, information management, information and communication technologies, management and economic theories, strategic management, change management, human resource management, organization learning, knowledge engineering, artificial intelligence and more (Raudeliūnienė, Davidavičienė, Jakubavičius, 2018). While the historical perspective provides a solid foundation for understanding the value of knowledge as an organizational asset, many studies lack an in-depth analysis of the processes that, in practice, constitute KM. Over the years, numerous scholars have proposed diverse frameworks and classifications of KM processes. Probst, Raub, and Romhardt (2000) identified seven interrelated KM processes, developing a model aimed at capturing the cyclical nature of knowledge management within organizations. In contrast, Davenport and Prusak (1998) focused on the practical dimension of knowledge flows, proposing a managerial and operational approach that considered organizational and technological challenges. Nonaka and Takeuchi (1995), within the concept of the knowledge spiral, proposed a dynamic model of knowledge creation consisting of four processes: socialization, externalization, internalization, and combination. Their approach was the first to clearly emphasize the interaction between tacit and explicit knowledge, while also highlighting the importance of organizational context. Alavi and Leidner (2001) identified four key processes supported by information technologies: knowledge creation, storage/organization, transfer, and application. In many key publications, scholars highlight the diversity and lack of consensus in defining and classifying KM processes. Heisig’s (2009) comparative analysis of 160 KM models from around the world reveals significant terminological and structural variation in the field. His research underscores the need for integrated conceptual frameworks that reconcile divergent approaches and standardize KM process definitions. More recent studies also confirm the absence of consensus regarding the definitions and classifications of KM processes. Serenko and Dumay (2015) point to terminological ambiguities and challenges in comparing KM research findings. Similarly, Massingham (2018) and Durst and Zieba (2018) emphasize the diversity of approaches and the

need to develop more flexible and universal conceptual frameworks. Despite the richness of models and approaches, the literature still lacks an in-depth discussion on the classification and typology of KM processes that have evolved over time. This gap forms the basis of the research problem addressed in this paper: despite the growing recognition of KM's strategic importance, there is still no consensus on how its processes should be defined, categorized, and applied across various organizational contexts. To date, numerous KM process frameworks and classifications have been proposed, typically including activities such as knowledge creation, storage, sharing, and utilization. However, these models often differ significantly in scope and terminology, leading to conceptual fragmentation and practical implementation challenges. Furthermore, many of these frameworks fail to reflect the dynamic and interdisciplinary nature of KM, as well as the evolving technological and organizational realities. The aim of this analysis is to critically evaluate existing KM process classifications, identify their limitations, and propose a more integrated and flexible framework that better serves both academic inquiry and the practical application of KM in contemporary organizations.

2. Methodology

The aim of this study is to critically examine the diversity of definitions and classifications of KM processes presented in academic literature over the past 25 years and to propose a more coherent and adaptable conceptual framework. The research addresses the following main research question: what similarities, differences, and inconsistencies exist in the definitions and classifications of KM processes in academic literature, and how can these be integrated into a unified conceptual framework?

To achieve this aim, a narrative literature review was conducted. This method was chosen because it enables a flexible, qualitative, and in-depth synthesis of knowledge in conceptually fragmented fields such as KM, where the rigid inclusion criteria of systematic reviews may limit the ability to capture the complexity and evolution of the discourse. A narrative approach allows for the incorporation of both theoretical and empirical perspectives across diverse academic traditions and organizational contexts. The selection of sources was based on their conceptual or empirical relevance to KM processes. Particular attention was given to works that presented definitions, typologies, or frameworks of KM processes from both theoretical and practical viewpoints. Publications were identified through purposive sampling to ensure a broad representation of perspectives, covering the development of KM thinking from the 1990s to 2025. The review process involved the extraction and analysis of definitions and classifications of KM processes according to three analytical dimensions: the terminology used to describe KM processes, the functional roles of the processes within organizational settings,

and the frequency and recurrence of specific processes across different models. A comparative analysis was then conducted to identify the most frequently cited and functionally significant KM processes. These processes were subsequently organized into four overarching and interrelated categories: knowledge creation, knowledge storage, knowledge sharing, and knowledge usage. The grouping was informed by the functional purpose of each process within the KM cycle, as well as by observable overlaps, dependencies, and feedback loops between them. This structure reflects the dynamic and cyclical nature of knowledge management, offering a more integrated understanding of how knowledge flows, evolves, and creates value within organizations.

This methodological approach not only enables the synthesis of a dispersed body of literature but also facilitates the identification of conceptual fragmentation, inconsistencies, and gaps in the field. The resulting framework lays the foundation for a more unified and operationally relevant conceptual model that can support both academic inquiry and practical applications of KM in contemporary organizations.

3. Results

KM processes refer to activities related to the systematic management of organizational knowledge in order to support the achievement of organizational objectives. A review of the literature indicates that these processes are conceptualized from multiple perspectives, including functional, technological, strategic, and social, reflecting the broad scope and interdisciplinary nature of KM research. From a functional and process-oriented perspective, authors such as Armistead (1999), Probst et al. (2000), and Staab et al. (2001) describe knowledge management as a set of structured activities, primarily encompassing knowledge acquisition, storage, sharing, and utilization. A similar approach is presented by Lytres et al. (2002) and Rollet (2003), who also conceptualize KM as a sequence of interrelated stages forming the organizational knowledge life cycle. Other authors, including Lin and Lee (2005), Nielsen (2006), and Franco and Mariano (2007), extend this scope by identifying additional processes such as knowledge transfer, capture, and application, leading to greater diversity in the classification of KM processes. A technological and system-based perspective is particularly evident in the studies by Lin and Lee (2005), Sun (2010), and Bigliardi et al. (2014), which focus on processes related to knowledge capture, storage, and retrieval supported by information systems and technological infrastructure. In contrast, a strategic perspective is reflected in the work of Nielsen (2006), Franco and Mariano (2007), and Kulkar et al. (2009), where processes such as knowledge acquisition, transfer, and application are analyzed in relation to strategy implementation and organizational performance. The social and behavioral

dimension of KM is emphasized by Becerra-Fernandez et al. (2004), Wee and Chua (2013), Kianto et al. (2016), Yusr et al. (2017), and Abualoush et al. (2018), who identify knowledge sharing, collaboration, and interaction as key mechanisms of knowledge flow and internalization within organizations. More recent studies, represented by Iqbal et al. (2019), Shahzad et al. (2021), Panahi et al. (2021), Yu et al. (2022), Bocoya-Maline et al. (2023), and Miraj et al. (2024), describe KM processes using integrative approaches that combine technological activities with human and relational factors. These authors frequently identify processes such as knowledge integration, reuse, and co-creation, highlighting the dynamic nature of knowledge in digital and networked environments. Despite the increasing complexity of the proposed models, the literature reveals clear differences in terminology, the number of identified processes, and the structure of the proposed conceptual frameworks. Table 1 summarizes how various authors define and apply KM processes over the last 25 years.

Table 1.

Analyzed KM processes in the last 25 years

Author, Year	Process	Acquisition	Creation	Share	Transfer	Embedding	Goals	Identification	Development	Distribution	Preservation	Measurement	Import	Capture	Retrival	Access	Use	Value	Organization	Reuse	Planning	Integration	Maintenance	Assessment	Discovery	Application	Storage	Customer oriented	Dissemination	Transmission	(Re)combination	Assembly	Generation	Retention	Utilization	Coding	Search		
Armistead, 1999		*		*	*			*	*	*	*	*																											
Probst, et al.,2000		*					*	*	*	*	*	*																											
Staab, et al.,2001		*											*	*	*	*	*																						
Lytres et al., 2002		*			*												*	*	*	*																			
Rollet, 2003		*		*															*		*	*	*	*															
Becerra-Fernandez et al.,2004				*										*											*	*													
Lin and Lee, 2005		*												*			*									*	*	*	*	*	*								
Nielsen, 2006		*		*					*					*			*					*										*	*						
Franco and Mariano, 2007															*												*												
Matula and Mooko, 2008		*												*					*							*	*							*					
Kulkar et al., 2009		*	*																*										*						*				
Sun, 2010		*	*	*																															*				
Dalkir, 2011		*		*										*												*			*								*		
Pinho et al., 2011		*	*	*	*																																		
Wee and Chua, 2013			*	*																*																			
Bigliardi et al., 2014			*	*	*					*	*			*					*								*											*	
Garcia-Fernandez, 2015			*		*																																		
Kianto et al., 2016		*	*	*													*									*	*							*		*			
Yusr et al., 2017		*																								*			*										
Abualoush et al., 2018				*																						*	*						*						
Iqbal et al., 2019		*		*																															*				
Shahzad et al., 2021		*																								*		*											
Panahi et al., 2021		*		*															*							*													
Yu et al., 2022		*		*																						*									*				
Bocoya-Maline et al., 2023			*		*												*										*												
Miraj et al., 2024			*		*																					*	*												

Source: authors' own elaboration based on literature review.

The conducted analysis indicates that nearly all authors consider processes related to knowledge creation or acquisition, although they employ different terms and semantic scopes. Becerra-Fernandez et al. (2004) and Lin and Lee (2005) emphasize knowledge capture and acquisition as the foundation for subsequent activities, whereas Nielsen (2006) and Franco and Mariano (2007) directly link knowledge acquisition to the achievement of organizational strategic objectives. Kulkar et al. (2009) extend this perspective by highlighting the role of knowledge integration in building organizational capabilities. In more recent studies, such as Iqbal et al. (2019), Panahi et al. (2021), and Yu et al. (2022), knowledge creation is conceptualized in a more dynamic manner and includes co-creation, recombination, and the regeneration of knowledge in digital environments. Another area consistently present in the analyzed models comprises processes related to knowledge storage. Probst et al. (2000) point to the importance of knowledge storage and protection as elements of organizational memory, while Staab et al. (2001) and Rollet (2003) emphasize the role of structuring and formalizing knowledge resources. Garcia-Fernandez (2015) additionally incorporates planning and evaluation aspects of knowledge resources, indicating the need for systematic management of their quality and accessibility. Despite terminological differences, all these approaches functionally address ensuring the durability, availability, and usability of knowledge over time. Processes related to the flow of knowledge among individuals and organizational structures constitute another common element of the analyzed concepts. Dalkir (2011), Pinho et al. (2011), and Wee and Chua (2013) emphasize the importance of knowledge sharing and collaboration as mechanisms enabling its dissemination and internalization. Bigliardi et al. (2014) and Kianto et al. (2016) draw attention to the role of knowledge integration among different organizational units and stakeholders. Yusr et al. (2017) and Abualoush et al. (2018) indicate that effective knowledge transfer is strongly conditioned by organizational and cultural factors. Shahzad et al. (2021) and Bocoya-Maline et al. (2023) further develop this perspective by analyzing knowledge flows in the context of digitalization and networked collaboration. The final, yet equally important, area concerns the use of knowledge in organizational practice. Franco and Mariano (2007) and Kulkar et al. (2009) emphasize the relationship between knowledge application and organizational performance and innovation. Iqbal et al. (2019) and Yu et al. (2022) extend this perspective by incorporating knowledge reuse, maintenance, and updating in dynamic business environments. Miraj et al. (2024), in turn, highlight the importance of continuity in knowledge use as a component of organizational resilience and adaptability. Despite a shared process-oriented core, the table reveals clear inconsistencies regarding the number of identified processes, the level of their aggregation, and the manner in which they are conceptualized. Some authors, such as Armistead (1999) and Probst et al. (2000), employ relatively simple models consisting of a limited number of key stages, whereas others, including Lin and Lee (2005), Bigliardi et al. (2014), and Panahi et al. (2021), propose more elaborate classifications comprising numerous detailed sub-processes. These differences

stem not only from divergent research objectives but also from the adopted theoretical perspectives, particularly technological, social, and strategic. Moreover, the lack of unified terminology results in similar activities being described using different labels, which hinders cross-study comparability and the accumulation of theoretical knowledge. The integration of these dispersed approaches is possible through the consolidation of processes with similar functional meanings into a coherent conceptual framework. The analysis indicates that most identified activities can be logically assigned to four overarching areas: knowledge creation, knowledge storage, knowledge sharing, and knowledge use. Processes such as knowledge acquisition, development, identification, and capture were grouped under knowledge creation, as they all contribute to generating new knowledge or transforming existing information into organizational assets. Knowledge organization, measurement, planning, assessment, preservation, and storage were classified under knowledge storage, as they focus on structuring, maintaining, and safeguarding knowledge for future accessibility and use. The knowledge sharing category includes processes such as transfer, dissemination, distribution, integration, and utilization, which facilitate the movement of knowledge across individuals, teams, or departments. Finally, knowledge use encompasses activities such as reuse, access, maintenance, retention, and application, emphasizing the practical deployment of knowledge to improve decision-making quality, organizational performance, and innovation. The Table 2 below shows how the grouping was done.

Table 2.
Grouping of KM processes

Knowledge creation	Knowledge storage	Knowledge share	Knowledge use
Knowledge acquisition	Knowledge measurement	Knowledge share	Knowledge use
Knowledge creation	Knowledge organisation	Knowledge transfer	Knowledge reuse
Knowledge embedding	Knowledge planning	Knowledge distribution	Knowledge access
Knowledge identification	Knowledge assessment	Knowledge integration	Knowledge maintenance
Knowledge development	Knowledge preservation	Knowledge dissemination	Knowledge retention
Knowledge import	Knowledge storage	Knowledge transfer	Orientation to customers and suppliers
Knowledge capture		Knowledge utilization	Knowledge goals
Knowledge retrieval		Knowledge search	Knowledge value
Knowledge discovery			
Knowledge (re)combination			
Knowledge assembly			
Knowledge generation			
Knowledge coding			

Source: authors' own elaboration based on literature review.

This integrated approach preserves the richness of empirical insights offered by authors such as Armistead (1999), Probst et al. (2000), Lin and Lee (2005), Kulkar et al. (2009), Bigliardi et al. (2014), Iqbal et al. (2019), Panahi et al. (2021), and Yu et al. (2022), while simultaneously reducing excessive terminological fragmentation. The proposed classification enables a more coherent understanding of knowledge management processes by integrating dispersed terminology into a simplified conceptual framework. It highlights the iterative and

interconnected nature of knowledge management, whereby creation leads to storage, storage enables sharing, and shared knowledge is ultimately applied and reused, thereby initiating new cycles of creation. Such a conceptual framework facilitates more consistent comparisons of empirical studies and provides a solid foundation for further operationalization of variables and the development of analytical models.

4. Discussion and conclusion

This study set out to critically examine the similarities, differences, and inconsistencies in the definitions and classifications of KM processes in academic literature over the past 25 years and to explore how these perspectives can be integrated into a unified conceptual framework. The findings demonstrate that, despite substantial diversity in terminology, scope, and analytical emphasis, there is a strong underlying convergence in how KM processes are fundamentally understood across different research traditions. A key similarity identified across the reviewed studies is the consistent recognition of a core set of knowledge-related activities that collectively form the knowledge lifecycle within organizations. Regardless of whether authors adopt functional, technological, strategic, or social perspectives, most frameworks include processes related to knowledge creation or acquisition, knowledge storage, knowledge sharing or transfer, and knowledge use or application. Early process-oriented models emphasize structured sequences of activities, while later approaches increasingly incorporate dynamic, relational, and technology-enabled dimensions. Nevertheless, the functional logic of generating knowledge, retaining it, mobilizing it across organizational boundaries, and applying it to create value remains remarkably stable across time and disciplinary orientations. This convergence suggests that the diversity observed in the literature reflects differences in analytical lenses rather than fundamental disagreement about the essence of KM processes. At the same time, the analysis reveals substantial differences and inconsistencies in how these processes are defined, labeled, and structured. One major source of inconsistency lies in terminology. Similar activities are frequently described using different labels, such as acquisition, capture, identification, or development for knowledge creation-related activities, and sharing, transfer, dissemination, or integration for knowledge flow processes. This terminological fragmentation complicates cumulative knowledge development and limits comparability across empirical studies. Another source of variation concerns the level of granularity in process models. Some authors propose parsimonious frameworks with a limited number of high-level stages, whereas others develop detailed classifications that include numerous sub-processes reflecting technological functions, social interactions, or strategic mechanisms. These differences are partly driven by distinct research objectives and theoretical orientations, particularly the emphasis placed on information systems, organizational behavior, or strategic management.

In addition, inconsistencies emerge in how boundaries between processes are conceptualized. In several models, certain activities are treated as independent processes, while in others they are embedded within broader categories. For example, integration or reuse may be conceptualized as separate processes or as components of sharing and use, depending on the analytical perspective adopted. This lack of conceptual alignment contributes to overlapping classifications and ambiguous process boundaries, reinforcing the fragmented nature of the KM literature. To address these challenges, this study proposes an integrative framework that consolidates dispersed process definitions into four overarching and interrelated categories: knowledge creation, knowledge storage, knowledge sharing, and knowledge use. This categorization is grounded in the functional purpose of each process within the KM cycle and reflects observable dependencies and feedback loops among them. Knowledge creation encompasses activities that generate new knowledge or transform information into organizational assets; knowledge storage focuses on structuring, preserving, and maintaining knowledge for future accessibility; knowledge sharing facilitates the movement and integration of knowledge across organizational actors and units; and knowledge use captures the practical deployment of knowledge in decision-making, innovation, and performance improvement. By aggregating conceptually overlapping terms into broader functional domains, the framework reduces terminological complexity while preserving the richness of existing empirical insights. The proposed framework highlights the iterative and cyclical nature of KM, emphasizing that these processes do not operate linearly but dynamically reinforce one another. Knowledge use generates new experiences and insights that feed back into knowledge creation, while storage enables continuity and organizational memory, and sharing ensures knowledge diffusion and recombination. This dynamic perspective aligns with contemporary organizational realities characterized by digitalization, distributed work, and continuous innovation, making the framework adaptable across different organizational contexts and levels of analysis.

From a theoretical standpoint, this study contributes to KM research by offering a coherent synthesis of fragmented conceptualizations and by providing a common analytical language that can support cumulative theory building. The framework enables more consistent comparison of empirical findings, facilitates operationalization of KM constructs, and supports the development of integrative models linking KM processes to organizational outcomes. For practitioners, the framework offers a structured yet flexible lens for diagnosing KM maturity, designing KM initiatives, and aligning technological investments with human and organizational capabilities.

Despite its contributions, this study has several limitations. The narrative review approach, while enabling conceptual depth and flexibility, does not provide the same level of replicability and exhaustiveness as systematic reviews. The selection of studies was purposive and may not capture all relevant publications or emerging streams of research. Furthermore, the proposed framework remains conceptual and has not yet been empirically validated across different organizational settings or industries.

Future research should therefore focus on empirically testing the proposed framework, examining causal relationships among the four process categories, and exploring how contextual factors such as organizational size, industry, digital maturity, and culture influence the configuration and effectiveness of KM processes. Longitudinal studies could further illuminate how KM process configurations evolve over time and how feedback loops between creation, storage, sharing, and use shape organizational learning and innovation. Such research would strengthen the practical applicability and theoretical robustness of the integrated conceptual framework proposed in this study.

5. Summary

The aim of this article was to analyze similarities, differences, and inconsistencies in the definitions and classifications of knowledge management processes presented in academic literature over the past 25 years and to develop a coherent and adaptable conceptual framework integrating dispersed approaches. A narrative literature review was employed, enabling a qualitative synthesis of concepts developed across diverse research traditions and organizational contexts. The analysis focused on the terminology used to describe KM processes, their functional roles within organizations, and their frequency of occurrence in existing models. The findings indicate that despite substantial conceptual fragmentation, most authors identify a common core of processes encompassing knowledge creation or acquisition, knowledge storage, knowledge sharing, and knowledge use. At the same time, significant differences were observed in the number of identified processes, the level of their granularity, and the way boundaries between them are conceptualized. These inconsistencies stem from divergent theoretical perspectives and the lack of unified terminology, which limits cross-study comparability and cumulative theory building. In response to the identified discrepancies, an integrated conceptual framework was proposed consisting of four overarching and interrelated categories: knowledge creation, knowledge storage, knowledge sharing, and knowledge use. The framework reflects the iterative and dynamic nature of knowledge management and enables the organization of dispersed terminology into a coherent analytical structure. The proposed approach provides a foundation for further empirical research and may support the design and improvement of knowledge management practices in organizations.

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COMPARISON OF MEDICAL WASTE MANAGEMENT IN POLAND AND IN INDIA – LITERATURE REVIEW

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Purpose: The aim of the article is to provide objective research about a comprehensive comparison of medical waste management procedures in Poland and India. It examines the legislative frameworks, waste generation figures, treatment techniques, and environmental consequences in both countries.

Design/methodology/approach: The basic research methods were the analysis of literature on the medical waste management in Poland and in India. The article focuses on the comparison of produced waste, their type, type of their classification and their impact on the environment.

Findings: The comparative analysis enables bringing critical observations on how to manage such type of wastes in different settings. Both examples show that stringent regulatory frameworks and advanced technologies can lead to positive outcomes. It is shown by the research that proper disposal of medical wastes, aiming at guaranteeing public security and preservation of nature must consider peculiarities of local environment to be implemented effectively.

Research limitations/implications: In the future, research will be continued in the field of statistical comparison of medical waste management in both countries.

Practical implications: The findings emphasize the importance on not only technological and legislative solutions for medical waste management but socio-cultural factors, involving stakeholders, and awareness. The comparative nature of study contributes to making a useful reference to policymakers, healthcare professionals, and waste management practitioners as it provides better practices of medical waste management anywhere in the world.

Originality/value: Medical waste management in the case of global health emergencies such as COVID-19 pandemic should be a potential research focus in the future. The knowledge of these impacts can help to develop more dynamic and adaptable waste management systems that are ready to cope with the quick increase in volume of the wastes. In addition, cross-country studies will promote international collaboration to share best practices innovations, and experiences. It can spread more integrated and efficient global strategies on the medical waste management that would result in better health outcomes and environmental stewardship.

Keywords: medical waste management, techniques, strategies, safety.

Category of the paper: Literature review.

1. Introduction

Medical waste management is a critical issue of both environmental and public health; this has different approaches in various nations. The comparative approach in this research between Poland and India offers an alternative angle to viewing the different strategies for such a challenge. Poland, as a country with the functioning health care system must comply to EU policies on medical waste. EU method is based on compliance, safety and sustainability which will reduce the rate of wastes generation as well encourages recycling. The Polish approach is a technology-focused (Halkos, 2021). However, in the case of India, there is a vast population to deal with making it more complicated when disposing medical waste. The nation suffers from issues due to its high level of waste production and varying process in its states associated with the faint law enforcement. Despite the fact these are issues that India is facing, innovative technologies and cost-efficient methods of waste management seem to grow in this country (Barma, 2022).

Both countries have an evolutionary waste management medical history. The evolution has been driven by European standards with changing healthcare requirements due to developing cum improved waste management system in Poland. In contrast, India's path shows rapidly increased urbanization and healthcare sector however leaving behind the provision of basic infrastructure for solid waste management. The classification of the medical waste, which is hazardous and non-hazardous also, complicates its control measures. Waste collection management is made worse by the extent and nature of waste produced in India, as well poor segregation practices. Contrastingly, the Polish system of waste separation has a simpler process as it possesses better infrastructure and compliance with regulation (Hag, 2022).

The influence of healthcare infrastructure and population structure on the number of medical wastes generated and managed is high. In India's heavily populated areas, the overwhelming numbers of wastes exceed established infrastructures while Poland has population densities that are more manageable despite their potential waste quantities. The modern technology has greatly transformed the system of waste management. In terms of waste treatment and recycling, Poland derives benefits from European innovations, while India is gradually investigating cost-effective and replicable methods. Environmental and health effects of improper management of medical wastes are prevailing in both countries, however much more acute in India because inconsistent waste assistance practices (Hag, 2022, Vlachokostas, 2020).

Both countries' policy and regulatory issues demonstrate the struggles in dealing with medical waste. By following EU directives, Poland leads to more homogeneous but a harsher regulatory environment. This regulatory framework is changing in India, but this change can be seen with varying value of implementations and enforcements across the states. The appropriate waste management practices are formulated based on stakeholder engagement

and public understanding. Visibility of public awareness improved, and the stake is high in Poland; on India's end visible improvement needs to act as motivation for intensity checking participation since it helps with better waste management. As this comparison between Poland and India, however, does not only reveal the statistical features for medical waste management but also shows the overall context as well including global practices and opportunity (Franco-Garcia, 2019).

2. Materials and Methods

This study is based on a structured literature review and data analysis of the legal acts from both countries – Poland and India. Additionally, statistical data analysis and semi-structured expert interview, documental and legal analysis, policy documents and scientific articles were analyzed to identify system-level deficiencies. Comparative analysis was used to highlight management of medical waste in both countries.

The aim of this study was to identify systemic challenges in infectious medical waste management in Poland and in India and show some differences in regulatory framework. Research objectives were indicated:

- **Research objectives:**

- Focus on the structure, efficiency, and regulatory compliance of medical waste management systems in Poland and India.
- Examine the specific challenges faced in managing medical waste in Poland and India and identify effective practices that could be implemented in similar contexts.
- Evaluate the influence of socio-economic, cultural, and geographical factors on the medical waste management strategies in both countries.
- Provide actionable recommendations for improvements in medical waste management, drawing on the insights from the comparative analysis.

- **Research questions:**

1. What are the structural and operational differences in the medical waste management systems of Poland and India?
2. What challenges are unique to Poland and India in the context of medical waste management, and how are these challenges being addressed?
3. How do socio-economic and cultural factors impact medical waste management practices in Poland and India?
4. What improvements can be recommended for both Poland and India based on the comparative analysis?

This study focuses on a comparative analysis of medical waste management in Poland and India. It includes the examination of legislative frameworks, waste management strategies, and literature review regarding waste generation and disposal. The study aims to identify challenges for both countries, considering the influence of various socio-economic and cultural factors. The findings aim to provide insights and recommendations for policymakers, healthcare facilities, and waste management authorities in both countries.

3. Results

3.1 Medical waste management in Poland

The Waste Act of 2022 defines the concept of medical waste as "waste generated in connection with the provision of health services and conducting research and scientific experiments in the field of medicine" (Dz.U., 2023). Therefore, medical waste will appear in hospitals (general, psychiatric), rehabilitation sanatoriums, addiction centers, hospices, medical and educational facilities, care and educational facilities, clinics, health centers, clinics, and individual medical and nursing practices. Medical waste can be divided into 2 groups: hazardous waste (infectious waste, special waste) and non-hazardous waste. These wastes may occur as solid substances (syringes, needles, limbs), liquid substances (blood, plasma, vomit) and gaseous substances. Since medical waste encounters the patient's blood and secretions, it may be dangerous to human health. Primarily because the patient may be a carrier of various types of diseases or pathogens such as viruses, bacteria or fungi that may cause AIDS, hepatitis C or the plague (Topolska, 2017).

Hazardous medical waste is generated at virtually every stage of a medical facility's operations. During the admission and diagnosis of a patient, medical waste may appear, such as: dressing materials, surgical gloves, sponges, cotton swabs, sticks, spatulas, pharmaceuticals, syringes, and needles. At the stage of conducting research, including laboratory tests, medical waste appears in the form of e.g., needles, pipettes, human tissues, or blood. Most hazardous medical waste occurs during surgery. During and after surgery, waste such as used surgical equipment (needles, scalpels, etc.), human remains and tissues, and blood are generated (Zalewska, 2019).

To classify waste, not only medical waste, an online waste database (BDO) was established and launched in 2018. Its main goal was to seal the waste management system. The main tasks of BDO are (BDO, 2023):

- collecting information on packaging and products in packaging introduced in Poland,
- collecting information on the achieved levels of recovery and recycling of waste from packaging and products,

- obtaining information on cross- border movement of waste,
- waste classification,
- keeping waste records based on submitted reports,
- control of the waste management market.

The waste catalog is a collection of all waste divided into groups, subgroups, and types of waste, depending on the source of their generation. Additionally, the catalog lists hazardous waste that poses a particular threat to human health and life and the environment, marked* (Dz.U., 2020, item 10). According to the waste catalog, medical waste is classified in group 18 and subgroup 01 (waste from diagnosis, treatment, and medical prevention).

Types of medical waste (Mesjasz -Lech, 2019, Zdęba-Mozoła, 2022):

1. Infectious waste: This group consists of materials that are contaminated with blood and other bodily fluids such as used dressings, bandages, and swabs. It also encompasses objects like discarded gloves, gauze and other used medical equipment that has got into contact with infectious materials.
2. Sharps waste: This category includes used needles, syringes lancets and other sharp medical tools. The importance of disposal of sharps waste properly to prevent injuries and hence the risk assessments pathogens associated with blood borne is significant.
3. Pathological waste: This category encompasses human tissues organs and body parts that are removed during surgeries autopsies or other therapeutic procedures. Pathological waste disposal helps to stop the development of infections spread and also preserves dignity with respects for the deceased.
4. Pharmaceutical waste: This type includes expired, unused, or contaminated medications and pharmaceuticals that require disposal. Right managing of waste from pharmaceutical is required for the purpose to avoid contamination due to environmental pollution in addition using medications improperly.
5. Chemical waste: This classification features different substances and dangerous agents used in medical operations, treatments, laboratory works. The proper treatment and well placement of chemical waste is also very important in the process to reduce environmental impact as well protecting public health.
6. Radioactive waste: Under this group come materials as are contaminated with radioactive substances for use in radiation therapy, nuclear medicine, and research activities. Here radioactive waste is managed and disposed of under strict regulation to avoid the exposure from radiations as well as contamination on environment.
7. General waste: This group includes non-toxic waste produced by medical organizations, including paper, cardboard food scraps and other infectious materials. Segregation and disposal of general waste, which are not considered a medical waste, need to be done properly for overall management of the wastes in hospitals.

The nature of medical waste is hazardous waste: these comprise of infectious garbage, pathological waste products, knives, pharmaceuticals, and physical cleansers. The breakdown of the percentages within each category is highly dependent on various types of medical activities that are observed in a particular centre.

The second group is in general non-hazardous waste: in most cases, more than 80% is not hazardous like domestic wastes. It can be distinguishing special category of waste like some operational units may produce certain categories of special waste such as radioactive waste that calls for specific treatment and management methods.

The specific nature of the work of medical facilities is related to constant contact with hazardous substances. Improper contact with blood or surgical waste may pose a risk of infection. Improper storage or transport of medical waste, or even worse, a complete lack of proper management of this type of waste, may lead to the release of potentially hazardous substances into the environment and, consequently, to contact with them by unaware third persons. In the event of improper storage of waste (e.g., in a common garbage container), hazardous compounds may spread even through animals, such as rats or cats, which is why it is so important to properly handle waste at the stage of storage. Due to the potentially dangerous impact of medical waste on the environment, it should be properly segregated and stored at the initial stage of its production. This is the first and very important step in the entire process of safe transport and waste disposal.

In the case of medical waste, its initial segregation and - more importantly - proper protection against the environment mainly concern waste such as:

- used dressings, syringes, surgical tools,
- waste from treatment and operating rooms,
- used and expired medicines.

To store medical waste (depending on the type of waste) plastic bags or hardened containers may be used. What type of container should be used depends primarily on the characteristics of individual medical waste. In the case of waste with sharp edges, e.g., needles or scalpels, hardened containers should be used. The proper selection of the agent and method of storage allows you to minimize the risk of potentially dangerous situations for the environment or for people who have direct contact with the waste, e.g., during its storage or transport. Hardened containers are resistant to most mechanical damage, moisture, and certain chemical reactions. Containers and bags for medical waste are delivered in different colors, depending on the target type of waste to be stored in them. Figure 1 shows examples of bags and containers for storing and transporting medical waste.



Figure 1. examples of bags and containers for storing and transporting medical waste.

Source: www1.

The following types of containers can be distinguished (Regulation of the Minister of Health of October 5, 2017, on the detailed method of dealing with medical waste (Dz.U., 2017; EKOMED, 2023):

- **red containers** – intended for collecting waste like residues from feeding people from infectious disease wards, blood, waste containing toxins or microorganisms,
- **yellow containers** – intended for collecting waste like chemical reagents – containing dangerous substances, cytotoxic drugs,
- **different colour containers e.g., blue** – intended for collecting waste like surgical and treatment tools, dressings, including plaster casts, bedding.

It is important to note that the containers are not designed with reusability. After filling, each container should be tightly closed in a way that prevents it from being opened again without leaving a clear trace. Professional containers used by companies are created in such a way that once closed, the container guarantees the waste producer that it cannot be reopened by unauthorized persons. Containers should be filled with no more than $\frac{2}{3}$ of their volume - this allows them to maintain appropriate properties of containers and resistance to damage, which is crucial for the safety of the waste producer due to his responsibility. An equally important element is the proper marking of the container or bag with waste – each of them should have an appropriate marking containing, among others: waste code or time of its closure.

It is worth remembering that the choice of a reliable company dealing with the transport and disposal of medical waste, which can provide and provide appropriate means of transport, is crucial for the safety of outsiders and the waste producer, because he is responsible for the waste generated (Ekomed, 2023, Przydatek, 2022).

Challenges and issues in medical waste management are related to:

1. **regulatory compliance:** adhering to the complicated and dynamic medical waste management regulations and policies can be difficult for healthcare facilities as well water managers themselves, regulators;
2. **infrastructure and facilities:** timely and enough regulations on infrastructures or facilities for the collection, separation of storage treatment as well as medical waste disposal is necessary. One of the challenges in promoting appropriate waste

management infrastructure in healthcare facilities, particularly those located outside urban areas;

3. **segregation and handling:** it is necessary to make proper segregation between different types of medical wastes in the generation point. On the other hand, difficulties in practice can occur while placing emphasis on training of healthcare personnel and provision them with equipment for segregation and safe & effective treatment of medical waste;
4. **transportation:** the transportation of medical waste from the healthcare facilities to treatment and disposal facility must be safe and compliant. Challenges may be associated with availability of specialized transport services and preservation of integrity waste containers during transportation;
5. **treatment and disposal:** choosing the right treatment method and mode of disposal for medical waste is not always an easy task. This may also involve certain alternative facilities such as autoclaving, incineration and chemical treatment which must be cleared by the relevant authorities;
6. **environmental impact:** managing the environmental effects of medical waste does not come easy for especially in terms of emissions, wastewater, and contamination. When it comes to ensuring that the process and methods of treatment and disposal are environmentally friendly;
7. **public awareness and education:** raising awareness among health workers, waste management personnel and the population in general on importance of correct handling and disposal medical wastes is also necessary;
8. **resource allocation:** effective implementation of medical waste management should be made possible by proper resources. Healthcare facilities and waste management companies may also face difficulties due to budget limitations and resource allocation.
9. **monitoring and enforcement:** close monitoring and control of the medical waste management regulations also need to be implemented. It is a challenge to be assured that regulatory authorities are provided with the capacity of compliance monitoring and where necessary, enforcement.

The realization of these challenges demands coordinated involvement between the healthcare institutions, waste disposal firms, regulatory organizations, and different stakeholders to formulate crucial procedures for medical announcement within Poland.

3.2 Medical waste management in India

Medical waste, also known as biomedical waste, refers to any waste solid or liquid that contains infectious or potentially infectious materials from medical, laboratory, or research activities such as diagnosis, prevention, and treatment of diseases. This waste poses a higher risk of infection and injury to healthcare workers, patients, and the surrounding community. It encompasses human anatomical waste, animal waste, microbiology and biotechnology waste,

waste sharps, discarded medicines and cytotoxic drugs, soiled waste, liquid waste, incineration ash, and chemical wastes (Datta, 2018).

Common generators of medical waste in India include hospitals, clinics, medical and veterinary colleges, blood banks, mortuaries, autopsy centres, biotechnology institutions, research laboratories, home healthcare facilities, and funeral homes. Hazardous chemicals and radioactive waste, although non-infectious, also require proper disposal (Kandasamy, 2022).

In India, the management and handling of biomedical waste are regulated by the Biomedical Waste (Management and Handling) Rules of 1998, along with subsequent amendments. These rules are presented in six schedules – types of biomedical waste, colour coding and container sizes, labels for biodegradable bags or containers for medical wastes, transport labels: standards of treatment and disposal; detailed indications on the organization's incinerator autoclaves including microwave systems. Biomedical waste classification- categories, treatment, processing and disposal options are shown in Table 1. Operating standards such as combustion efficiency and emission specifications are also outlined (Rules, 1988).

Appropriate handling of medical waste is important to avoid the risk associated with infection diseases since there are several germs which can cause harm to individuals while making it dangerous and hazardous for public health as well as environment.

Table 1.

Biomedical waste classification- categories, treatment, processing and disposal options (Datta, 2018)

Category	Types of waste	Colour and type of container
Yellow	Human anatomical waste, animal anatomical waste, soiled waste, discarded or expired medicine, laboratory waste, chemical waste, chemical liquid waste	Yellow colour non chlorinated plastic bags; thickness ≥ 50 microns or containers
Red	Contaminated waste (recyclable)	Red colour non chlorinated plastic bags; thickness ≥ 50 microns or containers
White	Waste sharps including metals	White colour translucent, puncture proof, leak proof, temper proof containers
Blue	Glassware, metallic body implants	Cardboard boxes with blue coloured marking or blue coloured puncture proof, temper proof containers

Types of medical waste in India (Rules, 1988; Datta, 2018):

1. general waste: this category includes non-hazardous waste from healthcare facilities, such as paper, packaging and food waste. While not inherently hazardous, proper disposal is still essential to prevent environmental pollution and maintain hygiene standards within the facility. The general type of medical wastes should be categorized into a different section and managed with the regulations municipal garbage management systems;
2. pathological waste: the pathological waste can be defined as tissues, organs, body parts and bodily fluids generated from surgery or autopsy laboratories. This kind of waste is dangerous from the point of view disease spread and require additional special care in

dusting. Thus, this waste should be stored in non-porous and puncture proof containers and treatment procedures like burning or autoclaving guarantees the pathogen elimination;

3. infectious waste: the types of waste that fall within this category include the wastes containing blood, body fluids or any other infectious material including used bandages and swabs. Complete segregation, packaging and treating the material is required to minimize chances of infections. The infective wastes should be stored in colour coded leak-proof containers and decolorized or decontaminated through process like incineration or autoclaving before they are finally dumped;
4. sharps waste: sharps waste includes needles, syringes, scalpels, and any other item that might cause injury or infection. It should be gathered in sharp-proof receptacles that will help to prevent the needle sticks and injuries. Sharps waste is usually dealt with through autoclaving or other approved sterilization method so that they do not cause further harm;
5. pharmaceutical waste: these types comprise of medications that have passed, drugs and contaminated medication as well as vaccines. Proper waste disposal is necessary to prevent pollution and avoid illicit use. The disposal of pharmaceutical waste seeks to adhere to the segregation and management employed by such a measure with secure storage, return into manufacturer or incinerating it at high temperature;
6. chemical waste: harmful chemicals used in the medical field, namely disinfectants, solvents and reagents should be managed and properly discarded to ensure people's life is protected as well as that of all nature. Hazardous waste management guidelines require that chemical wastes be collected, stored, and disposed of in a manner involving treatment or incineration at licensed sites;
7. radioactive waste: materials containing radioactive substances used in diagnostic and therapeutic procedures should be treated with special consideration on their handling as well as disposal to avoid radiation exposure or contamination of environment. The proper disposal of the waste must comply with regulations that include provision and use of shielding, containment within licensed radioactive facilities for treatment;
8. pressurized containers: this group contains aerosol cans, gas cylinders and various other pressurized containers utilized for the medical procedures. These materials should be de-pressurized and safely disposed of to avoid accidents or hazards. It is necessary to arrange the proper depressurization, and disposal means for the safe handling of pressurized containers.

In the case of India, medical wastes have also been becoming significant concerns in terms with respect to their quantity and composition due to increasing health care sector. Each year, the country produces approximately 484 tons of medical trash daily-a number that has been increasing over time as new facilities are developed. This waste is a mixed variety of both hazardous and non-hazardous substances. About 15-20% of total waste is classified as

hazardous and potentially infectious, which may compromise the health of people and nature. The remainder, between 80-85%, is non-hazardous just like municipal waste. Medical waste from major metropolis comprises of a larger proportion since the healthcare facilities are concentrated in these urban centres. The word 'toxic' refers to materials such as used syringes, contaminated gauzes expired drugs discarded surgical instruments and chemical wastes. These aspects are especially worrisome since if mishandled and discarded carelessly they can transmit diseases such as the human immunodeficiency virus (HIV), hepatitis among other infections (Devi, 2019).

The composition of medical waste in India also depicts the plurality of traditional systems and quality variation in health care services. In advanced cities filled with higher-level medical facilities, the content of complex items such as chemical and pharmaceutical residues cytotoxic drugs, radioactive materials are high. On the contrary, wastes from rural areas where is more basic healthcare services produce non-hazardous waste but with a lower percentage of infectious and hazardous. Nevertheless, even non-hazardous waste can be contaminated and become hazardous. There is the poor segregation of waste at source by mixing hazardous and non-hazardous wastes which makes management processes cumbersome. Additionally, there is a rising trend of disposable medical devices and plastics in the health industry leading to an alarmingly high rate at which wastes are generated. This case highlights the importance of sustainable waste management policies and practices (Gowd, 2021; Kaur, 2022).

With the rapid development of its health care industry, India has seen a sharp rise in medical waste creation over the past several years. This rise is due to various factors such as increasing population, higher prevalence of chronic diseases and improving accessibility to healthcare facilities. According to the recent data, India produces around 500 tons per day of medical waste, and this figure remains increasing with the growing number of hospitals, clinics diagnostic centres or laboratories (Sharma, 2020). The largest contributors to this growth are the urban centres, particularly metropolitan cities in which healthcare facilities have high population concentrations. In addition, medical waste has become different from the type of trash production. The amounts also increased on hazardous materials such as sharps, pharmaceuticals, chemical solid and liquid wastes among other infectious substances which are a major health threat resulting in losses of billions. However, this transformation partially arises from the current development in medical devices and techniques that frequently involve increased use of sophisticated surgical tools. Increases in biomedical waste during normal time were already increasing, and the COVID-19 pandemic massively accelerated this trend: largely due to personal protective equipment (PPE) masks and gloves highlighting challenges of rapid increases in volume for adequate management (Kothari, 2021).

The trends in medical waste generation in India also show the changing pattern of healthcare practices and consumer behaviour. Single-use disposable medical products are becoming prevalent focusing on the patient safety and infection prevention. This trend, however necessary to cut off cross contamination issues has led to mounting plastic-based wastes creating immense

environmental challenge. The incomplete separation of wastes at the source is still one of main problems, as hazardous and non-hazardous waste becomes mixed prior to collection. Moreover, there is an uprising understanding of environmental and health consequences of incorrect medical waste management creating stringent rules and policies. Both government and different environmental organizations are now pushing the direction for better ways of garbage management emphasizing dumping, recycling, and responsible disposal methods. On the other hand, implementation has huge differences regionally with many urban centres recording better management systems in comparison to rural areas. In the Indian context, with more advancements taking place in generation of medical waste over time demands for better strategies including education policy, strict regulations as well as adoption of eco-friendly disposal methods is pronounced than ever (Manzoor, 2019).

4. Discussion

The medical waste disposal in Poland and India illustrates several very different approaches which are related with the infrastructure of health care, the regulating system, as well as social-economic environment. The healthcare system in Poland is liberal, and the operations of the system fall under the regulations set by Europe Union regulation that promotes compliance with orders, safety and sustainability. This route has resulted in a functional, sophisticated, and integrated waste management paradigm that utilizes leading-edge technology to minimize wastes generation while fostering recycling.

Contrastingly, India has issues that are very complicated due to the demography and their large population of heterogeneous origin, but they produce lots of waste differently at state level. It comes based on the demand for more rigorous law enforcement and has taken an active step towards modernized efficient and cost-effective waste elimination practices. Despite this unattractive perspective, the situations of medical waste management in India continue to improve, an indicator of its urbanization and development of the health system.

The following countries have also made very significant progress in their approaches to medical waste management strategies. The Polish one also could be viewed as a reflection of the European standards, and reforms that is necessary for Indian health care was unavoidable many times not able meet increase in number. The variation in hazardous and non-hazardous waste among the two countries is associated with intricate strategies of management.

Finally, the provided analysis identifies the contextual connections that frame up medical waste management in Poland and India thereby giving an image of global operations with regards to possible cures. It shows that medical waste management systems used by these two countries are formed by healthcare infrastructures, characteristics of population demographics, technological advancements, and policy settings all which have played a critical role.

In Poland, the medical device is governed by European Union directives and national laws that similarly enact high standards of safety and quality. The law enacted on April 7th2022, Medical Devices, which seeks to harmonize the EU's MDR and IVDR imposes extensive pre-marketing criteria aimed at gaining market access for publicly funded health markets. Furthermore, Polish laws on the promotion and advertising of medical equipment as well as products of life sciences instruct to consider ethical standards and prohibit misleading advertisements. In addition, Poland's plastic waste and packing policy with implications for medical waste can be defined as the highly controlled environmental preservation practices that involved bans on several disposable plastics products and costs for single-use plastic garbage dealing.

However, India's regulatory framework for medical waste management is elaborate, stipulated to decrease risks arising from handling or disposal. These regulations are based on the Biomedical Waste Management Rules, initially notified in 1968 and amended in 2016 and 2018. A number of these regulations establish tough standards for segregation, transportation, storage, treatment, and disposal of biomedical waste; the decontamination wastes are classified depending on their hazard level and particular handling methods are provided for each specific group. To this end, hospitals and medical facilities in India should get the necessary sanction from their State Pollution Control Boards (SPCBs) or Pollution Control Committees (PCCs) regarding generation, management, and disposal of biomedical waste. Likewise, CPCB is very crucial in developing standards and the biomedical waste management guidelines to be used across the entire country. The 2016 revision of the rules changed much, such as a polar plan for chlorinated plastic bags and barcoding systems that served better waste tracking. However, the effective realization of such rules is not that easy process even in towns and rural districts due to informative deficiency and shortage of resources.

These differences reflect different strategies of waste management in Poland and India. Poland's regulatory environment, in line with the EU standards, is also safety and quality driven where medical devices as well as waste management have severe rules. Instead, although India's structure is rather comprehensive, its efficient implementation with difficulties in rural and backward areas manifests a broader lack of public awareness insufficient infrastructures and stricter control.

5. Conclusions

The research conducted in this article provides an analysis of the medical waste management systems in Poland and India. Through the comparison of these systems, the study emphasizes major dissimilarities in waste management practices that are based on different socio-economic, cultural, and regulation backgrounds. The Polish approach also influenced by

the European Union regulations gives evidence of the high standardization, efficiency and technology. This is useless for India's system, facing challenges because of its size and heterogeneity, but also demonstrates resilience and slow but steady progress towards reform. This comparative study does not only focus on the current situation of medical waste management in both countries but has also shed some light on the worldwide phenomenon of waste management practices.

The results of this study are important in terms of understanding the impact of medical waste disposal and its effects on public health and the environment. The comparison of Polish and Indian systems provides pivotal principles in terms of adaptability, resource accommodation, and innovative approaches to the healthcare challenges that are currently altering with pandemics like COVID-19.

Using a comparative analysis of medical waste management in Poland and India enables bringing critical observations on how to manage such type of wastes in different settings. Both examples show that stringent regulatory frameworks and advanced technologies can lead to positive outcomes, while the emerging scheme in India is relatively simple – it touches upon innovation and flexibility under resource shortages. It is shown by the research that proper disposal of medical wastes, aiming at guaranteeing public security and preservation of nature must consider peculiarities of local environment to be implemented effectively.

The findings emphasize the importance on not only technological and legislative solutions for medical waste management but socio-cultural factors, involving stakeholders, and awareness. Coherent solutions in the management of both wastes are fully dependent on this complex range of aspects. The comparative nature of this study contributes to making a useful reference to policymakers, healthcare professionals, and waste management practitioners as it provides a sort of roadmap for better practices of medical waste management anywhere in the world. The scope is limited to the analysis of existing data and does not include primary research or experimental interventions in the field. The findings aim to provide insights and recommendations for policymakers, healthcare facilities, and waste management authorities in both countries.

The case of Poland and India is not isolated, but representative of broader challenges in middle- and high-income countries with fragmented oversight. These results justify the need for the development of best-practice models and case-based solutions, especially in some crisis like COVID-19 pandemic.

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THE ROLE OF INTERNAL AUDIT IN BUILDING THE ORGANIZATIONAL RESILIENCE OF LOCAL GOVERNMENT UNITS

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Purpose: The article highlights the role of internal audit as a key tool for building the organizational resilience of local government units (LGUs) is discussed. Within the functioning of internal audit, those activities have been identified that support the management process in making proactive decisions aimed, for example, at the proper use of public financial resources. These activities include the following functions of internal audit: objective risk assessment, analysis of the effectiveness of processes and inspections, identification of problems in risk management and compliance assurance, the building of public trust.

Design/methodology/approach: The study was developed on the basis of literature research in the fields of public finance, internal control, and organizational resilience. The study is based on a critical analysis of the literature on the subject and, due to the topicality of the subject matter, is a continuation of the research conducted by the author in the area of organisational functioning under conditions of change, including ways of coping with difficult situations, situations of uncertainty or, finally, changes in the context of building organisational resilience. A selection of articles from the Google Scholar database was chosen to establish the definitions of organisational resilience. Additionally, the Scopus and WoS databases, previously used in the author's research, were consulted. The author's own observations and professional experience also proved to be helpful.

Findings: The considerations presented in the paper showed that building organizational resilience in the LGUs is a long-term and continuous process, comparable to the process of building the human body's immunity. It requires managers to undertake proactive measures under normal operating conditions – that is, in the pre-crisis phase – but it also requires continuous “efforts” in the crisis and post-crisis phases. The results of this study indicate the need for further research on building organisational resilience in local government units with regard to the role of internal audit, and in particular its efficiency and effectiveness.

Practical implications and Social implications: Raising awareness among managers and employees of the LGUs about the role of internal audit in building their organizations' resilience, which should contribute, on the one hand, to the effective use of this management tool (preventive actions and the use of the audit's advisory function), and on the other hand, to its continuous improvement.

Originality/value: The article helped to identify the most important functions of internal audit and their role in building the organisational resilience of local governments. The time frame for building organisational resilience using internal audit was also identified.

Keywords: organizational resilience, building organizational resilience, internal control, internal audit, local government units.

Category of the paper: Viewpoint, General review.

1. Introduction

Internal audit in the management of local government units (abbreviated as the LGUs) is still a tool that is not used efficiently and effectively. This affects the functioning of the LGUs, as well as the evaluation of the managers themselves, who (in accordance with Article 68 of the Public Finance Act) are responsible for all actions undertaken to ensure that objectives and tasks are carried out in a lawful, efficient, economical, and timely manner. As noted, 'internal audit does not concern only the examination of public finances, but also the internal control system, that is, risk management and organizational governance, thus supporting management in running a given unit' (Przybylska, Kańduła, Bogucka, 2024, p. 31). This is in accordance with Article 69(1)(1) and (2) of the Public Finance Act, which states that a head of a commune, mayor, chairman of the local government unit's board, or a head of the unit should ensure the functioning of an adequate, effective, and efficient internal control system. An adequate control system is one that has designed control mechanisms which address to the identified risks in the unit's operations. An effective control system, on the other hand, will achieve measurable results in mitigating the identified risks. An efficient system, in turn, is one that is implemented using the minimal possible resources and an optimal selection of methods and means. Internal audit, as an independent and objective activity, is meant to support managers in achieving objectives and tasks through a systematic evaluation of the internal control system, as well as by carrying out advisory activities for the head of the unit — 'consultative activities supporting management processes in the form of reports and recommendations aimed at improving the functioning of the unit' (Chojna-Duch, 2017, p. 110).

Although internal audit has been functioning in domestic public institutions for over 20 years, there is still much to be achieved both in terms of its operation and, above all, in terms of its potential impact on the LGUs. This also concerns the recognition of its role as a management tool in building organizational resilience, which, in the context of continuous environmental changes (including increasing uncertainty), appears to be a highly relevant issue and confirms its significant place within the internal control system. The role of internal audit is continuously evolving – initially, there was a shift away from focusing solely on the financial aspects of the organization, with auditors' activities becoming oriented toward evaluating internal control systems, risk management and organizational governance (Przybylska, Kańduła, Bogucka, p. 7). Subsequent legal adaptations of audit in Poland to EU standards have transformed the existing compliance audit toward a performance-oriented audit. It is a concept

aimed at verifying the actions undertaken by the unit and the results achieved in terms of effectiveness, efficiency and economy (Wolejszo, Wilczyńska, Walenia, 2024, p. 7).

Internal audit activities are conducted across all areas and processes of the organization, not just in the financial area. Internal audit, whose task is to evaluate complex business processes and complicated technology, focuses not on retrospectively identifying errors but on an anticipative role, aiming to prevent mistakes by integrating into an early warning system. The auditor's task is to identify solutions that minimize the risk of an event occurring (even if it has not yet happened), that is, to prevent the occurrence of this risk and thereby provide appropriate protection against it (Wolejszo, Wilczyńska, Walenia, 2024, p. 14).

The purpose of this study is to discuss the role of internal audit as a tool that provides objective information about the state of the organization and enables informed management decisions, which are essential for creating and strengthening the resilience systems of the LGUs. The following research hypothesis was put forward: the implementation of basic internal audit functions contributes to building organizational resilience. The study was developed on the basis of literature research in the fields of public finance, internal control, and organizational resilience. The study is based on a critical analysis of the literature on the subject and, due to the topicality of the subject matter, is a continuation of the research conducted by the author in the area of organisational functioning under conditions of change, including ways of coping with difficult situations, situations of uncertainty or, finally, changes in the context of building organisational resilience. A selection of articles from the Google Scholar database was chosen to establish the definitions of organisational resilience. Additionally, the Scopus and WoS databases, previously used in the author's research, were consulted.

2. Literature review

Building organizational resilience of the local government units

Modern organizations (including public organizations such as local government units) are surrounded by a high level of uncertainty. This uncertainty arises, on one hand, from the complexity of the organization as a system and the dynamism of its operations, but above all, it results from the variability and complexity of the environment, stemming from its unpredictability (Jędralska, Czech, 2011). Sometimes uncertainty is associated with the concept of risk, although these terms are not synonymous (Bochenek, 2012). Uncertainty is a nonmeasurable concept that cannot be measured or quantified. Risk, on the other hand, is associated with events that actually occur – it is an objective phenomenon. Risk and uncertainty are therefore complementary concepts, but not synonymous (Janasz, 2009).

For this reason, organizations need methods and tools that can detect potential disruptions, as well as those that enable adaptation (survival and subsequent functioning under new and changing conditions). Research indicates that building resilience is a universal issue, relevant to every entity that wants to survive and thrive in the future (Kołodziej, Żak, Rydzewski, Zatoński, 2024, p. 266). The concept of organizational resilience is understood in various ways. For example, the ability to absorb and adapt in a changing environment is a natural element of every organization's functioning and is referred to as organizational resilience (Zapłata, 2025, p. 104). The very concept of resilience is also a subject of interest in other disciplines, such as medicine, psychology, social sciences and, finally, security studies. A great deal of attention is devoted to the issue of building human resilience, particularly psychological resilience, which is also linked to problems arising from the development of modern civilization and digitalization. And just as a resilient human body is capable of overcoming various kinds of "difficulties," a resilient organization is similarly able to meet the current and future demands of its environment as well as emerging constraints. Deliberate resilience-building creates opportunities and supports the transformation of a company's business model, while in the context of public institutions it can be described as a strategic plan. The phenomenon referred to as organizational resilience can illustrate a dynamic process that constitutes a response to external factors and leads to change. If we assume that it is the ability to adapt to changing conditions, learn from mistakes, and strengthen resources, we may conclude that a resilient organization can not only survive difficult moments but also emerge from them stronger (Kolek, 2025, p. 257). A broad analysis of the literature confirms that organizational resilience has a positive impact on ensuring business continuity (Zapłata, 2025, p. 107).

Many authors studying resilience see in it numerous positive aspects, such as perseverance and increased reliability in the face of unforeseen events, crises or changes in the environment, the ability to continue functioning despite their occurrence and the maintenance of key activities (cited in: Ingram, 2023, p. 58). It has also been noted that risk management can serve as a "foundation" for measuring resilience, and (...) in shaping resilience, the following should be taken into account: detecting irregularities, preventing threats, assessing risk, as well as responding to irregularities (Woźniak, 2024, pp. 76-77). Until now, no attention has been paid to the functions of internal audit in the context of building organisational resilience in local government units.

One of the tools supporting local government unit managers is an internal audit. It provides objective information about the state of the organization and enables informed management decisions, which are essential for creating and strengthening the resilience systems of the LGUs. At this point, one should ask: what role does an internal audit play in building organizational resilience in the LGUs, or in building resilience within the units themselves? It seems reasonable to look for an answer to this question in the fundamental functions that audit performs and which determine its value to the organization, namely its effectiveness (cited in: Bednarek, 2017, p. 34). At this point, one can cite (cited in: Ogórek, 2024, pp. 18-19) the

“unique” characteristics of the internal audit function. He includes among the most fundamental of these the objective of ensuring that the internal control system is properly designed and functions effectively. It is otherwise described as the certification of the system under review (management systems operating within the unit).

The second characteristic of the internal audit function is its focus primarily on assessing the effectiveness and efficiency of the entire internal control system.

Another criterion of the internal audit function is the significant emphasis placed on work planning, which is based on risk analysis. This obligation arises from the provisions of the Regulation of the Minister of Finance of September 4, 2015 on internal audit and information about the work and results of the audit, which stipulate that by the end of the year, the head of the internal audit unit, in agreement with the head of the organization, prepares the audit plan for the following year based on a risk analysis.

The fourth, and equally important, characteristic of the internal audit function is the independence of auditors within the organization in which they perform their duties (Ogórek, 2024, pp. 18-19).

As it has also been noted, internal audit can function as a homeostat and as a correlator. The former, in an autonomous system (such as the LGUs), is aimed at maintaining the desired state by eliminating factors that cause the system to deviate from the desired state whenever a deviation from that state is detected. The same applies to internal audit, as it monitors and analyses processes occurring within the organization, identifying errors and irregularities. A homeostat ensures only the current balance. In contrast, a systemic correlator enables adaptation to environmental conditions and learning. It is the element of an autonomous system that stores and processes information. Internal audit, functioning as a correlator, identifies opportunities for improvements in the organization's operations, enabling it to reach a higher level of development (Kabalski, Grzesiak, 2017, pp. 12-13).

3. Methods

Implementation of the fundamental functions of internal audit in the local government units

The most important (and fundamental) functions of internal audit include: objective risk assessment, analysis of process and control effectiveness, identification of problems in risk management, ensuring compliance, and supporting the building of trust (i.a. Herdan, Stuss, Krasodomska 2009, p. 8; Gołębiowska, Zientarski, 2019, pp. 190-191).

Risk management in the LGUs constitutes a key element of internal control, being one of the responsibilities of a head of a commune, mayor, chairman of the local government unit's board. Among the standards set out in the Public Finance Act, alongside the internal environment, objectives, control mechanisms, information, communication, monitoring and evaluation, risk management is included. This element represents a challenge for the LGU managers because neither the legislative nor the executive authority has specified how to implement this process in practice. Local government units are therefore expected to act in accordance with applicable law. The difficulty lies in clarifying the concept of risk, which, like the concept of organizational resilience, is not precisely defined. This ambiguity arises, among other things, from the many definitions of risk that have emerged over the past decades (Zawiła-Niedźwiecki, 2013, p. 29) and from the wide range of fields in which the term is used (e.g. management, finance, insurance, psychology, statistics). Risk, as a phenomenon, is widespread and occurs in different environments and at various scales (Kokot-Stępień, 2015, p. 534). Most often, risk is defined in the context of potential losses and negative consequences arising from situations differing from expectations (taking the form of negative risk). In economic activity, risk should also be viewed as the possibility of not achieving the intended result or achieving a result different from what was expected (in which case it takes the form of neutral risk) (Zachorowska, 2006, p. 58). Regardless of the definition adopted, the risk mechanism is the same - it originates from a threat, which then generates consequences. Internal audit identifies the threat, assesses its potential impact and verifies whether effective procedures exist to mitigate this risk.

Another function performed by internal audit in the LGUs is the analysis of the effectiveness of processes and internal control. The role of audit within the internal control system is to support the the LGU manager in achieving the set objectives through systematic evaluation of this control. These activities, on the one hand, involve analysing and assessing processes, which allows of their optimization, increases efficiency and prevents ineffective solutions that could weaken organizational resilience. On the other hand, internal audit assesses the effectiveness of internal control. This enables the continuous improvement of control mechanisms within the LGUs and provides managers with a tool to support the (optimal) decision-making.

Through the identification and resolution of problems, internal auditors uncover issues that were previously unknown and that may threaten the stability of local government units. This function enables the early detection of problems (i.e. preventing their occurrence) or their correction if they have already arisen. Moreover, audit verifies whether the LGU operates in accordance with the law and internal procedures, which forms the foundation for stable functioning and minimizes the risk of penalties or sanctions that could undermine its resilience (this is the compliance assurance function). Through this function, internal audit fulfils the objectives of internal control (as defined in Article 68 of the Public Finance Act), which include, in particular, ensuring that activities comply with legal regulations and internal procedures.

By ensuring effective management and transparency, internal audit contributes to increasing public trust in managers (the trust-building support function), as well as in the LGU as an institution. As it has been noted, in public units (including the LGUs - as public institutions) that manage large amounts of public funds, mismanagement, abuses or lack of transparency can lead to serious consequences for both financial stability and citizens' trust in public institutions (Szczerbak, Gęborys, 2025). By identifying gaps and potential weaknesses, internal audit enables the LGUs to improve mechanisms that prevent crises, ensure financial stability and maintain the continuity of public services thereby fostering social trust and strengthening resilience in the face of internal and external challenges. The profession of internal auditor is not officially recognized as a profession of public trust, although auditors' work obliges them to adhere to ethical and professional standards. Their professional ethics encompass knowledge related to the application of ethical theories in situations that people practicing a given profession may encounter, as well as the full set of principles, norms, and values guiding the conduct of members of this profession (Przybylska, Kańduła, Bogucka, 2024, pp. 59-60). Furthermore, implementing effective control mechanisms, including audits, risk management systems, and modern technological tools, minimizes threats and increases organizational resilience to unforeseen events (Chodyka, 2025, p. 12).

4. Results

4.1. Supporting the Audit Function in building organizational resilience in the local government units

Internal audit activities aimed at building the organizational resilience of a unit require support from management and the removal of unnecessary barriers that may weaken this process. One of the essential conditions for the proper performance of internal audit tasks in the LGUs is ensuring direct contact with the manager. Ongoing communication and mutual trust form the foundation for the proper execution of internal audit functions. It is important for the manager to define expectations regarding internal audit and to clearly communicate their priorities. The internal auditor should demonstrate diplomacy and possess highly developed communication skills in order to effectively maintain proper relations with the manager. The attitude and professionalism of the internal auditor play a crucial role in audit activities; at the same time, it is extremely important for managers to be aware of what audit truly is and what its role within the organization entails. Internal audit can serve as an effective tool for assessing internal controls, while a competent internal auditor acts as a driver of change supporting the unit manager, which in turn contributes to the process of building organizational resilience. At this point, a question arises: does the lack of direct subordination of the audit to

the manager result from insufficient knowledge or negligence on the part of the managerial staff (heads of a commune and mayors)? Is this a deliberate action? This question could serve as a basis for conducting research in this area, also in the context of the LGUs resilience.

However, in cases of doubt regarding the internal auditor's ability to perform certain tasks, the auditor should discuss these matters with the unit manager. It is important that, through mutual dialogue, a solution is developed that satisfies the unit manager while remaining consistent with the principles and standards of internal audit. Within the operations of the LGUs, there are a number of tasks that the internal auditor should not perform. These include participating in the operational activities of the unit, that is, assuming responsibility for management. This is the role and responsibility of the unit manager. Moreover, a breach of organizational independence or individual objectivity may occur in the form of restrictions on the scope of the audit or even a prohibition on examining a specific area, limitations on access to documentation, personnel, or assets, as well as constraints on resources. The internal auditor assesses the correctness of risk management implementation in the LGUs. However, the auditor cannot be involved in activities that determine the acceptable level of risk, i.e. the so-called risk appetite (Korombel, 2017). The internal auditor also cannot make decisions regarding the response to risk, including the implementation of risk response mechanisms, nor bear responsibility for the risk management process. Nevertheless, a key challenge remains increasing managerial awareness and knowledge among those responsible for the functioning of local government units, which will allow for the full utilization of the potential of new methods in the future (Sobociński, 2025, p. 90). On the other hand, it has been noted that internal audit continues to be undervalued by unit management, and often "leaders" are unable to leverage the experience and knowledge of auditors (Ciak, 2017, p. 61).

4.2. The temporal context of building organizational resilience in the local government units

The time context of building organizational resilience in the LGUs involves continuously adapting to a changing environment, being prepared for future changes and planning for unforeseen events. It encompasses both responding to current occurrences and developing the capacity to react flexibly and quickly to future, unknown challenges. From a time perspective, attention is given to the stages of organizational resilience in reference to the three phases of crisis management, i.e. the pre-crisis, crisis, and post-crisis phases (cited in: Zapłata, 2025, p. 106). This illustrates the dynamic nature of organizational resilience, which, like both the environment and the organization itself, changes over time. Consequently, strengthening resilience requires actions that consider the type and intensity of these changes (cited in: Zapłata, 2025, p. 202). It turns out that both the environment and the process of building organizational resilience demand continuous "effort". Organizational resilience is reinforced during the pre-crisis phase to prepare for potential threats. Signals indicating an impending crisis are detected (internal audit), and preventive measures are taken (the LGU management).

During the crisis phase, organizational activities focus on minimizing the negative effects of the crisis (with operational actions dominating). In the post-crisis phase, after the threat has been eliminated and its causes addressed, efforts concentrate on returning to pre-crisis conditions, drawing a lesson, and improving the organization for the future (these post-crisis actions are largely carried out in collaboration with management by the internal audit function).

In practice, direct contact between the LGU manager and the auditor is important at every stage of internal audit activities. Already at the annual planning stage, when the auditor conducts a risk analysis and selects audit areas for the plan for the following year, it is crucial to take into account the unit manager's priorities in this regard. Therefore, the selection of areas for audit tasks should be based on mutual dialogue. Similarly, in the case of advisory activities conducted by the audit - an objective and scope of these activities should always be agreed upon between the internal auditor and the unit manager. The manager is the primary recipient of the internal audit's results. Even after incorporating audit recommendations at the planning stage, there remains a risk during the implementation phase concerning potential irregularities or failure to achieve the intended benefits (Szołno, 2018, p. 226). Hence, collaboration (so-called "synergy" - auth.) between the unit manager, who monitors action plans on an ongoing basis, and the internal auditor, who periodically checks them, remains an essential element.

Moreover, the time context of building organizational resilience in the LGUs is linked to the organizational conditions of the internal audit unit, specifically the number of personnel (full-time positions) involved in internal audit. Due to the creation of a one-person audit position, the auditor's ability to contribute to building organizational resilience is significantly limited by time. In multi-person audit units, it is possible to conduct audits in several areas simultaneously and to employ staff specializing in different fields. This will depend on many factors and is within the decision-making scope only of the head of the local government unit.

Another issue is to pay attention to internal audit in the LGUs as a tool supporting the process of building organizational resilience in a systematic and continuous manner. The elections of heads of a commune and mayors are linked to the concept of a five-year term. It should be noted that the mayor's term of office is connected with a restriction on the right to be elected – that is, a person who has already been elected twice as a mayor of a given municipality is not eligible to run for that office again in the same municipality (in accordance with Article 11, §4 of the Election Code). Although the tenure of the LGU managers such as heads of a commune and mayors is limited, in most cases the tasks and functions of internal audit in the LGUs are carried out by the same employee (or group of auditors) over many years.

5. Summary

Viewing internal auditing as a management tool that supports building organizational resilience in the LGUs is, on one hand, a topic familiar to researchers, but on the other hand, it still requires deeper study and understanding. Such understanding or exploration of the issue should contribute to strengthening awareness (e.g. among the LGU managers and/or employees) of the benefits and opportunities arising from the conduct of internal audit. For internal audit to be recognized as a truly effective tool supporting the manager in running a local government unit and improving its functioning, including building organizational resilience, it must be provided with appropriate conditions. The foundation for this lies in ensuring functional and organizational independence, as well as promoting knowledge about its role and responsibilities. Here, the role of highly qualified and communicative staff in internal audit units is crucial (Łukaszuk, 2021, p. 234). Internal audit, as a key tool for building organizational resilience in local government units is carried out through the performance of its fundamental functions, which include: objective risk assessment, analysis of process and control efficiency, identification of problems in risk management and compliance, and the building of public trust. However, internal audit activities aimed at building the organizational resilience of the unit themselves require support from management. The cooperation in question must be based on the organizational and functional independence of the audit, which involves separating audit activities from those of other organizational units to ensure objectivity and prevent conflicts of interest, as well as guaranteeing the direct subordination of the internal audit to the unit manager.

The analysis indicates that:

- in professional literature, much attention is devoted to issues related to organizational resilience in various contexts,
- a similar situation applies to research in the area of internal audit in local government units,
- however, there are no studies related to the role of internal audit in building the organizational resilience of local government units,
- the implementation of basic internal audit functions contributes to building organizational resilience.

Further research on the impact of implementing basic internal audit functions on the effective building of organizational resilience in local government units.

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THE IMAGE OF A PROFESSIONAL SPEEDWAY RIDER IN THE CONTEXT OF PUBLIC RELATIONS MANAGEMENT

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Purpose: The main objective of this article is to identify and evaluate factors influencing the image of speedway riders. Nowadays, these factors are mainly determined through social media, which continues to be an important intermediary between athletes and stakeholders. An additional objective is to attempt to find differences between the image of speedway riders and other athletes.

Design/methodology/approach: In order to achieve the intended goal, source research methods and numerical data were used to determine the factors influencing the image of speedway riders. The primary research was conducted on a group of 134 respondents, users of the Awangarda Żużlowa website, between 24 and 31 August 2025. The data was subjected to statistical analysis using statistical measures and an independence index. The subject of the study was to assess the current image of speedway riders and to determine the strength of the factors influencing their image. The study was conducted using the CAWI method and analysed using Excel spreadsheet functions.

Findings: The result of the study was to demonstrate the role of image management in sports marketing and to determine the strength of the impact of individual factors on the image of an athlete.

Research limitations/implications: The main limitations of the study are the variety of factors that may influence the management of an athlete's image, the high mobility of the environment, and the multi-channel nature of the methods used to reach stakeholders.

Practical implications: It is hypothesised that the optimal application of the proposed research method will provide knowledge on the objective assessment of athlete image management policies, mainly through social media. This knowledge will fill a research gap, as previous studies on image have focused on individual, well-known athletes. The findings of the research will contribute to broader implications for image management.

Social implications: It is assumed that with the optimal application of the proposed survey method, a tool is gained for the objective evaluation of the communication management policy through social media. The method replaces a qualitative assessment of this management, showing the position among different types of media or competitors.

Originality/value: The article is aimed at people involved in managing aspects such as public relations, communication and image management. What is new about this article is that it is the first study on speedway racing in terms of image creation through public relations management and athlete behaviour in the internet space. This, in turn, affects communication management not only at the level of social media, but also in multi-channel marketing.

Keywords: social media, image management, communication.

Category of the paper: Research paper.

1. Introduction

The concept of image in a marketing context is linked to the belief that it is not what a person is, but how they are perceived by others. In literature, image is defined as a complex intellectual or sensory interpretation, a way of perceiving someone or something; a product of the mind resulting from deduction based on available premises, both real and imagined, conditioned by impressions, beliefs, ideas and emotions (Skrucha, 2022).

In the legal sense, image is also a personal asset, which means that an athlete's image is subject to legal protection. With the development of the media, image often takes on a commercial dimension - it becomes a value that can be 'exploited', e.g. in advertising, sponsorship and marketing (Stępień, 2016).

This article deals with issues related to image creation and brand building, which in turn should be part of a larger public relations management policy. All these elements are therefore interrelated. The field of discussion here is the application of principles present in sports marketing, where the subject is an athlete, a representative of speedway.

The „image of an athlete” is a rather complex construct - it encompasses psychological, social, media, economic and legal aspects.

The topic of an athlete's image is not an unknown issue. In Poland, many authors have dealt with the role of image and its creation. What should be noted is that the literature is dominated by works that examine the image of a famous athlete. In this way, Polish and foreign athletes are described using a comparative method. The image of Stephen Curry and LeBron James, NBA basketball players, was examined using this method (Każmierczak, 2023). Among the Polish athletes examined in the context of image were Justyna Kowalczyk-Tekieli (Dumalewska, 2022), tennis player Iga Świątek (Puto, 2023), ski jumper Kamil Stoch (Zielińska, 2021) and former footballer Jakub Błaszczykowski (Gaudym, 2022). In each of these cases, the focus was on media personalities operating in open social media. As can be seen from the analysis, the topic of an athlete's image is relatively often chosen as the basis for theses.

Nowadays, the creation of an athlete's image is mainly based on social media, which is very important in this respect and is visible through interest in clubs, events and sports results. In all of them, the athlete is often the central figure.

Here, the principles of sports marketing apply, where the subject is the athlete, a representative of speedway.

Attention is drawn here to the phenomenon of athletes creating themselves in social media and the emergence of a new category of athletes, namely e-athletes. This approach requires the researcher to accept the fact that the modern world of sport includes not only well-known and media-savvy athletes, but also those who are athletes of a different, more niche category. In the case of e-athletes, on the one hand, the prefix of the name evokes computer and internet connotations, while on the other hand, the core of the name refers to activities traditionally associated with movement and physical effort (Kinal, 2021). Interestingly, athletes themselves also describe issues related to image during their own intellectual development (Ennaoui, Pieniacka, 2025) and raise topics related to media coverage, which are closely linked to image (Łasiński, Pawlukiewicz, 2018; Wesołowska, 2024).

In addition to typical marketing issues in the context of image building, legal issues should also be taken into account. Athletes are products of the modern market, but their image is protected. It is worth noting that there are no specific international legal regulations in this area that would ensure uniformity of rules applicable in individual national legal systems. The key point is that these rules vary greatly, which is related to the deep and historical roots of image issues in the civil law of a given country. In the case of athletes in a global world, it is important to bear in mind that they operate in different legal systems (Król, 2022; Tylec, 2009).

Sport functions on a much broader level than entertainment. Today, it is the result of commercialisation, which means that it has transformed into a business that needs public interest to ensure financial stability. The authorities of major sports disciplines must adapt their activities to the demands of society and the media. Athletes must also submit to these constraints (Safin, 2024). An example of this is the ostracism and even ban on supporting Russian initiatives after Russia's aggression against Ukraine in 2022.

The following section will present theoretical issues concerning the connection between an athlete's image and social media and public relations in the light of a review of foreign literature sources.

2. The relationship between an athlete's image and social media and public relations

The earlier mentioned terms refer to the interest in the image of athletes by Polish authors. In foreign literature, there is slightly less thematic diversity. Less attention is paid to specific athletes, and more to model solutions and the connection between image and public relations management and branding. An athlete's image and brand are built by combining unique and recognisable sets of associations and characteristics that create a specific brand image. An emotional bond with the audience is particularly effectively built through communication

in social media, which are inseparable and constitute one of the basic mechanisms of personal brand building. According to the Athlete Brand Image Model (ABIM), we distinguish three most important dimensions of brand image: sporting results, attractive appearance and attractive lifestyle.

In this context, it is also important to link this to public relations management. The activities of this promotional tool combine management tools such as: the use of various forms of communication aimed at identifying common views or interests of different groups; contributing to the development of partnership-based and friendly relations between social services, clients and the public; ensuring mutual understanding based on truth and full social awareness; and ultimately shaping positive public opinion and a favourable image (Akhmadieva et al., 2021).

Public relations in sport is defined as a function based on management communication, aimed at identifying key audience segments of a sports organisation, assessing its relations with these segments and supporting desirable relations between the sports organisation and these segments. Nowadays, it is not only the quality of the competition that is important, but also the way in which a sports organisation or club presents itself to the public. In order to implement effective strategic public relations, sports organisations should understand the expectations and behaviours of their audience and various stakeholder groups (Halemba et al., 2013). "Public relations specialists take into account the complex sports value chain and strategically manage communication and the image of celebrities, from their inception to communication with fans.

The specific goal of public relations in sports organisations is to strengthen the relationship between the organisation and its stakeholders" (Constantinescu, Serbanica, 2016).

When building an image, one of the main stages in developing an organisation's marketing strategy may be to define its main objectives. The main objectives of public relations in sport include:

- building consumer confidence in the club or sports organisation and sports equipment manufacturers,
- gaining credibility in terms of the quality of sporting events and equipment technology,
- attracting new spectators and participants to events,
- increasing attendance at matches,
- stimulating public support for specific sporting events,
- transferring the reputation of the sports brand to partners and sponsors.

In addition, professional crisis management is extremely important in a sports organisation. It is used when the organisation's image needs to be improved, for example as a result of hooliganism during matches, racism, financial crisis, internal conflicts, referees' decisions or doping (Sznajder, 2012).

An athlete's image is a derivative of their personal image, communication management through social media, and the management of promotional tools, such as public relations. This is because athletes are part of a larger organisation and their image affects the image of the whole. This is well illustrated by the example of Argentine athletes named the best ambassadors of their country (Hemeury, 2023).

It is worth noting that creating an athlete's image is now easier thanks to social media, which facilitates contact with athletes, provided that they are able and willing to manage their own media accounts. These conditions apply to organisations that include social media clauses in their contracts with athletes. Such restrictions result both from the personal characteristics of the athlete and from public relations policy. In today's media world, athletes are positioned as employees who must follow established rules. In creating their image through social media, they are part of a sports organisation with strict rules regarding the behaviour of athletes on the Internet.

Foreign literature on research into the role of social media dates back to 2010, when Twitter became the first platform enabling direct communication between athletes and fans, and the concepts of micro-communication, instant news and authenticity building were introduced (Pegoraro, 2010). Shortly afterwards, the first foundations for research on athlete branding were laid (Arai, 2014), where the authors created the first comprehensive model of “athlete brand image” (ABI), consisting of three components:

1. Athletic performance – achievements, playing style, professionalism.
2. Attractive appearance – physical appearance, recognisability, media presence.
3. Marketable lifestyle – personality, lifestyle, fan relations, media activity.

Social media began to be seen as a new arena for communication, where athletes become interactive media actors and there is a sense of closeness between fans and athletes. The concept of digital intimacy, i.e. a sense of closeness between fans and athletes, was introduced (Kassing, Sanderson, 2012). At the same time, changes in communication style emerged, the impact of sporting success on the brand was defined, and the role of visual storytelling was identified.

Contemporary research focuses on the development of issues related to the image of athletes, social media, and public relations management. This research integrates issues such as fan psychology, perception, image and social media algorithms. It shows that a consistent image translates into increased response, greater fan stability and better sponsor effectiveness. All of these factors ultimately influence fan loyalty and engagement (Constantinescu, Serbanica, 2016).

Many researchers have addressed the topic of social media. In light of the literature review, it should be noted that this tool is related to building relationships between athletes, clubs and fans (Abeza et al., 2013; Filo et al., 2015). The causal relationship between athlete brand communication and the process of communication in social media and the added value of the sports industry has also been studied (Ritnuang, 2025). This highlights the link between the media and the overall communication process.

Another area of research was the role of sports celebrities and champions in the communication policy of sports clubs (Clavio, Kian, 2010; Badaghi, 2021). Their involvement in social media indicated a close relationship between the public relations of a sports organisation and an athlete, as well as an emphasis on creating a sports brand from an athlete (Doyle et al., 2020/2021; Ilievska Kostadinović, Kostadinović, 2025; Nan, 2025; Kunkel, Doyle, 2019).

This review shows that brand creation was carefully planned by the sports organisation, which decided in which direction the athlete's brand could go (Nikseresht et al., 2021), although the autonomous behaviour of athletes on social media was also studied (Xu, 2025), and even patterns of behaviour were sought where the athlete would become an authority figure in the eyes of fans (Rodrigues, Arola-Fernandez, 2024). Recent studies confirm that communication in the context of image, brand and public relations is extensive and occupies an important place in sports management, but its dynamic development means that there are still many research gaps (Pedersen, 2025).

One such research gap is the study of the image of speedway representatives, where the individual image is combined with the image of the club, and athletes represent several clubs and the national team. In this case, it is difficult to draw clear boundaries between personal branding, communication and public relations, but social media remains the common denominator.

3. Research methods

A review of the literature indicates that athletes' behaviour significantly shapes their image in the eyes of fans and the public. This image is a result of public relations management, where athletes consult their behaviour on the internet with their club or sports organisation. Clubs and players are aware of the power of the media and are therefore increasingly turning to a variety of personal branding strategies, from media activity to direct contact with fans. However, it should be emphasised that public perception does not always correspond to the intentions of athletes, as the perception of their behaviour is based not only on facts but also on emotions. For this reason, media messages should be well thought out and balanced.

The image of athletes is created both by their sporting achievements and their attitudes outside of sport. Behaviours such as fair play, teamwork and activity on social media are particularly well received. On the other hand, arrogance, aggressive driving and avoiding contact with fans can have a negative impact on how a player is perceived.

First of all, it should be emphasised that a speedway rider is a specific type of athlete. This specificity stems from the fact that he is simultaneously a competitor for several club teams in different countries and for the national team. Therefore, the image of a speedway rider must

correspond to the various image goals of these clubs and the goals of the national team. For example, the most outstanding speedway rider today – multiple world champion Bartosz Zmarzlik – competes for Orlen Oil Motor Lublin in the PGE Ekstraliga and for the Swedish team Lejonen Gislaved, as well as in national team tournaments. In addition, he is the ambassador for the 4F Polska brand. This requires diverse behaviour and adherence to communication rules. This is evident in social media (Figure 1).

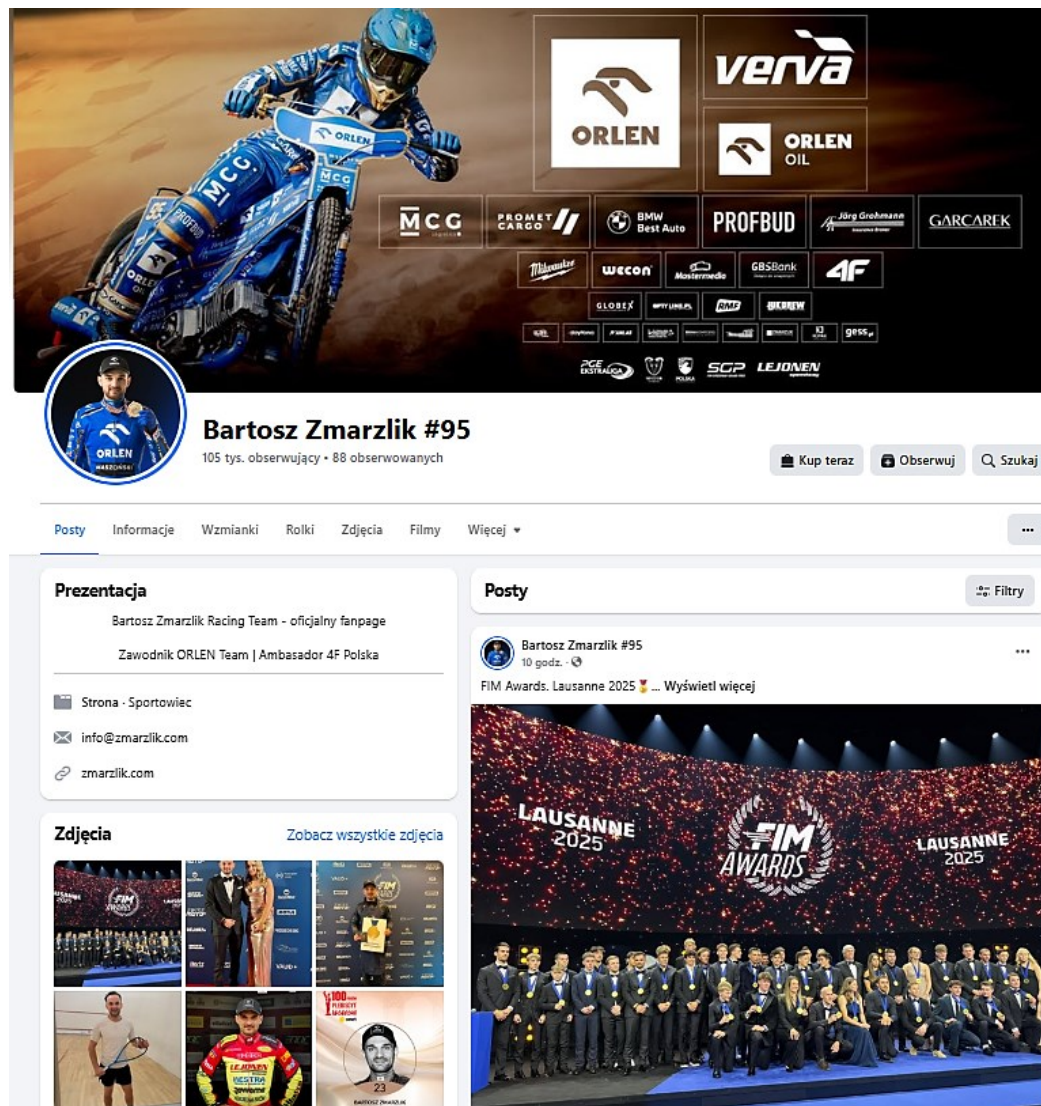


Figure 1. Fanpage of Bartosz Zmarzlik on Facebook.com

Source: <https://www.facebook.com/zmarzlik95>.

The study concerned the image of speedway riders in social media, treated as a group of individuals with different achievements, degrees of popularity and sporting levels. The aim of the study was to determine whether and to what extent specific behaviours of speedway riders affect the assessment of their image by fans. The study was conducted using an online survey (CAWI), and the research tool was a questionnaire. The respondents were fans and observers of speedway, who assessed the riders both in terms of their overall image and specific behaviours relevant from the perspective of public opinion. The sample was selected in a non-

random, typical manner, which allowed us to focus on a group of recipients particularly involved in this discipline.

Athletes' public image is shaped by both their sporting achievements and their conduct outside the sport. It is particularly positive when sporting achievements align with their attitude towards fans, personal image, professionalism, treatment of sponsors and self-presentation.

The data obtained was subjected to statistical analysis in order to verify the relationship between the variables under study. The chi-square independence test was used for the calculations, which allows us to check whether the distribution of image ratings differs significantly depending on the declared behaviour of speedway riders. In this case, a null hypothesis was proposed, which assumes that the selection of individual image elements does not result in a higher rating for sporting elements. The alternative hypothesis, on the other hand, assumed that the selection of individual image elements results in a higher rating for sporting elements.

The calculation procedure involves presenting the observed frequencies in the form of a contingency table, in which respondents' answers are counted for individual variable categories. Based on the contingency table, a table with expected (theoretical) frequencies was created, analogous to the table with observed frequencies. Expected frequencies are calculated on the assumption that the variables are independent (Słowińska, 2019).

The individual expected frequencies indicate how many respondents should represent a given research condition, i.e. a given combination of variable categories, in order to fully satisfy the postulate of variable independence presented in the null hypothesis.

For further analysis, theoretical data were determined for each cell according to the following formula:

$$n'_{ij} = \frac{n_i * n_j}{\sum_{i,j=1}^n n_{ij}} \quad (1)$$

where:

n_i – is the marginal value of rows and

n_j - marginal value of columns j ,

$\sum n_{ij}$ - sum of all observations.

In the further part of the procedure, theoretical frequencies were used with the observed ones to calculate the empirical chi-square statistic, according to the formula:

$$\chi^2 = \sum_{i=1}^k \sum_{j=1}^s \frac{(n_{ij} - n'_{ij})^2}{n'_{ij}} \quad (2)$$

When calculating the value of the χ^2 statistic, for the sake of clarity, you can also create a table with the individual components of the χ^2 statistic (calculations according to the fractional notation). Then, after calculating the individual components of the statistic, add up all the component values. The result of this operation is the value of the χ^2 statistic.

The final stage of verifying statistical hypotheses with the χ^2 test is to compare the calculated value of the empirical statistic with the critical value. The critical values for the accepted level of significance (usually 0.05) and the corresponding degrees of freedom are read from special chi-square distribution tables.

The degrees of freedom (df) for the variables under study are determined by multiplying the number of rows by the number of columns minus 1, i.e. degrees of freedom = $(r-1)*(k-1)$.

1. Hypotheses are verified on the basis of the χ^2 and χ^2_{α} values. In the χ^2 independence test, there are null and alternative hypotheses, formulated as follows:
2. Hypothesis zero: the variables under study are independent.
3. Alternative hypothesis: the variables under study are dependent.

If the calculated χ^2 value is less than the critical value, there are no grounds for rejecting the null hypothesis, i.e. the variables are independent, whereas in the opposite situation, the null hypothesis should be rejected, which means that the variables under study are dependent. The χ^2 independence test is not used to assess the strength and direction of the relationship between variables. Based on the result obtained, we only determine whether there is a relationship or not. In order to determine the strength of the relationship, one of the available correlation measures should be determined, e.g. the V-Cramer coefficient. The V Cramer coefficient is used for multi-part tables and is expressed by the formula:

$$V = \sqrt{\frac{\chi^2}{n(m-1)}} \quad (3)$$

where:

V - V-Cramer's coefficient,

χ^2 - chi-square test result,

n - number of observations,

m - the smaller of the numbers k and l determining the number of rows and columns.

After substituting the numbers into the equation, a value between 0 and 1 is obtained, and the closer to zero, the more independent the characteristics are.

4. Research methods

The table contains empirical (observed) data, presented in the form of a contingency table. The calculations are based on assessments of the impact of individual elements, expressed as the level of significance of a given factor. Respondents first answered the question about what influences the image of a speedway rider, and then determined the strength of that element. The most frequently selected element shaping the image was the sporting level (120 responses), followed by personal image (82 responses) and activity on social media (63 responses). Slightly fewer respondents considered organisational professionalism, loyalty to sponsors and self-presentation to be image-shaping factors (47, 53 and 42 responses, respectively). The selected factors were correlated with the assessment of their strength of influence on the image. Here, as many as 75% of respondents rated it highly (at 4 and 5 on a five-point scale), meaning that most of these behaviours and interactions are important for the image.

This raised a research problem of determining whether the assessment of image elements is independent of these elements, i.e. whether they can be treated separately.

Table 1.

Assessment of elements of speedway riders' image

Image elements/Ratings	Very important factor	Important factor	Medium important factor	Not very important factor	Unimportant factor	Total
Sporting achievements	42	54	18	4	2	120
Organisational professionalism	18	25	3	1	0	47
Personal image	30	38	11	1	2	82
Social media activity	27	20	13	1	2	63
Loyalty to sponsors	17	27	6	1	2	53
Self-presentation	14	21	7	0	0	42
Total	153	189	61	10	9	422

Source: Own work based on research.

Table 1 identifies the elements that influence the image of a speedway rider and assigns them a level of significance. These elements are divided into those related to sport and sporting discipline (sporting achievements, organisational professionalism, loyalty to sponsors) and individual elements (personal image, social media activity, self-presentation). The data was processed using the chi-square test to verify the hypothesis that the level of significance is independent of the elements influencing the image. For further analysis, theoretical data were determined for each cell (Table 2).

Table 2.*Theoretical frequencies of speedway riders' image element ratings*

Image elements/Ratings	Very important factor	Important factor	Medium important factor	Not very important factor	Unimportant factor	Total
Sporting achievements	43,51	53,74	17,35	2,84	2,56	120
Organisational professionalism	17,04	21,05	6,79	1,11	1,00	47
Personal image	29,73	36,73	11,85	1,94	1,75	82
Social media activity	22,84	28,22	9,11	1,49	1,34	63
Loyalty to sponsors	19,22	23,74	7,66	1,26	1,13	53
Self-presentation	15,23	18,81	6,07	1,00	0,90	42
Total	153	189	61	10	9	422

Source: Own work based on research.

In accordance with the chi-square test procedure, the theoretical and observed frequencies were used to calculate the empirical chi-square statistic. The calculations are summarised in Table 3.

Table 3.*Table of squares of differences between theoretical and empirical values*

Image elements/Ratings	Very important factor	Important factor	Medium important factor	Not very important factor	Unimportant factor
Sporting achievements	0,05	0,00	0,02	0,47	0,12
Organisational professionalism	0,05	0,74	2,12	0,01	1,00
Personal image	0,00	0,04	0,06	0,46	0,04
Social media activity	0,76	2,39	1,66	0,16	0,32
Loyalty to sponsors	0,26	0,45	0,36	0,05	0,67
Self-presentation	0,10	0,25	0,14	1,00	0,90

Empirical value: $\chi^2 = 14,67$.

Source: Own work based on research.

The empirical statistics were compared with the theoretical statistics from the chi-square distribution tables with the appropriate degrees of freedom. In this case, the number of degrees of freedom will be 20, because $(6-1) \cdot (5-1)$, and the confidence level will be 0.95. The theoretical statistics from the chi-square distribution tables with 20 degrees of freedom and a significance level of 95% is 31.4104.

The Cramer's coefficient calculated for these data was 0.16, which indicates a low correlation between the elements influencing the image of a speedway rider.

The empirical statistic is $\chi^2 = 14.67$ and is smaller than the theoretical statistic (31.4104). Therefore, there are no grounds for rejecting the hypothesis of independence of characteristics with the given probability (0.95). Based on this result, it can therefore be concluded that, with a 95% probability, the image elements do not affect the level of existence. The lack of grounds for rejecting the null hypothesis indicates that individual characteristics do not directly determine image ratings. The factors can be treated separately. The assessments are holistic in nature – fans and observers formulate them on the basis of the overall image of the players, rather than individual behaviours or characteristics. The assessments are therefore

multidimensional and general, and do not refer to specific elements of the speedway riders' image.

It is also worth noting that social media was the most important element of image. This is a factor where the number of responses in the 'Very important factor' category exceeded the number of responses in the 'Important factor' category. The role of social media in image creation has therefore been confirmed.

5. Discussion

The research conducted allowed us to formulate several key conclusions regarding the image of speedway riders and the factors shaping its perception in public opinion.

Firstly, the results indicate that the overall image of speedway riders is perceived positively by the vast majority of respondents.

Secondly, the respondents see speedway riders as ambassadors of sport and a positive image of Poland on the international stage. Over 70% of respondents confirmed that speedway riders represent not only their discipline, but also Polish sport as a whole. This shows that successes achieved on the international stage have a significant impact on creating a positive image of the riders.

Thirdly, it should be noted that the overall image of speedway riders is positive, but its perception is multidimensional and does not always result from a rational analysis of specific behaviours. This happens both in the real and virtual worlds. Opinions are also influenced by emotional factors related to club affiliation, the atmosphere of the competition, and the individual preferences of fans. This opens up opportunities for clubs and sports organisations, which should control the behaviour of athletes through public relations management activities. This can be done through specific provisions in player contracts regulating the rules of speedway riders' presence in social media.

In summary, research confirms that the image of speedway riders is generally positive and stable, and that shaping it requires consistent and long-term efforts. Although individual elements, such as media activity or self-presentation, do not directly translate into fan ratings, they contribute to the overall image of the riders and can play a supporting role in the long term. The results of the research also indicate that in order to further strengthen the image of speedway as a discipline, it is important to maintain a high level of sportmanship and emphasise values such as fair play, professionalism and openness to contact with fans. This is the role of communication and public relations management, where social media, which is still very important to fans, should play a major role.

The findings of this article do not contradict other publications, but may serve as a starting point for further research on the behaviour of athletes treated individually or in the context of clubs and national teams.

The article does not present any changes to the detailed public relations strategy for speedway riders, but it does show that in their case, the classic approach to public relations strategy needs to be modified. This is due to the internationalisation of athletes and their reduced attachment to their clubs. A speedway rider is an athlete who works for several clubs during the season, in different countries and in national teams. Their cosmopolitanism requires the club and the national team to adopt strategies that go beyond standard public relations. The article showed that individual elements, such as media activity or self-presentation, do not have a direct impact on fans' assessments, and should therefore be excluded from public relations strategies. This is important for this strategy because neither the player's clubs nor the national team have a decisive influence on what the athlete posts on social media or how he creates his own image. Going deeper, they can only use legal measures (contract provisions) to correct what is unacceptable to them. In other team sports, the player is almost completely subordinate to the club and its public relations, while in speedway, the athlete is an independent employee (and often an employer) whose relationship with a particular club is looser. Other athletes are more attached to their clubs. Other athletes are more attached to their clubs. The difference stems from the task-oriented nature of speedway riders' work, which focuses mainly on results, without involvement in club life, contact with fans, and limited sponsorship obligations.

The research is part of a larger study and may serve as an introduction to a more detailed examination of the relationship between the media, communication and public relations management.

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GREEN TRANSFORMATION AND ORGANIZATIONAL RESILIENCE IN THE PACKAGING INDUSTRY: CHALLENGES AND BARRIERS

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Purpose: The purpose of this paper is to examine the role of organizational resilience in the green transformation of the packaging industry, with particular emphasis on barriers that limit the pace and effectiveness of this process.

Design/methodology/approach: This study draws on an examination of academic literature, regulatory documents, and sectoral reports related to sustainable development and the circular economy.

Findings: The study identifies key barriers to the green transition: the high costs of innovative materials and technologies, limited availability of alternative raw materials, infrastructural shortcomings in recycling, regulatory uncertainty, and the risk of greenwashing. SMEs, which numerically dominate the industry yet operate with constrained financial, technological, and human resources, are particularly vulnerable to these challenges. Such limitations reduce their adaptive capacity and may lead to market concentration in favor of larger players, thereby weakening the overall resilience of the sector.

Practical implications: Overcoming barriers to ecological transformation requires coordinated actions: investment in innovation and infrastructure, supportive regulatory frameworks, and promotion of digital solutions. For business practice, this means that green transformation should be perceived not only as a compliance burden but also as a strategic opportunity to strengthen resilience and competitiveness.

Social implications: The successful implementation of sustainable packaging solutions can reduce environmental risks, foster consumer trust, and support the transition toward a circular economy, thereby contributing to broader societal goals of sustainability and climate mitigation.

Originality/value: This paper contributes to the debate on organizational resilience by linking it explicitly with the green transformation of the packaging industry. It provides a comprehensive overview of sector-specific barriers and emphasizes the strategic importance of resilience as both a precondition and an outcome of ecological transition. The study is particularly relevant to policymakers, industry practitioners, and scholars interested in sustainability management.

Keywords: organizational resilience; green transformation; sustainable packaging; packaging industry; barriers.

Category of the paper: General review.

1. Introduction

Contemporary organizations operate in an environment characterized by high dynamics of change, uncertainty, and increasing regulatory and social pressure. In particular, companies from resource-intensive industries, such as the packaging sector, face the necessity of adapting to new realities related to climate transition, sustainable development requirements, and disruptions in global supply chains (Bocken et al., 2014; Geissdoerfer et al., 2017; Niero, Hauschild, 2017). These conditions require not only incremental improvements in efficiency but also profound organizational and technological transformations that redefine existing business models.

Packaging plays a key role in the modern economy, serving multiple functions simultaneously: protective, logistical, marketing, and informational. It secures products during transport and storage, extends their shelf life, and provides consumers with essential information on quality, safety, and sustainable origin (Wikström et al., 2019; Chan, 2022). Particularly in the food and pharmaceutical industries, packaging is a prerequisite for ensuring health safety and reducing losses, which would be significantly higher without proper protection (Alamri et al., 2021; Lv et al., 2025). At the same time, from a market perspective, packaging is increasingly perceived as a carrier of innovation and a tool for building competitive advantage (Nordin, Selke, 2010). This wide range of functions makes the packaging sector one of the most strategic areas of the modern economy, but also one of the most exposed to environmental and regulatory pressures.

The packaging industry is among the most strategic areas of the contemporary economy. According to estimates, its global value reached approximately USD 1080 billion in 2024 and may grow to USD 1452 billion by 2032, with an average annual growth rate (CAGR) of 3.9% (Fortune Business Insights, 2024). Eurostat (2023) reports that in the European Union, around 84 million tons of packaging were placed on the market in 2021, of which nearly 41% consisted of paper and cardboard, 19% of plastics, 19% of glass, and 16% of metals. While recycling rates in the EU are relatively high (averaging around 65%), they differ significantly across materials: over 80% for paper and metals, about 75% for glass, but only 40% for plastics (Eurostat, 2023). These figures highlight the growing regulatory and market pressure for the packaging sector to evolve toward a circular economy and climate neutrality.

A key process defining modern management in the packaging sector is the green transition, understood as the implementation of strategies and technologies leading to climate neutrality, minimization of environmental impact, and resource circularity. In light of strategies such as the European Green Deal, Fit for 55, and the Packaging and Packaging Waste Regulation (PPWR), the role of packaging companies is becoming not only productive but also transformative (European Commission, 2022). At the same time, increasing importance is attached to organizational resilience, understood as the ability to flexibly and proactively

respond to disruptions, unpredictable changes, and crisis situations. As Ducheck (2020) points out, organizational resilience is not merely a passive survival capability but an active process of learning, adaptation, and innovation. Particularly in the packaging sector, exposed to fluctuations in raw material prices, legislative changes, and consumer pressure, combining resilience with green transition is emerging as a key strategic challenge.

Although sustainable packaging, circular economy practices, and organizational resilience have been widely discussed in the literature, these issues are typically examined separately. Existing studies tend to focus either on environmental innovations and eco-design solutions, or on resilience from a general management or supply chain perspective. Relatively little attention has been paid to how the green transition in the packaging sector specifically shapes companies' adaptive capacity and what structural, technological, and regulatory barriers may limit this process. This fragmentation reveals a research gap concerning the integrated analysis of sustainability transformation and organizational resilience at the sectoral level.

The aim of this article is to analyze the challenges associated with the green transition in the packaging sector and their impact on organizational resilience. The study adopts a qualitative, review-based approach grounded in the analysis of scientific literature, policy documents, and industry reports to synthesize existing knowledge and identify critical determinants of adaptation. The remainder of the paper is structured as follows. Section 2 presents the theoretical background and literature on sustainable packaging and resilience. Section 3 describes the research methodology. Section 4 presents the results of the analysis in the form of identified challenges and barriers. Section 5 discusses the findings in relation to existing studies and outlines implications for theory and practice, followed by conclusions.

2. Organizational Resilience and Ecological Transformation in the Packaging Industry

In contemporary contexts, organizational resilience is emerging as a key capability enabling not only survival but also the development of firms under conditions of disruption and external pressures. It is defined as the ability of a company to effectively anticipate disturbances, cope with them, and adapt rapidly. Resilience is conceptualized as a complex, dynamic meta-capability encompassing both the ability to respond to sudden crises and to learn and evolve as a result (Linnenluecke, 2017; Ducheck, 2020; Hillmann, Guenther, 2021).

Ducheck (2020) identifies three stages of the resilience process: anticipation, coping, and adaptation. Together, these enable organizations to function effectively in uncertain and turbulent environments. Both cognitive capabilities (e.g., risk analysis) and behavioral capabilities (e.g., implementing change) play a central role, pointing to the necessity of a comprehensive approach to resilience management (Williams et al., 2017). Resilience should

not be understood as a one-time reaction to crisis, but rather as a dynamic process of learning, reorganization, and the strategic use of available resources and knowledge.

The literature distinguishes between two complementary types of organizational resilience: planned resilience and adaptive resilience. Planned resilience refers to the deliberate design of structures, procedures, and strategies intended to protect the organization from disruption. This is a systemic approach, focused on risk identification and the preparation of contingency plans (Linkov, Palma-Oliveira, 2017; Barasa et al., 2018). An example in the packaging sector is the adjustment of production processes to comply with EU regulations requiring that all packaging be fully recyclable by 2030. Companies that invest in alternative materials, recovery technologies, and modernization of production lines in advance are demonstrating planned resilience. In contrast, adaptive resilience refers to an organization's ability to flexibly respond to sudden, unpredictable events. Its essence lies in rapid learning, improvisation, and the reorganization of resources in response to crises (Barasa et al., 2018). A good example from the packaging sector was the set of measures undertaken during the COVID-19 pandemic, which forced a rapid increase in the production of unit and hygienic packaging, reconfiguration of supply chains, and the introduction of additional product safety measures. In practice, both types of resilience – planned and adaptive – complement one another, forming the foundation of long-term resilience in the packaging sector.

New approaches to building organizational resilience highlight the importance of integrating three key areas: digitalization, security, and innovation. Tarapata and Woźniak (2022) refer to these as the “organizational resilience triangle”, which constitutes the basis for ensuring business continuity and adaptive capacity. Digitalization enables the streamlining of operational processes, more effective data management, and faster responses to disruptions through technologies such as ERP systems, artificial intelligence, and predictive analytics. Security, encompassing both physical and cyber domains, is critical for minimizing the risk of failures, crises, or data loss. Innovation, in turn, paves the way for new business models, the implementation of ecological solutions, and the development of products tailored to market needs.

The packaging industry is currently one of the most innovative and digitally advanced sectors of manufacturing. Increasingly, solutions from the fields of smart packaging and connected packaging, based on digital technologies such as IoT sensors, QR codes, and blockchain-based tracking systems, are being adopted. These technologies enable monitoring of product life cycles, improved supply chain security, and greater transparency for consumers (Towards Packaging, 2025). The digitalization of production processes, data management, and logistics has become a fundamental tool for strengthening organizational resilience, allowing for faster disruption detection and more efficient resource utilization. At the same time, the packaging sector demonstrates a high degree of innovativeness. According to the European Patent Office (2021), packaging accounted for approximately 6% of all bioplastics-related innovations between 2010 and 2019. Companies in the sector allocate

an average of 3% of their revenues to research and development (R&D), exceeding the rates observed in many other manufacturing industries (Damodaran, 2025). Industry reports also forecast dynamic growth in these segments: Grand View Research (2023) projects the smart packaging market to grow at a CAGR of 6.2% between 2024 and 2030, while Mordor Intelligence (2025) predicts the green packaging market will expand at a CAGR of 7.37% over the 2025-2030 horizon.

3. Sustainable Packaging and Green Transformation as the Foundation of Organizational Resilience

The ecological transformation of the packaging industry currently constitutes one of the key processes shaping the competitiveness and long-term stability of enterprises. Changing legal regulations, increasing societal pressure and consumer expectations, as well as global challenges associated with the climate crisis and limited resource availability, position the packaging sector at the core of the green transformation. Its central element is sustainable packaging, which functions both as an instrument for achieving environmental goals and as a source of competitive advantage and organizational resilience.

The concept of sustainable packaging has evolved alongside the development of regulations, technologies, and stakeholder expectations. As noted by Kozik (2018), definitions proposed by industry organizations such as the European Organization for Packaging and the Environment and the Sustainable Packaging Alliance identify five areas constituting the idea of sustainable packaging (Figure 1):

- environment – minimizing the negative impact of packaging across its life cycle,
- society – meeting the needs of users,
- economy – optimizing the costs of production, distribution, and end-of-life management,
- time – accounting for long-term environmental consequences for future generations,
- development – supporting innovation and the competitiveness of enterprises.



Figure 1. Five Core Areas of Sustainable Packaging.

This concept is not static; it is dynamically evolving in response to new technologies, regulations, and market needs. Packaging development is a continuous, dynamic process, open to new solutions, without the possibility of achieving a single universal end model. In this sense, sustainable packaging aligns with the logic of innovation while simultaneously reinforcing the need to build organizational resilience: companies must be capable of flexible responses, continuous learning, and adaptation in order to maintain competitiveness in a volatile market environment (Kozik, 2018).

In this context, ESG strategies are gaining importance as they structure corporate activities and strengthen adaptive capacity. Research shows that organizations pursuing consistent environmental, social, and governance strategies are better able to anticipate regulatory, environmental, and reputational risks (Broadstock et al., 2021; Wang et al., 2023). Within the packaging industry, EU regulations – particularly the proposed Packaging and Packaging Waste Regulation (PPWR) – play a pivotal role, as they will enforce significant sectoral changes, compelling firms to adapt to new legal and environmental requirements. This necessitates strategic flexibility, the ability to adjust technological processes, business models, and stakeholder communication to a dynamically shifting regulatory environment. Companies that treat regulations not as barriers but as catalysts for transformation thereby gain long-term resilience and competitive advantage.

A particularly significant element in this process is the circular economy, within which the reduce-reuse-recycle (3R) model plays a central role, enabling resource consumption reduction, extension of product and material lifecycles, and minimization of waste. From the perspective of organizational resilience, the implementation of 3R principles strengthens not only environmental efficiency but also operational stability – by reducing dependence on unstable raw material supplies and fluctuating material prices, while lowering the risk of production

interruptions (Zapłata et al., 2024). Thus, the circular economy becomes not only an instrument of environmental protection but also a source of strategic resilience and adaptive flexibility for enterprises.

Ecological transformation, understood as the transition toward a low-emission, circular, and ESG-compliant economy, represents both a challenge and an opportunity for the packaging sector. Its effective implementation requires risk anticipation, operational flexibility, and strategic adaptability – competencies that lie at the very foundation of organizational resilience. Industry analyses indicate that green strategies enhance flexibility and innovativeness, thereby strengthening firms' resilience (Ayming, 2024). At the same time, they enable the creation of new sources of competitive advantage based on reputation, customer trust, and stakeholder loyalty (Bojewska, 2024). Investments in innovations in the field of sustainable packaging not only reduce environmental risks but also build the foundations for long-term development in a dynamic and evolving environment. bles, figures and formulas – continuous numbering in the text.

4. Methods

This study adopts a qualitative, exploratory research design based on desk research and a narrative literature review. Such an approach is appropriate for conceptual and review-oriented studies that aim to synthesize dispersed knowledge, identify patterns, and systematize complex phenomena rather than to test hypotheses through quantitative or experimental methods. Given the multidimensional and evolving nature of sustainable packaging and organizational resilience, an integrative analysis of academic, regulatory, and sectoral sources allows for a comprehensive understanding of both theoretical developments and practical constraints.

The research process relied exclusively on secondary data. The empirical material consisted of three main categories of sources:

1. peer-reviewed academic publications concerning organizational resilience, sustainable development, circular economy, and sustainable packaging,
2. regulatory and policy documents at the European and international levels, including strategies, directives, and regulations shaping the environmental obligations of the packaging sector (e.g., the European Green Deal and the Packaging and Packaging Waste Regulation – PPWR),
3. sectoral reports, statistical databases, and market analyses prepared by public institutions and industry organizations (e.g., Eurostat, consulting reports, and industry outlooks).

The selection of materials followed purposive and relevance-based criteria. Sources were included based on their topicality, scientific credibility, direct relevance to the research objective, and their contribution to understanding environmental, technological, and organizational determinants of the packaging sector's green transition. Particular attention was paid to recent publications and documents reflecting current regulatory and market conditions. The review was not conducted according to a formal systematic review protocol; instead, it followed a flexible, iterative search and selection process typical of narrative reviews, enabling the inclusion of diverse and context-specific evidence.

The collected materials were analyzed using qualitative document analysis and thematic content analysis. First, key concepts and recurring themes were identified, including definitions of sustainable packaging, regulatory pressures, technological constraints, cost barriers, and organizational resilience mechanisms. Second, the evidence was compared and synthesized to categorize the main challenges and barriers affecting the sector. Finally, relationships between sustainability-oriented practices and organizational resilience were interpreted to develop an integrated conceptual framework explaining how green transformation influences firms' adaptive capacity.

This methodological approach enables a holistic and interdisciplinary perspective and facilitates the integration of insights from different types of sources. However, it also has limitations. As a narrative and non-systematic review, the study may involve a degree of subjective interpretation and selection bias. Moreover, the analysis is based on secondary data and does not include primary empirical research. Therefore, the findings should be understood as analytical and conceptual contributions rather than statistically generalizable results.

5. Challenges and Barriers in the Green Transformation of the Packaging Sector – Results

The green transformation in the packaging industry is a complex process, requiring enterprises to implement technological innovations while continuously adapting to rapidly changing regulations and growing market expectations. The analysis of the reviewed sources indicates the presence of multiple barriers that affect the pace and scope of this transformation. However, organizations face a range of barriers that significantly hinder the development of organizational resilience. The most important include high implementation costs of new solutions, limited availability of alternative raw materials, technological and infrastructural barriers, regulatory uncertainty, and the risk of greenwashing.

One of the key challenges is the cost of implementing sustainable solutions, such as biodegradable materials, recovery systems, and investments in research and development. Alternative raw materials, such as PLA and PHA, are still characterized by higher production

costs and limited scale – particularly compared to conventional plastics – which significantly restricts their adoption (Naser et al., 2021; Gundlapalli, Ganesan, 2025). PLA and PHA require further technological improvements and adequate infrastructure to become economically competitive and widely used in packaging applications. A lack of economies of scale – stemming from insufficient production volumes – renders their prices unstable and supply chains vulnerable to disruptions. The limited number of suppliers and low-quality standardization of bio-based materials further increase costs and operational risks for packaging producers (Shah, Gangadeen, 2023; Börner, Zinn, 2024). At the value chain level, additional costs arise from the integration and harmonization of activities with subcontractors, recyclers, and transport companies, complicating systemic implementation of the circular economy (Cerqueira-Streit et al., 2023; Stumpf et al., 2023).

Traditional bioplastics also often fail to meet visual, hygienic, or durability requirements comparable to conventional plastics (Abe et al., 2021), limiting their application in industries with stringent quality standards. Moreover, their deployment requires costly investments in infrastructure, restructuring of production processes, and adaptation to evolving regulations and standards, which places a particular burden on SMEs (Brendzel-Skowera, 2021; Schwarz, 2023). As a result, the introduction of bioplastics is often perceived as a costly and high-risk process that demands strategic vision and adaptive change management (Cerqueira-Streit et al., 2023; Stumpf et al., 2023).

High capital expenditures are also associated with the development of chemical recycling technologies and closed-loop material systems (McKinsey & Company, 2019), which, although promising, remain economically unviable in the short term. Additionally, compostable or biodegradable packaging often ends up in mixed waste streams because local facilities lack composting chambers or installations adapted for safe decomposition (Kaiser et al., 2018; European Environment Agency, 2023; U.S. Environmental Protection Agency, 2021). The absence of clear standards for compostability – for instance, differences between home and industrial composting – creates confusion among both producers and consumers, leading to mismanagement of packaging waste (European Parliament, 2023; U.S. Environmental Protection Agency, 2021).

Another major barrier in the packaging industry's green transformation is the set of technological and infrastructural limitations associated with recycling. A large proportion of packaging, especially in the food sector, has multilayered structures (e.g., plastic-aluminum laminates), which makes sorting, separation, and processing significantly more challenging (Schmidt et al., 2022). In practice, this means that despite sustainable design initiatives, many packages are not effectively recycled. The lack of standardized sorting systems, variations in waste management infrastructure across countries, and limited availability of advanced installations such as chemical recycling plants, result in a significant share of packaging still ending up in landfills or incineration. Furthermore, despite rapid technological progress,

chemical recycling processes remain costly and inaccessible to many SMEs (European Environment Agency, 2024).

A further challenge lies in adapting to shifting legal frameworks. Although the European Union has introduced multiple legislative initiatives – such as the Packaging and Packaging Waste Regulation (PPWR) and the Single-Use Plastics Directive (SUP) – their interpretation and implementation vary significantly across member states. Some countries have adopted stricter regulations, while others still lack appropriate implementing measures. This inconsistency creates regulatory uncertainty, complicating investment planning and long-term strategic development in sustainable packaging. Producers often operate under legal instability, unsure which packaging formats will remain compliant in the future, which discourages investment in innovation (Geissdoerfer et al., 2017; Forest.fi, 2023; Baker McKenzie, 2025). Another complication is the fragmented and unclear implementation of Extended Producer Responsibility (EPR). While EPR in theory requires producers to assume full responsibility for packaging lifecycles, in practice systems are inconsistently applied, and settlement mechanisms across operators and industries lack transparency. The absence of harmonized eco-modulation fees means that environmentally friendlier solutions are not always rewarded with lower costs (OECD, 2021). For firms operating across multiple European markets, divergent national regulations increase compliance costs and hinder the adoption of standardized international solutions. The lack of regulatory stability and predictability reduces companies' willingness to make long-term environmental investments, thereby weakening the effectiveness of the industry's ecological transition.

An increasingly important challenge in the green transformation process is the growing risk of greenwashing – that is, practices that create the appearance of environmental responsibility without substantive changes to production or waste management. With rising consumer awareness and pressure from regulators and investors, many companies intensify their environmental communication, but such claims are not always supported by verifiable data or audited indicators. Ambiguous labels such as “eco”, “bio”, or “environmentally friendly”, which are neither standardized nor certified, often mislead consumers. Research shows that consumers can quickly detect inconsistencies in brand messaging, leading to declines in trust, reputation, and sales (Delmas, Burbano, 2011; Lavuri, 2022; Wang, 2023). The problem is exacerbated by the lack of consistent regulations on environmental claims. Although the EU is preparing the Environmental Claims Directive (so-called “green claims”), clear verification requirements are not yet in place. As a result, firms may employ green marketing slogans without providing objective evidence (European Commission, 2025). Such practices undermine consumer trust in the entire sector and distort fair competition, as companies genuinely investing in sustainable solutions may be disadvantaged against those engaging in greenwashing. To counteract these risks, companies should adopt transparent environmental communication strategies based on measurable indicators (e.g., CO₂ emissions, recycled material share, biodegradability) and established standards such as ISO 14021, the EU Ecolabel,

or ESG reporting, which ensure independent verification and comparability of data (Szopik-Depczyńska et al., 2022).

SMEs are particularly vulnerable to the negative effects of these barriers, as they make up the majority of firms in the EU (Eurostat, 2024). In Poland, for example, around 90% of enterprises in plastics processing are SMEs, which often operate with limited resources and have lower capacity to invest in innovations, recycling technologies, or alternative materials (Poland Insight, 2025). High costs of implementing innovative materials, limited access to external financing, and the lack of internal R&D departments mean that smaller firms are frequently unable to meet regulatory requirements or quickly adapt to new technologies (Brendzel-Skowera, 2022). Consequently, SMEs may be more exposed to supply chain disruptions and raw material price fluctuations, directly impacting their operational resilience. Moreover, their lack of production scale hinders the ability to establish partnerships with bioplastic or recycle suppliers, who typically require large and stable orders. SMEs therefore face greater difficulty in building resilience, particularly in anticipating disruptions, ensuring operational stability, and adapting to regulatory changes. This increases the risk of marginalization of smaller firms in the green transformation process and fosters market concentration in favor of larger players capable of absorbing high innovation costs. Ultimately, structural inequalities may weaken the resilience of the entire sector, as excessive dependence on large corporations reduces diversity and flexibility in responding to crises.

Overall, the identified barriers can be grouped into economic, technological, infrastructural, regulatory, and reputational categories. These categories summarize the key challenges documented in the reviewed sources.

6. Discussion

The results of this study provide a comprehensive view of the barriers affecting the green transformation of the packaging sector and their implications for organizational resilience. While previous research has examined sustainable packaging, circular economy adoption, and resilience independently, this analysis integrates these perspectives, highlighting how sector-specific constraints influence firms' adaptive capacity and long-term stability (Geissdoerfer et al., 2017; Niero, Hauschild, 2017). Unlike earlier studies, this paper offers a holistic perspective that considers economic, technological, regulatory, and reputational factors simultaneously.

One key insight is that the green transition is not merely a technical or environmental challenge but also a strategic and organizational one. Although sustainable packaging and circular models are widely recognized for their potential to reduce environmental impacts and generate competitive advantage (Bocken et al., 2014; Kozik, 2018), their implementation

involves substantial costs, infrastructure gaps, and regulatory uncertainty. These constraints can limit firms' investment capabilities, slow innovation, and restrict strategic planning, particularly for resource-constrained SMEs. In this sense, sustainability initiatives can simultaneously serve as drivers of resilience and as sources of vulnerability, depending on organizational context and capabilities.

The findings largely align with previous research on sectoral barriers. High costs and limited availability of bio-based materials, underdeveloped recycling infrastructure, and fragmented regulatory systems have been documented as obstacles to circular packaging practices (Kaiser et al., 2018; European Environment Agency, 2023; OECD, 2021). This study extends the literature by showing that when these barriers interact, they reduce operational flexibility, adaptive capacity, and ultimately the resilience of firms and the sector as a whole (Duchek, 2020; Linnenluecke, 2017).

SMEs emerge as a particularly critical focus. Despite their numerical dominance in the European packaging sector, they are disproportionately affected by the costs and risks of green transformation. Limited financial and technological resources, together with weaker bargaining power in supply chains, constrain their capacity to adopt alternative materials and implement innovative solutions (Brendzel-Skowera, 2022). If smaller firms are unable to adapt, market concentration may increase, reducing diversity and flexibility at the sectoral level. This, in turn, has broader implications for resilience across the entire industry. Supporting SMEs through targeted policy interventions, knowledge transfer, and access to innovation is therefore essential for maintaining sectoral stability.

The reputational dimension also plays a significant role in shaping resilience. The prevalence of greenwashing, as highlighted in the results, illustrates that organizational credibility and transparency are as important as operational and technological capabilities. Companies that fail to provide verifiable evidence of their environmental performance risk eroding consumer trust, undermining brand stability, and limiting long-term resilience (Delmas, Burbano, 2011; Lavuri, 2022). Transparent, evidence-based communication and adherence to recognized standards such as ISO 14021 or ESG reporting are therefore critical components of resilient green strategies.

Overall, the study suggests that organizational resilience and green transformation are interdependent processes. Firms that actively invest in innovation, digitalization, and circular solutions enhance their capacity to anticipate disruptions and adapt to change. Resilience emerges not only as a reactive response to crises but also as a proactive capability that allows firms to leverage sustainability as a source of long-term competitive advantage (Hillmann, Guenther, 2021).

From a practical perspective, these findings underline the need for coordinated investments in infrastructure, regulatory alignment, and support mechanisms, particularly for SMEs. Without systemic measures, the pace and effectiveness of the green transition remain constrained. From a scientific perspective, the study highlights the value of integrating sectoral,

technological, and organizational perspectives to understand the dynamics of sustainable transformation.

These insights provide the foundation for the study's conclusions on how resilience strategies can facilitate green transformation, emphasizing that addressing structural barriers while strengthening adaptive capabilities is essential for ensuring the long-term sustainability, stability, and competitiveness of the packaging sector.

7. Conclusions

The green transformation of the packaging sector is a complex and multifaceted process, shaped by regulatory pressures, technological challenges, market dynamics, and societal expectations. This study demonstrates that economic, infrastructural, and institutional barriers – such as high costs of innovative materials, limited recycling infrastructure, regulatory fragmentation, and reputational risks – directly influence firms' adaptive capacity and long-term organizational resilience.

Organizational resilience emerges as a critical enabler of the green transformation. Companies that invest strategically in innovation, digitalization, and circular economy practices are better equipped to respond to uncertainty, anticipate disruptions, and maintain competitiveness. SMEs, which dominate the sector in terms of numbers but often operate with limited resources, face particular challenges. Supporting smaller firms through policy interventions, knowledge transfer, and improved access to innovation is essential to maintain industry diversity and overall sectoral resilience.

From a practical perspective, these findings underscore the importance of coordinated actions, including investment in infrastructure, harmonization of regulatory frameworks, and promotion of transparent, evidence-based environmental communication. Scientifically, future research should investigate the effectiveness of specific resilience strategies, ESG practices, and digital technologies in enabling successful green transformation.

Overall, the study confirms that green transformation and organizational resilience are mutually reinforcing processes. Addressing structural barriers while strengthening adaptive capabilities is crucial for ensuring the long-term sustainability, stability, and competitiveness of the packaging sector.

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MULTI-CRITERIA OPTIMIZATION OF CUSTOMER SERVICE PROCESSES USING COMPUTER SIMULATION

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Purpose: The aim of this paper is to analyze the impact of service time on the efficiency of a service system in the context of the trade-off between minimizing customer waiting time in a queue and maximizing the utilization rate of service stations.

Design/methodology/approach: The study was conducted using discrete-event simulation in the FlexSim environment. A model of a customer service system with three service stations was developed, where customer arrivals were described by an exponential distribution and service times by a triangular distribution. The modal value of the service time was defined as the decision variable. Multi-criteria optimization was applied using the OptQuest module to identify compromise solutions.

Findings: The results revealed relationships between service time, queue length, and workstation utilization. Compromise solutions were identified, allowing for relatively short waiting times while maintaining a high yet stable level of resource utilization. It was found that excessive workstation loading leads to a rapid increase in waiting time and the number of customers abandoning the system.

Research limitations/implications: The main limitation of the study is the use of simplified modeling assumptions, including a homogeneous customer stream and the lack of direct comparison with analytical queueing models. Future research may extend the model by incorporating additional factors such as customer differentiation, service prioritization, or dynamic resource allocation.

Practical implications: The results can support service managers in planning the number of service stations, defining service time standards, and making decisions related to the organization of customer service processes.

Social implications: Improving the efficiency of customer service systems may contribute to enhanced service quality, reduced waiting times, and lower levels of customer frustration, thereby positively affecting overall customer satisfaction.

Originality/value: The value of the paper lies in the application of a simulation-based optimization approach to the analysis of a service system under realistic operating conditions, including variability in service times and customer behavior. The study provides practical insights for service management and a basis for further research in service process optimization.

Keywords: computer simulation, multi-criteria optimization, customer service process, queueing system, FlexSim.

Category of the paper: Research paper.

1. Introduction

The contemporary service sector is characterized by increasing variability in customer demand and the need for rapid response to client needs. Managing customer flow and optimizing service processes have become key elements shaping the quality of provided services and the competitiveness of organizations (Rosak-Szyrocka et al., 2022; Ingaldi, 2020). In many institutions, such as administrative offices, banks, customer service centers, or public agencies, the main challenge lies in balancing the number of employees involved in service delivery with the dynamically changing number of customers entering the system (Krynke, 2021, 2023a).

In such systems, it is particularly important to reach a compromise between reducing customer waiting times and ensuring the rational use of human and infrastructural resources (Krynke, 2023b; Gonçalves et al., 2025). An insufficient number of service stations leads to longer queues, decreased customer satisfaction, and potential reputational losses for the organization (Ingaldi, Ulewicz, 2019). Conversely, an excessive number of service positions results in underutilized personnel and increased operational costs (Putra et al., 2024).

Simulation tools are increasingly used to analyze and optimize service processes. Simulation makes it possible to reproduce the actual course of a process, assess system behavior under different conditions, and evaluate the effects of organizational changes without interfering with the real object (Beaverstock et al., 2017). One of the widely used environments for modeling service processes is FlexSim, which enables model development, performance analysis, and the execution of optimization experiments (Mou, 2024).

The purpose of this study is to develop a model of a service system with three workstations and to analyze the impact of service time parameters on key performance indicators such as queue length, average waiting time, and workstation utilization rate. The conducted research aims to demonstrate how appropriate management of process parameters can improve the efficiency of service systems and enhance service quality (Nawrocki, Zieliński, 2024; Pachura et al., 2024).

2. Simulation as a tool for analysis and improvement of service processes

Service systems are characterized by variability in both the number of customers and service times, which makes their analysis using traditional deterministic methods often insufficient (Kowalik, Klimecka-Tatar, 2018). In such cases, simulation methods are particularly useful, as they allow for modeling the behavior of systems under realistic conditions, incorporating event randomness and interactions between system components (Álvarez Sánchez, Suárez del Villar Labastida, 2022).

Discrete-event simulation (DES) enables the analysis of customer flow through the system, assessment of resource utilization, and identification of process bottlenecks. This allows not only an accurate reproduction of the current system performance but also testing of potential improvement scenarios without interfering with real-world operations (Pawlak, 2025). As a result, both the costs and risks associated with implementing organizational changes can be reduced.

In practice, simulation is particularly valuable in the service sector, where customer waiting time, resource utilization, and the quality of service interactions are the main factors influencing perceived service quality (Ilk, Shang, 2022). Simulation analysis makes it possible to determine how changes in process parameters, such as the number of service stations, service time, or queue discipline, affect system performance and customer satisfaction.

The FlexSim environment provides tools for both building simulation models and conducting comparative and optimization experiments (Daroń, 2022). Its built-in experimentation module allows the analysis of multiple system configurations, while the use of heuristic algorithms in optimization enables the search for solutions that balance customer waiting time with resource utilization levels (Krenczyk et al., 2018; Laguna, 2011).

In the context of service process analysis, optimization does not usually aim to find a single “ideal” solution, but rather to identify compromise solutions that ensure an acceptable level of service time while maintaining reasonable resource utilization (Kaczmar, 2019). This approach is particularly important in service systems where customer arrivals are inherently irregular and difficult to predict.

3. Model description and simulation assumptions

3.1. Model structure

The simulation model was developed in the FlexSim environment and represents a customer service system consisting of three independent service stations. Customers arrive at the system randomly, following a probability distribution of interarrival times, and are directed to a shared waiting area. Subsequently, each customer is assigned to the first available service station.

The model includes the following components:

- Entry area (Source) – generates customers entering the system.
- Waiting area (shared queue) – represents the space where customers wait for service.
- Three service stations (ServiceDesk1, ServiceDesk2, ServiceDesk3) – each characterized by a specific service time, which may differ among the stations.
- Exit (Sink) – represents customers leaving the system after completing their service.

Additionally, to reflect the aspect of customer satisfaction, a constraint on the maximum acceptable waiting time was introduced. If a customer's waiting time before the start of service exceeds 60 minutes, the customer abandons the queue and leaves the system as a dissatisfied customer. The number of such customers is recorded, and its analysis is presented in the results section.

The spatial layout of the model, including the placement of key system components, is shown in Figure 1.



Figure 1. Layout of service stations in the FlexSim environment.

Source: Own study.

The figure illustrates the visual representation of the customer service system. The entry point generates arriving customers, who then move to the waiting area (displayed as a queue). The three service stations are arranged in parallel, allowing for simultaneous processing of multiple requests. After service completion, customers leave the system through the exit element (Sink). The spatial arrangement and flow design were structured to allow intuitive observation and interpretation of system behavior.

Upon entering the system, each customer moves to the common queue shared by all service stations. When one of the stations becomes available, the next customer in line is automatically assigned to the nearest free operator and begins service.

3.2. Customer flow logic in the ProcessFlow environment

The operational logic of the model was implemented in the ProcessFlow module, which allows for a precise representation of the customer's lifecycle within the system. This logic defines the sequence of events occurring from the moment a customer enters the system, through the service process, to either successful completion or withdrawal after exceeding the acceptable waiting time (Figure 2). The input stream generates “customer” entities, which are directed to a shared queue. Each customer is then either served at the first available workstation or, if their waiting time exceeds the predefined threshold, leaves the system as a dissatisfied customer. Customers who successfully complete the service process exit the system as satisfied customers.

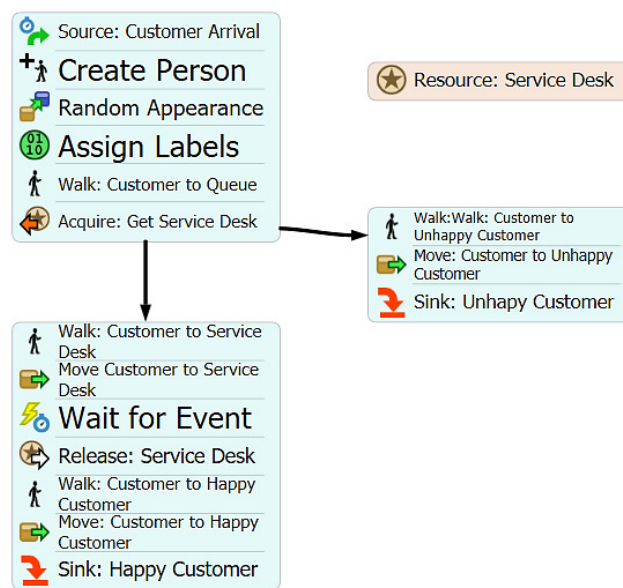


Figure 2. Customer flow diagram in the ProcessFlow module of the FlexSim environment.

Source: Own study.

The ProcessFlow model enables a detailed representation of both the service processes and the decision-making logic governing customer behavior.

Customer arrivals are generated according to an exponential distribution, reflecting the random nature of arrivals in the system:

$$T_{Arrival} = \text{exponential}(0.0, 200, \text{getstream}(\text{activity})) \quad (1)$$

Upon creation, each customer entity is assigned a timestamp label, which allows for the subsequent calculation of total waiting time. The customer is then directed to the shared queue. When a service station becomes available, the customer proceeds to that workstation for service.

The service time at each station is defined using a triangular distribution, where the modal value serves as the optimization parameter:

$$T_{Service} = \text{Triangular}(T_{min}, T_{max}, T_{mode}) \quad (2)$$

where:

$$T_{min} = 200 \text{ s,}$$

$$T_{max} = 900 \text{ s,}$$

$$T_{mode} = \text{optimization parameter (range: 200-900 seconds).}$$

The modal value T_{mode} takes values within the range of 200 to 900 time units, and its variation directly affects both the utilization level of the service stations and the average customer waiting time in the queue.

The modal value was defined in the model parameter table and linked to the service time of operators within ProcessFlow, enabling direct control by the optimization module.

The simulation was executed over a time horizon corresponding to one operational working day, with the duration of a single model run set to 8 hours. This configuration enables the analysis of system performance under typical operating conditions while ensuring result repeatability and comparability across scenarios with varying modal service times.

3.3. System performance criteria and optimization variables

The evaluation of the service system's performance was based on three primary indicators describing its efficiency and service quality.

The first indicator is the average customer waiting time in the queue. This value reflects the operational effectiveness of the system and serves as a key measure of customer comfort. Longer waiting times increase the risk of negative service perception and the formation of service bottlenecks.

The second performance indicator is the utilization rate of service stations, which determines the level of system resource load and indicates whether available workstations are used effectively. Low utilization suggests underuse of personnel and infrastructure capacity, while excessively high utilization can lead to queue growth and the risk of system overload.

The third evaluation criterion is the number of customers abandoning the service process. In the model, it was assumed that if the waiting time exceeds 60 minutes, the customer leaves the system without receiving service, and is thus classified as a dissatisfied customer. This measure serves as an indirect indicator of customer satisfaction and enables the assessment of how system parameters influence service quality and potential customer loss.

Within the optimization process, a single decision variable was defined, the mode of the triangular distribution representing the service time at each workstation. The modal value, interpreted as the most probable service duration, can take values within a specified range. Its variation directly affects the customer service rate, and consequently, the queue length, resource utilization level, and the number of customers who abandon the queue.

The objective of the optimization procedure is to determine the modal value that ensures a balance between minimizing customer waiting time and the number of dissatisfied customers, while maintaining an appropriate level of workstation utilization. Hence, the analyzed problem is of a multi-objective nature, where the result is not a single optimal solution but a set of Pareto-efficient solutions that guarantee balanced system performance.

4. Results and analysis

In order to determine the impact of the modal value of the service time on the performance of the system, an optimization experiment was carried out using the OptQuest module in the FlexSim environment. The optimizer configuration included 40 feasible solutions, for which successive combinations of input parameters were automatically generated. Each scenario was executed multiple times, with the number of replications ranging from 5 to 10. The replication count was dynamically adjusted depending on how many simulation runs were required to achieve an 80% confidence interval at a 5% significance level.

This approach ensured statistically stable results that could serve as a basis for comparing the analyzed scenarios and assessing the effect of the modal parameter on the average queue waiting time, workstation utilization, and the number of customers who abandoned the service process.

Figure 3 presents the Pareto curve illustrating the relationship between the average waiting time of customers in the queue and the average utilization rate of service workstations. The numbered circles (1-40) correspond to consecutive scenarios generated by the optimizer. The red arrow indicates scenario 25, which was selected for further analysis as it represents a compromise solution, ensuring high but still stable workstation utilization (approx. 89%) combined with a moderate waiting time and a limited number of customer resignations. A detailed analysis of the waiting time distribution for this scenario is presented later in Figure 5.

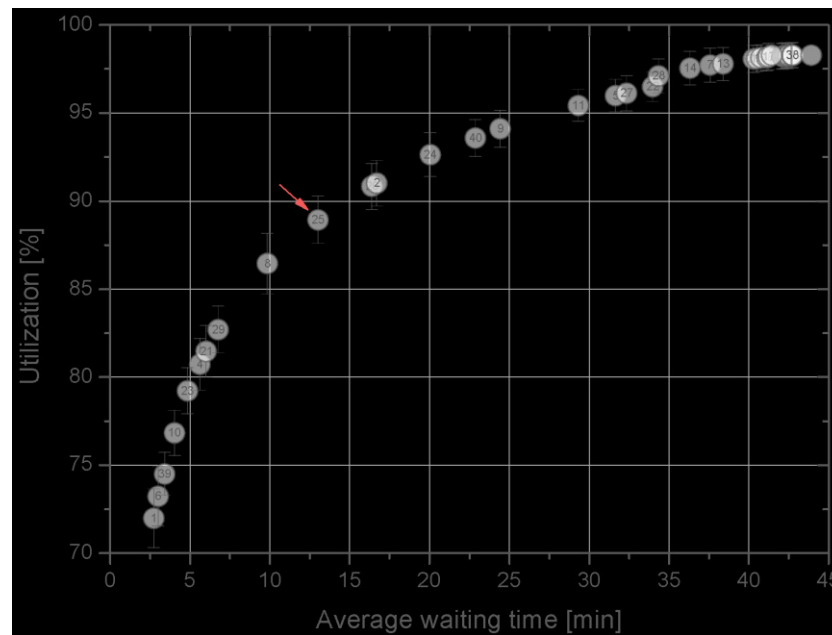


Figure 3. Relationship between average customer waiting time and workstation utilization.

Source: Own study.

The analysis of the chart shows that at low workstation utilization levels (below approximately 70-85%), the average waiting time remains acceptable from both the customer's and the organization's perspective. However, as workstation utilization increases beyond this range, a sharp rise in the average waiting time is observed. This indicates that the system enters an overload region, queues grow faster than the service capacity can handle.

From a practical point of view, this highlights the necessity of maintaining workstation utilization below a certain threshold value. Otherwise, the apparent cost efficiency of higher utilization becomes illusory, leading to reduced service quality and increased customer dissatisfaction.

Figure 4 shows the relationship between the modal value of the service time (as assumed in the triangular distribution) and the customer dissatisfaction ratio, defined as the proportion of customers who abandoned the service process due to exceeding the permissible waiting time:

$$R = \frac{\text{number of dissatisfied customers}}{\text{total number of customers}} \cdot 100\% \quad (3)$$

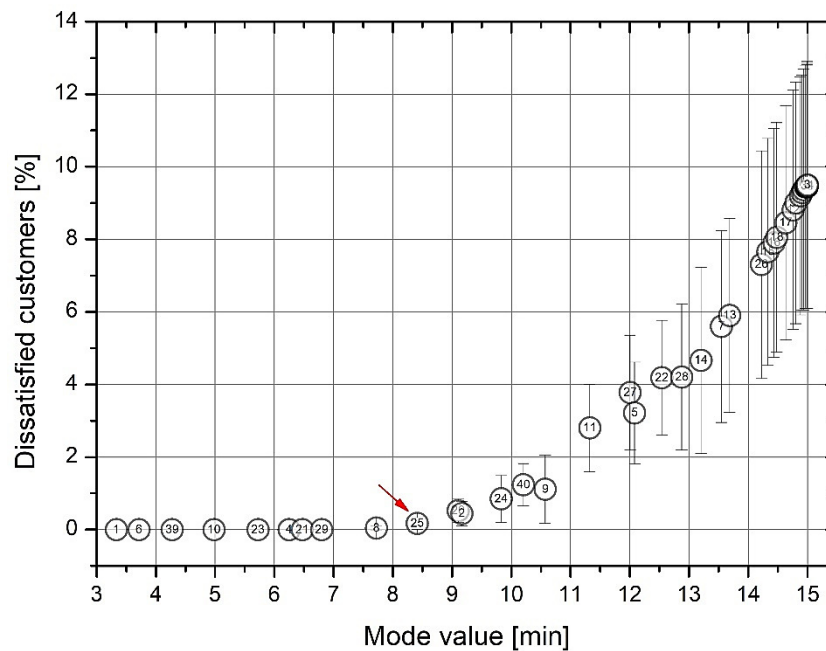


Figure 4. Relationship between the modal value of service time and the customer dissatisfaction rate.

Source: Own study.

As before, the red arrow indicates scenario 25, selected for further analysis due to its compromise nature, combining high workstation utilization (approx. 89%) with relatively short waiting times and a limited number of customer resignations.

The results clearly show that increasing the modal value of the service time leads to a noticeable rise in the dissatisfaction ratio. This outcome is intuitive, the longer the individual service takes, the faster the queue grows, and more customers exceed the threshold waiting time of 60 minutes, after which they abandon the system without being served.

Thus, the modal value of the triangular distribution is a key optimization parameter in the model. However, it cannot be minimized without constraint, excessively low modal values would violate the realistic conditions of the process. Therefore, optimization aims to find such a system operating point that maintains a balance between performance and service quality.

Figure 5 presents a histogram of the distribution of customer waiting times in the queue. The histogram was constructed using data from all ten replications, with the values transformed into probability density form, so that the chart reflects a continuous distribution and allows for interpretation regardless of the number of observations.

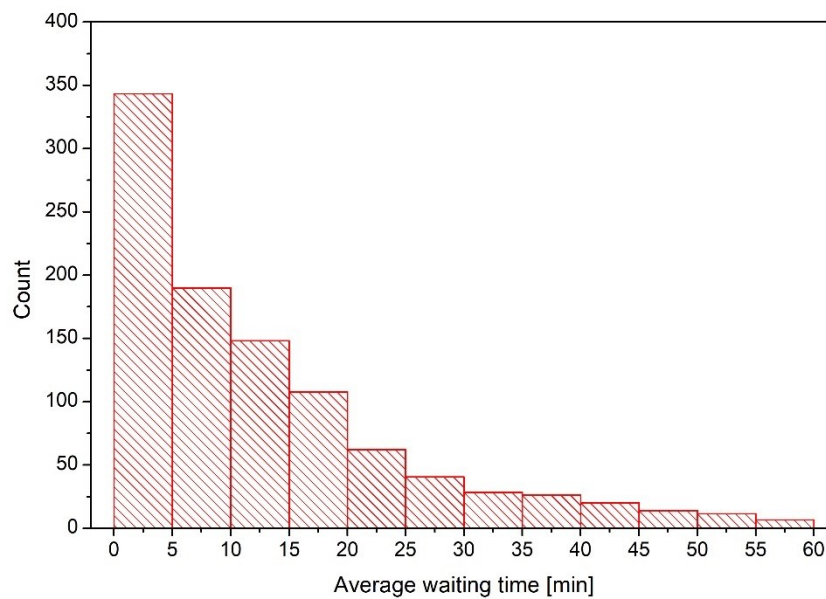


Figure 5. Histogram of customer waiting time distribution (probability density).

Source: Own study.

The histogram indicates a strongly skewed distribution, which is typical of queueing systems operating under conditions of partial load imbalance. Most customers experience waiting times shorter than the average, while a relatively small number of cases are characterized by significantly extended waiting times, resulting in dissatisfaction and resignation from further waiting.

Such system behavior confirms the previous findings regarding the influence of service parameters and workstation load on queue stability. At the same time, this distribution justifies the necessity of using multiple replications and aggregated results, as a single simulation run may not provide a representative outcome.

5. Summary

The conducted research confirmed that computer simulation combined with multi-criteria optimization constitutes an effective tool supporting the improvement of customer service systems. The use of the FlexSim environment enabled the development of a model that accurately reflects the actual course of the service process and allows for the analysis of how variations in time parameters affect key performance indicators of the system.

The application of the OptQuest optimization algorithm made it possible to determine a set of compromise solutions illustrating the relationship between the utilization level of service workstations and the average customer waiting time. The analysis of the Pareto curve revealed that the equilibrium point of the system occurs at a workstation utilization level of

approximately 89%, which ensures a relatively short waiting time and a limited number of customer resignations.

The simulation results clearly indicate that excessive workstation loading leads to a sharp increase in the average waiting time and destabilization of the system. This means that striving for maximum resource utilization may produce effects opposite to those intended, resulting in system overload, reduced service quality, and customer loss. Therefore, optimal management of service time requires a compromise between operational efficiency and customer satisfaction.

The analysis of the waiting time distribution (Figure 5) confirmed the characteristic asymmetry typical of queueing systems operating under unstable load conditions. Most customers are served in less than the average time, while a small number of cases with significant delays have a substantial impact on the perceived quality of service.

From a managerial perspective, the obtained results may support decision-making in planning the number of service workstations, determining time standards, and reorganizing processes depending on customer inflow dynamics. The model developed in the FlexSim environment can be further extended to include additional variables such as differentiation of employee competence levels, customer prioritization, or the application of dynamic resource allocation.

In conclusion, it can be stated that the use of simulation and optimization methods enables not only a deeper understanding of the mechanisms governing service system performance but also the development of practical recommendations that support managerial decisions aimed at improving service processes.

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TRADE-OFFS IN LAST-MILE LOGISTICS: LINKING DELIVERY MODELS TO KEY PERFORMANCE METRICS AND SUSTAINABILITY

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Purpose: Although extensive research has addressed operational efficiency and emissions in urban last-mile logistics, there is a lack of systematic analysis integrating financial costs, environmental sustainability, and other factors influencing delivery model selection. This paper aims to fill this gap by providing a comprehensive perspective on last-mile logistics, highlighting key factors that affect delivery model choice, and examining trade-offs among service efficiency, economic viability, and ecological impact in both urban and rural contexts.

Design/methodology/approach: The study is based on a literature review. Leading last-mile delivery models are presented, and key decision factors are identified and categorized as internal, external, or mixed. Based on this analysis, a Comparative Matrix of Last-Mile Delivery Models and Key Decision Factors is proposed, along with guidelines for its practical application.

Findings: The Comparative Matrix synthesizes the positive and negative effects of each last-mile delivery model with respect to nine decision factors. By illustrating the potential of different solutions, the matrix serves as a practical decision-support tool for selecting an optimal last-mile delivery model.

Practical implications: The matrix can guide companies in the decision-making process when choosing a last-mile delivery model.

Social implications: The tool may influence corporate social responsibility and promote environmentally sustainable practices in last-mile logistics.

Originality/value: This paper distinguishes itself by adopting a broad, systemic approach. It analyzes the main factors influencing last-mile delivery model choice, differentiates between urban and rural contexts, and considers both financial and environmental impacts. The resulting comparative matrix offers a practical, evidence-based framework for decision-making.

Keywords: last-mile delivery model, choice, matrix.

Category of the paper: research and viewpoint paper.

1. Introduction

The rapid expansion of e-commerce has fundamentally transformed global retail and logistics systems. Between 2016 and 2022, business-to-business (B2B) and business-to-consumer (B2C) e-commerce sales across economies representing approximately three quarters of global GDP increased by nearly 60%, reaching USD 27 trillion (UNCTAD, 2024). This growth has intensified pressure on logistics networks, particularly on last-mile logistics—the final stage of delivery from a local distribution node to the end customer. In e-commerce supply chains, last-mile delivery has become the most complex, cost-intensive, and environmentally burdensome segment, accounting for over half of total shipping costs and a disproportionate share of urban transport emissions (WEF, 2024a, 2024b). Rising customer expectations regarding delivery speed, reliability, and flexibility further exacerbate these challenges, while labor shortages, congestion, and regulatory constraints limit efficiency gains.

Against this background, companies are confronted with an expanding range of last-mile delivery models, including traditional home delivery, pick-up and drop-off (PUDO) points, click-and-collect, microhubs, crowdshipping, and autonomous or green delivery solutions. Each model entails distinct trade-offs in terms of cost, service quality, environmental impact, technological requirements, and regulatory feasibility. The purpose of this paper is to develop a structured and systematic framework to support decision-making in the selection of last-mile delivery models in e-commerce. Specifically, the study identifies key internal and external decision factors and synthesizes them into a comparative matrix that enables the evaluation of alternative last-mile solutions, with particular emphasis on financial and environmental outcomes.

Although the literature on last-mile logistics is extensive, existing studies tend to focus on individual delivery models, technologies, or isolated decision criteria. This fragmentation limits their usefulness for practitioners who must simultaneously consider multiple, interdependent factors under varying strategic and regional conditions. There is therefore a need for an integrative and flexible decision-support tool that captures the multidimensional nature of last-mile delivery choices. By consolidating insights from the literature into a holistic comparative matrix, this paper addresses this gap and provides a practical instrument that can be adapted to different company strategies, product characteristics, and regulatory environments. In doing so, the study contributes to both academic debate and managerial practice by bridging the divide between conceptual analyses and operational decision-making in last-mile logistics.

2. Literature grounding

The logistics definition presented by the Council of Logistics Management focuses on the processes of planning, implementation, and control, which aim to ensure the efficient and economically justified flow of materials and finished products. This approach captures the role of logistics as a discipline that significantly contributes to the optimization of economic processes (Council of Supply Chain Management Professionals [CSCMP], 2013).

The traditional delivery model operating within the business-to-business (B2B) structure has for years been the foundation of logistics, focusing on cooperation between producers and large retail units. This process relied on transporting goods from manufacturing plants to extensive distribution centers, from where products were shipped to retail stores. Individual customers could only purchase goods at physical sales points, which required them to visit stores in person (Christopher, 2016).

With the dynamic growth of e-commerce, a revolution in logistics has taken place. The introduction of the business-to-customer (B2C) model significantly simplified the logistics process by eliminating intermediaries such as retail stores and enabling the direct shipment of goods from producers or warehouses to end customers. This change accelerated the delivery process but also created new logistical challenges related to the need for faster responses to growing customer expectations (Hübner, Kuhn, Wollenburg, 2016).

Three fundamental stages are distinguished in the logistics of product distribution to the customer. The first stage of this process, First Mile Delivery, involves moving goods from the place of production to warehouses or distribution centers, where they are properly prepared for further transportation. Often, this is the stage where the product takes its final form, especially if it requires assembly from various components or the addition of supplementary elements. The importance of this stage highlights the decisive role of inventory management and warehouse logistics in ensuring smooth product flow. Warehouse space must be planned with optimization in mind, which allows for the quick location of individual goods and their seamless movement for the next stage. The intermediate stage, Middle Mile Delivery, covers the transportation of goods from central warehouses or main logistics hubs to regional and local distribution points, where products await the final stage of the journey (Lacy, Dahan, Erera, 2023). The last stage, Last Mile Delivery, is the delivery of the product to the end consumer, which for many customers represents the most tangible and decisive moment of the entire process (Schiffer, Schneider, 2020; Boysen, Fedtke, Schwerdfeger, 2020). The last mile delivery stage is considered the most demanding part of the entire logistics process, as it involves delivering products directly to the customer and requires coordination with local distribution centers and transport partners. In the context of e-commerce, this stage plays a dual role: on the one hand, it represents the technical conclusion of the logistics process, while on the other, it is a key element in building brand image and customer relationships (Plazier, Rauws, Neef, Buijs, 2024).

The way a company manages this stage directly affects how its reliability and quality of service are perceived. This part of the delivery process is particularly complex, as it requires precise planning, rapid execution, and the integration of growing consumer expectations. Increasingly, customers perceive speed and convenience of delivery as decisive factors in their purchasing decisions. The last mile is also associated with the highest environmental costs in the entire distribution process.

2.1. Main Last-mile delivery models

There are many options for organizing last-mile delivery.

According to the literature, the last mile delivery (LMD) process can be structured according to several models. The most well-known models are listed below, along with a brief description of each.

Home Delivery (Traditional Model)

- Goods are delivered directly to the customer's doorstep.
- Still the most widely used approach, but also the most expensive due to fragmented routes, low vehicle utilization, and high labor costs.
- It strongly impacts customer satisfaction but raises sustainability concerns (Trapp et al., 2021; Yılmaz, Aktaş, Demirel, 2022).

Pick-up and Drop-off (PUDO) Points

- Customers collect parcels from parcel lockers, convenience stores, or partner retail outlets.
- This model reduces failed deliveries, lowers costs, and consolidates delivery routes, which contributes to lower CO₂ emissions (Zhang, Demir, 2025).

Click-and-Collect (In-store Pickup)

- Customers order online but collect products directly from the retailer's physical store or a designated collection point.
- Provides convenience for customers who want to save shipping costs or combine shopping trips (Hübner et al., 2016).

Crowdshipping

- Involves using freelance couriers or private individuals (e.g., via apps) to perform deliveries.
- Offers flexibility and scalability but raises concerns about reliability, quality control, and labor rights (Gatta et al., 2019; Le Pira et al., 2021).

Autonomous and Innovative Delivery Models

- Drones and autonomous ground vehicles are being piloted to increase efficiency in urban areas.
- Though not yet widespread, they represent future-oriented solutions that could reduce costs and emissions while speeding up deliveries (Levkovych, Saraceni, 2023; Shaklab et al., 2023).

Microhubs Model

- Involves the use of small, decentralized urban warehouses or transfer points located close to customers.
- Goods are transported in bulk to microhubs and then distributed via environmentally friendly vehicles (e.g., cargo bikes, e-vans).
- This model helps reduce congestion, lower emissions, and improve delivery speed in dense urban areas (Novotná, Švadlenka, Jovčić, Simić, 2022).

Green Delivery Models

- Focus on environmentally sustainable solutions, such as bicycle couriers, electric vans, or cargo bikes in dense urban areas.
- Increasingly adopted to reduce the environmental footprint of logistics (Liu, Zhou, Yuen, Wang, 2024).

The choice of last-mile distribution model depends on many factors. Therefore, the decision regarding the selection of a specific last-mile distribution model should result from a thorough multi-factor analysis and take into account the interrelations between the considered factors.

3. Methods**3.1. Main factors determining last-mile delivery model**

A review of the literature on logistics and last-mile delivery enables the identification of several key factors that determine the choice of an appropriate model. In the author's opinion, the most important ones include the listed below. They can be grouped into external and internal factors, i.e., those depending on the microenvironment and the company's internal conditions and capabilities. Stakeholders involved in the design and financing of solutions and available technologies have been considered as both external and internal (mixed) factors. This is because stakeholder engagement stems both from the company's involvement and from cultural, business, and legislative conditions. Available technologies, in turn, depend not only on current technological capabilities but also on the company's ability to finance such solutions.

The following nine key decision factors were identified.

- firm strategy (internal factor),
- cost considerations (internal factor),
- the level of customer service and compliance with the Service Level Agreement (SLA) (internal factor),
- environmental impact (external factor),
- stakeholders involved in the design and financing of solutions (external/ internal factor),
- available technologies (e.g., route optimization algorithms, sorting systems, drones, parcel lockers) (external/internal factor),
- product characteristics (internal factor),
- regulatory framework (external factor),
- location (urban versus rural areas) (external factor),
- regional context (global/national), as it influences legal and environmental regulations, customer expectations, and the feasibility of financing delivery solutions (external factor),

Each of the listed factors has a significant impact on the others and should contribute to the selection of the optimal solution. Therefore, a systemic and holistic approach to this issue is essential. This study focuses primarily on costs and environmental aspects. However, to make an optimal decision regarding the last-mile model, all nine factors must be taken into account, as the remaining seven strongly influence both financial and environmental costs. The key factors influencing the choice of the last-mile model are discussed in greater detail below.

3.1.1. Internal factors

Product Characteristics in last-mile delivery

The design of last-mile logistics solutions is strongly influenced by the characteristics of the products being delivered. Different types of goods require distinct logistical approaches to ensure efficiency, security, and customer satisfaction. For example, perishable goods such as food and pharmaceuticals, demand strict temperature control, timely delivery, and compliance with safety regulations. This often requires specialized infrastructure such as refrigerated vehicles, insulated packaging, and monitoring systems that guarantee product integrity throughout the delivery process (Accorsi, Manzini, Ferrari, 2014; Soysal, Bloemhof-Ruwaard, Haijema, van der Vorst, 2018). In contrast, the delivery of durable goods such as consumer electronics focuses more on minimizing the risk of damage and theft, often requiring secure packaging, insurance coverage, and in some cases, proof of delivery (Allen, Browne, Woodburn, Leonardi, 2012).

Product size and weight are also decisive factors in shaping delivery strategies. Large or bulky items, such as furniture or household appliances, cannot be accommodated by parcel lockers or compact vehicles, and therefore rely on specialized fleets offering home delivery and installation services (Mangiaracina, Perego, Seghezzi, Tumino, 2019). On the other hand, lightweight and compact products are better suited for automated delivery options, including parcel lockers and drones, which increase flexibility and reduce costs in dense urban environments (Boysen, Briskorn, Schwerdfeger, Weidinger, 2021).

Product value adds another dimension to last-mile logistics decisions. High-value items require enhanced security measures, such as real-time tracking, restricted delivery windows, or in-person verification at the point of delivery (Vakulenko, Hellström, Hjort, 2018). In contrast, low-value goods can be efficiently managed through unattended delivery systems, which increase convenience and reduce operational costs.

Taken together, these factors: product type, size, weight, and value shape the selection of last-mile delivery models and technologies. As e-commerce continues to expand, tailoring logistics systems to product-specific requirements will remain a critical challenge for operators aiming to balance efficiency, sustainability, and customer expectations.

Unlike product characteristics - an independent variable - the firm's strategy constitutes a dependent variable, determined by the objectives set by the company's management.

Firm strategy

The choice of a last-mile delivery model should align with the company's overall strategy. If the strategic goal is to increase market share, special attention should be paid to the level of customer service in logistics, as it directly influences customer acquisition. Shorter and more reliable delivery times increase customer satisfaction, and the choice of last-mile model has a significant impact on this parameter.

Empirical evidence indicates that superior service generates substantial tangible benefits, whereas inadequate performance entails considerable costs. A detailed examination of consumers satisfied with last-mile delivery highlights several positive outcomes: increased customer loyalty resulting from access to faster delivery options, a greater willingness to pay for enhanced delivery speed, higher monthly expenditure, and more frequent purchasing behavior. Specifically, 74% of satisfied customers intend to increase their purchase levels by 12% with their preferred retailer, and 53% express willingness to subscribe to paid delivery memberships. Conversely, 48% of dissatisfied customers plan to cease purchasing from poorly performing retailers, while those who continue to buy from them expect to reduce their spending by approximately 45% (Cap Gemini, 2019a; Ko, Cho, Lee, 2018).

When cost reduction lies at the core of a company's strategy, it significantly influences the choice of the last-mile delivery model. Expensive solutions, such as courier deliveries, are likely to be eliminated in such cases. However, as evidenced by the CapGemini study cited above, a strong cost-reduction orientation may ultimately result in lower revenues due to the loss of dissatisfied customers.

Financial considerations and service level shaping Last-mile delivery model decision are resulting from firm strategy.

The level of customer service

In last mile delivery the customer service level is one of the most critical performance indicators, as it directly influences customer satisfaction, loyalty, and brand perception. Key elements include delivery speed, reliability, flexibility in delivery options, and transparency through real-time tracking (Li, Li, 2018).

To ensure consistent service quality, companies often define a Service Level Agreement (SLA), which specifies measurable performance standards such as on-time delivery rates, maximum delivery times, acceptable error margins, and customer support response times. In the context of e-commerce, SLAs serve as a contractual framework that aligns customer expectations with operational capabilities, while also supporting continuous improvement and accountability in last mile operations (Buldeo Rai et al., 2023).

Customer preferences play very important role while shaping the last mile delivery strategy. The findings of Nogueira, Rangel, and Shimoda (2021) indicate that sociodemographic factors shape consumer attitudes toward sustainable last-mile delivery, with clear behavioral differences among groups. Female consumers were more inclined to prioritize sustainability over delivery speed and cost, which contrasts with Deliana and Rum (2019), who reported no gender difference in green consumption. Age also played a role: respondents under 24 and over 49 were more willing to accept slower deliveries in favor of sustainability, showing some alignment with earlier studies but also highlighting greater green potential among older consumers. Education level further influenced flexibility, as highly educated respondents were more likely to accept longer delivery times to reduce environmental impact (Rai et al., 2019). Income, however, did not significantly alter time or cost flexibility, though higher-earning individuals tended to be less sustainable in their choices—opposite to what previous research suggested (Chuanmin et al., 2014). Overall, only a minority of respondents were willing to adjust delivery preferences to support more sustainable last-mile solutions.

SLA and costs are closely interrelated. Managers must align service level agreements (SLAs) with the company's financial capacity and the profitability of individual customers. The more profitable the customer, the higher the SLA offered. In turn, the SLA level directly affects last-mile delivery solutions: the higher the SLA, the more flexible the delivery conditions and the shorter the delivery Times -consequently leading to higher costs.

Financial Considerations in last-mile delivery

Last-mile delivery is estimated to account for 40-55% of overall logistics costs due to fragmented routes, high labor intensity, and congestion in urban environments (Capgemini Research Institute, 2019). Labor cost driver are driver wages and benefits and they can account for 50-60% of last mile delivery costs in traditional (door-to door) model.

Autonomous vehicles and drones promise to reduce these costs by lowering labor expenditures, increasing delivery density, and improving route optimization. However, significant capital investments are required for infrastructure, vehicle acquisition, and compliance with regulatory standards.

Autonomous delivery robots and drones can reduce operational costs in dense metropolitan areas by exploiting economies of scale. For example, route optimization and automation can cut delivery expenses by up to 20-30% compared to conventional vans (Liu et al., 2023). Nonetheless, these savings are offset by high research, development, and certification costs, as well as insurance premiums reflecting liability uncertainties (Rodrigues, Lemos, 2021). Furthermore, deployment in dense urban areas often requires additional investments in micro-hubs and charging infrastructure, which can be costly for smaller operators.

In rural areas, financial challenges are even more pronounced. Long travel distances, low parcel density, and limited charging or landing infrastructure make traditional van deliveries economically inefficient, with costs per package up to three times higher than in urban zones (Allen et al., 2018). Drones and hybrid models, while offering potential efficiency gains, require high upfront expenditures in technology and regulatory approvals. Public subsidies or partnerships are often necessary to make such investments viable, particularly in developing economies (Clarke, Hinchliffe, 2020).

From a long-term perspective, financial viability also depends on environmental regulation. Carbon pricing, low-emission zones, and EU Green Deal objectives create financial incentives for low-emission technologies by penalizing fossil-fuel-based deliveries (European Commission, 2020). Thus, financial and environmental considerations are increasingly intertwined: while autonomous and electric last-mile solutions may be costly to implement initially, they can reduce long-term expenses by avoiding environmental penalties and accessing green subsidies.

3.1.2. External factors affecting Last-mile delivery model choice

Legal and environmental regulations in last-mile logistics

Regulation of last-mile logistics increasingly targets autonomous vehicles, including ground robots and delivery drones. In the European Union (EU), drones are governed by Regulation (EU) 2018/1139 and EASA rules, which classify operations into categories (“open”, “specific”, “certified”) depending on risk and impose requirements for operator registration, risk assessment, and certification (European Union, 2018). Road vehicles fall under the General Safety Regulation (EU) 2019/2144, which introduces advanced driver-assistance obligations and paves the way for automated driving systems (European Union, 2019). UNECE regulations

on cybersecurity and software updates further shape technical compliance (Xu, Wei, Mi, Chen, 2025).

Liability remains a central issue. Autonomous delivery accidents raise questions about whether manufacturers, operators, or software providers bear responsibility. Current EU law combines product liability and national tort law, but harmonization is incomplete (Alatawneh et al., 2025a). Data protection under the General Data Protection Regulation [GDPR] (European Union, 2016) and cybersecurity regulations, such as UNECE R-155 (UNECE, 2020), also apply, given the extensive collection of geolocation and sensor data.

Environmental concerns strongly influence legal frameworks. While autonomous electric vehicles and drones reduce local emissions, broader assessments include lifecycle impacts of batteries and energy sources (Alatawneh et al., 2025). The EU pursues stricter emission standards and promotes zero-emission logistics to meet climate goals. Drones can shorten routes and reduce congestion but raise issues of noise, energy efficiency, and wildlife disturbance.

Future regulations are expected to integrate the EU AI Act, which will classify many AI systems used in autonomous logistics as “high-risk,” requiring transparency and safety controls. Policymakers are urged to clarify liability, enforce lifecycle environmental assessments, and harmonize cross-border standards to ensure safe and sustainable last-mile logistics.

Regional Diversity in Last-Mile Logistics Regulations

Regulatory and technological conditions for last-mile logistics vary significantly across regions, reflecting differences in economic development, technological capacity, and environmental policy. In the European Union (EU), harmonized rules for drones and autonomous road vehicles aim to ensure safety and cross-border compatibility. Strong environmental frameworks, such as the European Green Deal and emission reduction targets, accelerate the adoption of low-carbon last-mile solutions, including electric vans, drones, and micro-mobility robots.

By contrast, the United States follows a fragmented regulatory approach. The Federal Aviation Administration (FAA) governs drone use, but states and municipalities impose additional restrictions on airspace and sidewalk delivery robots. While the U.S. is a leader in technological experimentation, especially in urban drone trials, inconsistent rules across jurisdictions often slow large-scale deployment (Rodrigues, Lemos, 2021).

In emerging economies, last-mile logistics often faces challenges of limited infrastructure, high urban density, and weaker regulatory enforcement. Countries in Sub-Saharan Africa and South Asia, for example, experiment with drone deliveries for medical supplies, supported by international organizations, but broader commercialization is constrained by limited legal frameworks and high costs (Clarke, Hinchliffe, 2020). In contrast, China has rapidly integrated drones and autonomous vehicles into urban logistics ecosystems. China is gradually building a comprehensive legal and regulatory framework for data security in autonomous driving,

combining legislation, technical standards, and policy measures to ensure compliance (Xu, Wei, Mi, Chen, 2025).

Environmental regulations also differ widely. While the EU imposes strict emission standards and lifecycle assessments, many developing countries prioritize economic efficiency over sustainability. However, cities like Dubai adopt proactive smart mobility strategies, blending regulatory support for automation with environmental planning (Chaudhry, Masoumi, Dienel, 2025).

This diversity underscores the need for adaptive legal frameworks. Policymakers must balance technological innovation, safety, and environmental protection in line with local economic and institutional capacities. Without regional harmonization, global logistics operators face regulatory fragmentation, which may limit the efficiency and sustainability of last-mile delivery systems.

Environmental impact

In some large urban areas (like eg. Paris), freight transport accounts for only 10-15% of total traffic - dominated primarily by private cars - yet it generates about a quarter of CO₂ emissions and significantly contributes to NO_x and particulate matter pollution (Dablang, Diziain, Levifve, 2011). Beyond environmental concerns, last-mile logistics often conflicts with urban policy goals of creating safe, livable, and attractive public spaces. At the same time, its critical role in ensuring the functioning and prosperity of cities makes its elimination impossible, reinforcing the urgent need to shift towards sustainable solutions (European Commission, 2021; Haarstad, Rosales, Shrestha, 2024). Globally, transport is responsible for nearly one quarter of CO₂ emissions, with road freight alone contributing 29.4% of transport-related emissions (Ritchie, 2020).

The challenges of last-mile logistics are intensified by urban densification, the rapid growth of e-commerce, and the expansion of the on-demand economy, which together increase both the necessity of efficient delivery systems and their negative externalities. Scholars consistently highlight that strict service-level requirements, fragmented order sizes, frequent deliveries, and dispersed drop-off points make last-mile logistics the least efficient stage of the supply chain and a major contributor to congestion and air pollution (Mommens, Brusselaers, Van Lier, Macharis, 2019).

Consequently, there is growing recognition among stakeholders that last-mile logistics must become more sustainable (Gonzalez, Garrido, Vassallo, 2023). This shift is reflected in rising citizen expectations for cleaner air, safer streets, and higher-quality public spaces in local authorities enforcing stricter regulations on freight flows and their impacts, and in logistics operators increasingly adopting advanced technologies and experimenting with collaborative delivery models (Le Pira et al., 2024).

Rural and Metropolitan Contexts in Last-Mile Logistics

The design of last-mile logistics solutions differs substantially between rural and metropolitan areas, reflecting population density, infrastructure availability, and regulatory considerations. Urban agglomerations face high delivery volumes, traffic congestion, and stricter environmental regulations. Consequently, solutions in large cities increasingly rely on micro-hubs, cargo bikes, sidewalk delivery robots, and short-range drones to reduce emissions and mitigate congestion (Liu et al., 2023b). Municipal governments often support these innovations through low-emission zones, restrictions on heavy vehicles, and subsidies for zero-emission fleets (European Commission, 2020).

In contrast, rural areas present the challenge of sparse populations, long travel distances, and limited infrastructure for electric vehicles. Autonomous drones and mobile parcel lockers are often more cost-effective than traditional truck deliveries in such contexts, particularly for healthcare supplies and time-sensitive goods (Clarke, Hinchliffe, 2020c). However, legal frameworks for beyond-visual-line-of-sight (BVLOS) drone operations remain a bottleneck in many jurisdictions (FAA, 2023).

Environmental considerations also differ. In metropolitan areas, last-mile emissions contribute significantly to local air pollution and noise, prompting strict regulation. Rural areas face less regulatory pressure but must address economic sustainability of low-volume deliveries, where the environmental cost per package may be higher due to longer routes (Allen et al., 2018b). Hybrid models - combining centralized truck deliveries with autonomous drones or lockers - are increasingly explored as a compromise.

Ultimately, last-mile logistics must be adapted to spatial context: dense agglomerations favor short-range, low-emission, high-frequency deliveries, while rural regions require flexible, long-range solutions leveraging autonomy and shared infrastructure. Legal and regulatory systems should reflect these differences to ensure both efficiency and sustainability.

3.1.3. Internal and external (mixed) factors affecting Last-mile delivery model choice

Stakeholder Participation in Last-Mile Logistics

The rapid growth of e-commerce has fragmented last-mile deliveries, making cooperation among stakeholders essential for achieving sustainable Logistics (Kiba-Janiak, Marcinkowski, Jagoda, Skowrońska, 2021). Stakeholders cooperate for reasons such as cost savings, efficiency gains, knowledge exchange, or regulatory compliance.

Collaboration can take different forms. Vertical cooperation aligns supply chain partners to improve responsiveness, while horizontal cooperation between logistics providers reduces costs, empty mileage, and inefficiencies (Gansterer, Hartl, 2018). Public-private partnerships also play a critical role, as cities cannot address last-mile challenges without private actors. Such partnerships facilitate infrastructure improvements, knowledge sharing, and route optimisation but raise issues of data ownership and trust.

Local authorities are particularly important in balancing stakeholders' needs. Through urban logistics plans, regulations, and infrastructure investments, they aim to reduce emissions, maintain urban attractiveness, and enhance quality of life (European Commission, 2021). While cooperation involves trade-offs, it is key to mitigating conflicts and advancing sustainable last-mile solutions (Plazier, Rauws, Neef, Buijs, 2024).

Available/required technology

Rapid technological progress is reshaping last-mile delivery, offering solutions that improve efficiency and reduce environmental impact (Le Pira et al., 2024). A major challenge is decarbonising fleets, with regulations and low-emission zones driving adoption of electric, hybrid, and fuel-cell vehicles (Bosona, 2020). Non-motorised modes, such as e-cargo bikes, offer low-cost and flexible alternatives in congested areas. Automation is also emerging, with drones, robots, and autonomous vehicles set to transform deliveries, though raising new concerns about safety and regulation. Technology further enables new delivery models. Parcel lockers, unattended delivery, and consolidation centers increase efficiency and sustainability. Micro hubs help optimise freight flows, though location constraints and limited volumes often require government support). Finally, digitalisation and new entrants—from start-ups to tech giants—are reshaping logistics through innovative, data-driven business models. Collectively, these innovations highlight technology's central role in building sustainable last-mile logistics.

3.2. Comparative Matrix of Last-Mile Delivery Models and Key Decision Factors

The result of the literature analysis on the selection of the last-mile delivery model is the Comparative Matrix of Last-Mile Delivery Models and Key Decision Factors (table 1). This matrix presents the positive and negative effects of applying a specific last-mile distribution model in light of the nine decision factors discussed above. By synthetically illustrating the potential of each solution, the matrix can serve as a useful tool to support the decision-making process related to the selection of an optimal last-mile delivery model.

Table 1.
Comparative Matrix of Last-Mile Delivery Models and Key Decision Factors

Last-Mile Delivery Model	Decision factors							Supporting decision factors	
	Firm Strategy	Financial Considerations	Customer Service & SLA	Environmental Impact	Product Specificity	Regulatory Framework	Urban vs. Rural/Regional Context	Stakeholders & Financing	Available/required Technologies
Home Delivery (Traditional Model)	(+) Fits customer-centric growth strategies; enhances loyalty and repeat purchases through convenience and reliability. (-) Cost-oriented strategies may avoid this model due to high expenses	(+) High revenue potential via customer preference. (-) Accounts for 40-55% of logistics costs; high labor and fuel costs	(+) Maximizes satisfaction through door delivery. (-) High SLA costs; risk of failed deliveries	(-) High CO ₂ , congestion, and noise emissions	(+) Suitable for valuable, perishable, or bulky goods requiring secure handling	(-) Subject to vehicle emission limits, driver work-time rules, and low-emission zone restrictions	(-) Urban: costly and congested. (-) Rural: longer routes, up to 3× higher cost per package	Retailers, couriers, customers; funded via delivery fees or subsidies	Route planning, telematics, real-time tracking
Pick-up & Drop-off (PUDO) Points	(+) Supports cost-efficiency strategies and sustainability-oriented approaches by consolidating deliveries	(+) Lower operational costs through route consolidation. (-) Requires infrastructure investment	(+) Reduces failed deliveries; ensures SLA reliability. (-) Less convenient for door-oriented consumers	(+) Lower emissions via consolidated routing	(+) Standardized parcels. (-) Unsuitable for large, fragile, or temperature-sensitive items	(-) Must comply with data and security standards (GDPR for smart lockers)	(+) Urban: efficient and eco-friendly. (-) Rural: limited locker density, accessibility issues	Retailers, locker operators, logistics providers, local governments	Parcel lockers, RFID, route optimization systems
Click-and-Collect (In-store Pickup)	(+) Aligns with omnichannel retail strategies aiming to integrate e-commerce with physical stores.	(+) Eliminates delivery costs. (-) Requires in-store staffing and storage	(+) Flexible for customers; integrates with shopping trips. (-) SLA limited by store hours.	(±) Reduces delivery emissions but customer trips may offset benefits	(+) Best for non-perishable, low-value, or impulse-buy products	(-) Subject to retail operational and consumer safety regulations	(+) Urban: convenient near dense retail zones. (-) Rural: limited due to sparse retail networks	Retailers finance infrastructure; logistics providers minimally involved	Order management and inventory systems, in-store scanning

Cont. table 1.

Crowdshipping	(+) Fits asset-light, flexible business strategies; enables market entry with minimal capital	(+) Low entry costs, scalable. (-) Surge pricing and quality variability	(+) Fast and flexible service. (-) SLA reliability risks due to variable workforce	(±) Mixed impact: small vehicles can reduce emissions, but fragmented routing may raise them	(+) Small, urgent, low-value goods. (-) Not suitable for high-value or bulky items	(-) Subject to labor laws, platform regulation, and insurance liabilities	(+) Urban: effective for food and parcels. (-) Rural: low density limits feasibility	Platforms, freelancers, customers; shared financing	Mobile apps, GPS, algorithmic matching
Autonomous & Innovative Models (Drones, AGVs, Robots)	Supports innovation-driven strategies and green transformation goals; aligns with long-term sustainability and cost reduction	(+) 20-30% cost savings potential. (-) High upfront capital, R&D, and compliance costs	(+) High SLA potential—fast and reliable. (-) Limited payload and weather constraints	(+) Zero local emissions. (-) Battery lifecycle, noise, and wildlife impacts	(+) Lightweight, urgent, or high-value items (e.g., medical goods)	(±) Regulated under EU 2018/1139, EASA, and national aviation rules; liability and cybersecurity under GDPR & UNECE R155	(+) Urban: efficient for dense areas. (±) Rural: long-range drones viable but costly and legally constrained	Tech firms, logistics providers, governments (PPP models)	Drones, AGVs, AI route planning, IoT monitoring, charging stations
Microhubs & Urban Consolidation Centers	Ideal for sustainability-focused and efficiency-oriented strategies in dense cities	(+) Economies of scale reduce delivery costs. (-) Requires costly urban real estate	(+) Improves SLA reliability and delivery speed	(+) Major emission reduction via EVs and e-cargo bikes	(+) FMCG, groceries, e-commerce parcels	(±) Governed by urban mobility plans, low-emission zone regulations	(+) Urban: highly effective. (-) Rural: low density limits viability	Municipalities, real estate investors, logistics operators	Routing software, EV fleets, consolidation systems
Mobile Parcel Lockers / Hybrid Drone Models	Fits innovation and cost-control hybrid strategies, especially in low-density regions	(±) High initial costs but lower per-parcel costs over time	(+) Reliable SLA; 24/7 availability	(+) Reduces repeated delivery attempts and emissions	(+) Non-perishable, small, standardized items	(-) Must comply with airspace and data protection regulations	(+) Urban: supports flexible service. (+) Rural: improves accessibility where traditional routes fail	Governments, e-commerce platforms, logistics providers	Drones, IoT-enabled lockers, route optimization

Source: own work.

To facilitate the decision-making process for users of the matrix, the assessment of the suitability of a given last-mile distribution model can be quantified by assigning numerical values to individual cells of the matrix. Each positive effect (“+” in the matrix) is assigned a value of 1, while each negative effect (“–”) is assigned a value of –1. This approach enables a straightforward evaluation of the overall value of a particular solution.

Given that the significance of individual decision factors will vary depending on the company’s adopted strategy, operational characteristics, and broader context (such as regional regulations, technological capabilities, or stakeholder collaboration), it is reasonable to assign differentiated weights to these factors. The total sum of these weights should equal 1.

By multiplying the value obtained in a given cell by the weight assigned to the corresponding decision factor, one obtains the final quantified value for each cell in the matrix.

This allows for a clear and straightforward comparison of the results obtained by the individual last-mile models.

4. Discussion and limitations

In the matrix, the factor: „regional diversity in Last-Mile logistics regulations has been omitted. This results from the impossibility of assigning a specific last-mile delivery model to this factor. However, this factor may be incorporated into the matrix in the form of a weighting coefficient assigned to other decision factors.

Decision factors such as stakeholders & financing and available/required technologies serve a supporting role within the matrix but are not quantifiable. This is justified by the fact that the ability to secure financing for certain solutions through stakeholder involvement increases the likelihood of their implementation. However, stakeholder engagement depends on multiple factors, including existing regulations—which, for example, may encourage collaboration to develop environmentally friendly solutions—or the presence of best practices in partnership management. Consequently, this factor is difficult to quantify.

Possession of the required technologies is a necessary condition for the implementation of specific last-mile delivery models, but the ability to finance them depends on the company’s situation and strategy, as well as the potential for co-financing by stakeholders. Therefore, quantification of this factor is also not feasible.

As a result, quantifiability applies to 7 of the 9 decision factors discussed.

The key to the effective application of this tool lies in the selection of appropriate decision criteria and the assignment of contextually adequate weights to them.

Depending on the company’s operational profile and macro-environmental conditions, the number of decision factors may be adjusted to specific needs or contextual requirements.

In the existing literature, there is a substantial body of work on last-mile delivery models. Each model could serve as the basis for extensive, dedicated studies. The same applies to the decision-making factors discussed; each could be explored in considerable depth in individual studies. The present paper is synthetic in nature, aiming to provide a comprehensive and systematic overview. However, it certainly does not examine all topics in as much detail as specialized studies devoted to a single aspect of the discussion.

The matrix presented in this paper is illustrative and must be adapted to the specific requirements of the company applying it. Not all potential advantages and disadvantages associated with the implementation of a particular last-mile delivery model are listed in the matrix. The matrix requires careful contextualization with respect to the conditions of the specific company and its product.

The assessment of the potential of the presented matrix requires its practical application in companies facing the choice of a last-mile delivery model.

5. Summary

Despite extensive research on operational efficiency and emissions in urban last-mile logistics, there remains a notable gap in the literature regarding the integration of economic, environmental, and operational considerations in delivery model selection. Existing studies often focus on a single dimension—such as cost optimization, service performance, or carbon emissions - without systematically evaluating how these dimensions interact or considering the full range of factors that influence the choice of last-mile delivery models. This paper addresses this gap by providing a comprehensive, multi-dimensional perspective on last-mile logistics, with a particular focus on the trade-offs between service efficiency, economic viability, and ecological impact in both urban and rural contexts.

A literature review was conducted, synthesizing current research on leading last-mile delivery models, including traditional carrier-based systems, crowd-sourced and gig-economy solutions, locker-based networks, and emerging green logistics practices. Through this process, the study identifies and categorizes the primary decision factors affecting delivery model selection into three groups: **internal factors** related to organizational resources, capabilities, and operational processes; **external factors** including regulatory requirements, market demand, and environmental constraints; and **mixed factors**, which represent interactions between internal capabilities and external conditions.

Building on this analysis, the paper proposes a **Comparative Matrix of Last-Mile Delivery Models and Key Decision Factors**, designed to illustrate the positive and negative impacts of each delivery model against nine critical decision criteria, including cost efficiency, service quality, environmental footprint, flexibility, scalability, resource utilization,

and regulatory compliance. The matrix provides a structured, practical tool for logistics managers, enabling informed decision-making by highlighting potential trade-offs and synergies among different delivery models.

The study further discusses how this framework can be applied in practice, both in urban centers with high population density and complex traffic patterns, and in rural areas where delivery distances, infrastructure, and cost structures pose distinct challenges. By integrating operational, financial, and ecological perspectives, the research contributes to the literature on sustainable logistics management and offers actionable guidance for companies seeking to optimize last-mile operations while advancing environmental sustainability.

Ultimately, the paper emphasizes the necessity of a **holistic, context-sensitive approach** to last-mile logistics decision-making, where strategic choices in delivery models must carefully balance competing objectives, including service performance, cost minimization, and ecological responsibility. The proposed framework supports both academic understanding and practical implementation, offering a versatile tool for future research and managerial decision-making in evolving logistics landscapes.

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DEREGULATION 2025 – ANALYSIS IN THE LIGHT OF REGULATION THEORY

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Purpose: The aim of this article is to assess the changes made in 2025 in the scope of legal regulations relating to economic entities in terms of their regulatory and deregulatory characteristics, viewed in the light of the theory of regulation and deregulation.

Design/methodology/approach: In the article regulation and deregulation theory is used as a base to contextualize the changes proposed and made in 2025 by the government, called deregulation. The deduction was a basic method used in the assessment of changes and their place in the regulatory-deregulatory cycle.

Findings: Only a few changes from the field of economy can be strictly called deregulation - only these which have the feature of direction change of a regulation vector. As an example, can be given the introduction of the possibility to object to control activities, which reverses the principle of ordering the hierarchy of systems - the state and the enterprise.

Research limitations/implications: The widespread and imprecise use of the terms regulation and deregulation (particularly by legislative bodies) and the statements found statements in the literature on the subject that deregulation consists in limiting or even eliminating the administrative tools used by the state need to be clarified in the light of the theory of regulation and deregulation, which becomes a premise for further research on this issue. The problem with the process of clarifying concepts is that economic theory has not yet been able to determine how to measure the degree of regulation and, therefore, the need for deregulation.

Practical implications: Firstly, the systematization and precise application of the concepts of regulation and deregulation may contribute to creating opportunities for entrepreneurs to properly identify legislative changes and thus make optimal economic decisions. Secondly, it may change the image of the state as a regulator acting in an orderly and predictable manner, especially given that legislative changes take time.

Originality/value: Introducing and explaining the regulatory-deregulatory cycle the article orders the meaning of regulation and deregulation thanks to which all who use these terms should consequently and precisely define a change of law in economy. It refers, in particular, to entrepreneurs who, having heard information about deregulation from the government, must understand the direction of political and economic regulation goals and in consequence can expect the direction change of a regulation vector, not only as a newly defined process of the existing regulation principles by changing the area of freedom of existing regulation rules.

Keywords: regulation, legislation, practice of deregulation.

Category of the paper: conceptual paper.

1. Introduction

One of the government's actions implemented as part of its socio-economic policy for 2025, as understood by the government, was deregulation. During this work, a special team was appointed to develop regulatory changes that would meet the expectations of society, especially entrepreneurs, in reducing bureaucracy and making life and business easier. The team, led by Rafał Brzóska and Maciej Berek (the head of the Standing Committee of the Council of Ministers), developed 125 deregulation proposals submitted to the public and 63 bills submitted to the Sejm. "Among the changes signed by the president are, among others, the establishment of a six-month *vacatio legis* for bills amending tax regulations and the raising of the revenue limit below which an entrepreneur is exempt from registering as a VAT payer to PLN 240,000 from the current PLN 200,000. A significant number of deregulation bills are currently at various stages of parliamentary work (*Deregulacja rzqdu...*). Therefore, based on at least the two examples above, the question should be asked how the indicated changes fit into the theory of regulation and deregulation. Hence, the aim of this article is to assess the changes made in 2025 in the scope of legal regulations relating to economic entities in terms of their regulatory and deregulatory characteristics, viewed in the light of the theory of regulation and deregulation. Consequently, the research hypothesis states that not all changes referred to as deregulation have the characteristics of deregulation. This study adopts a qualitative approach where regulatory and deregulation theory is used as a framework to contextualize the changes proposed and implemented by the government in 2025, referred to as deregulation.

2. Literature review

Regulation is an element of state intervention in the functioning of the economy and takes the form of legal norms defining the rules of conduct for entities. Deregulation, in common sense, means removing restrictions on the free operation of the economy, increasing the freedom of economic activity of economic entities, and reducing the state's involvement in the economy (Puzio-Waławik, 2015). Referring to the basic goal of the regulatory role of the state defined as the increase in social welfare, it can be assumed that regulations in the economy can only grow in a cumulative manner, because deregulation understood as state intervention in the economy is carried out by defining new, different legal norms, and therefore is in its essence a regulation. The reasons for this should be sought in regulatory pressure from economic entities and the public interest. Both factors contribute to the increase in the number of regulators. However, in real world, both situations such as regulatory creation and the reverse—the abolition of regulators—occur. Therefore, it is reasonable to conclude that regulation is

a process of establishing norms through their creation or abolition (narrowing or expanding the scope of freedom of regulated entities) which the extreme state of the intermediate states is, on the one hand, the absence of any rules, and on the other, a state in which everything that happens in regulated entities requires the active role of the regulator, (in the form of a rule and an institution). Defining regulation in this way requires the selection of a similar concept of process that will indicate a change in the direction of regulation. It is certain that a critical point can be identified causing the regulatory process to reverse after this point, and consequently, a change in the regulatory pattern toward which the regulatory system strives - deregulation. Therefore, the essence of deregulation is, on the one hand, a change in regulatory principles through the process of replacing them, whereby the principles - abolished and introduced - must have a different direction of the regulation vector, shifting the regulatory goal towards its extreme states opposed in principle (Letkiewicz, 2013).

From the perspective of this study, the basic perspective for analyzing the process of regulation and deregulation is one of the regulatory roles of the state and the perspective of economic entities, and consequently the extreme states of regulation/deregulation. From this research perspective, the regulatory-deregulatory process is perceived through the area of freedom left to enterprises, where one extreme is a complete lack of freedom – the supremacy of the state in the socio-economic system in which there is an economic state that does not take market regulators into account – a command-and-distribution system, and the other extreme state is the functioning of a socio-economic system based exclusively on the mechanisms and principles of a fully free market. Nowadays, the doctrine of socio-economic policy implementation (policy objectives are the most important regulator), both extremes' states are theoretically possible, but politically unacceptable. These states, therefore, define the area of regulation of the socio-economic system implemented by the state at a given time and place, raising the following questions:

- Where are we in terms of the basic regulatory doctrine?
- What changes are necessary to bring the current state of regulation into direction of regulatory doctrine?
- What is the vector of regulation, i.e., do the proposed changes clarify the existing area of freedom, or is it deregulation, i.e., a change in the extreme state of the role of the state in the socio-economic system?

The answers to this set of questions will allow us to clearly define whether we are dealing with regulation or deregulation. The answers can be found by understanding the essence of the regulatory-deregulatory cycle, the course of which is presented in Figure 1. The regulatory perspective requires us to look at the regulatory-deregulatory cycle from the point of view of the regulatory principles applicable in the given economic system, together with the identification of the direction of change taken by regulators. Therefore, the following sequence of deregulatory activities can be identified:

- revolutionary deregulation – consisting of changes in the rules of fundamental regulators, such as the constitution, which lays down the foundations for the functioning of the economy – the Polish constitution states that "The social market economy, based on the freedom of economic activity, private property, solidarity, dialogue, and cooperation between social partners constitutes the basis of the economic system of the Republic of Poland" (*Konstytucja Rzeczypospolitej Polskiej z dnia 2 kwietnia 1997 r.*);
- deregulatory regulation – concerning changes in economic regulators, consisting of changes in legal regulations implemented on the initiative of legislative bodies, leading to the establishment of consistency between specific regulators and the fundamental regulator for the socio-economic system and concerning the establishing and conducting of the economic activity – the main act in the Polish legal system is the Entrepreneurs Law and changes in the relationship between entrepreneurs and the state, e.g., the Tax Ordinance Act or tax laws;
- regulatory deregulation – concerning changes in economic regulators, consisting of changes in legal regulations implemented on the initiative of economic entities, leading to the establishment of compliance between the regulators operating in these entities and specific regulators in the socio-economic system; an example of such deregulation was the legal sanctioning of a lease agreement, which in the 1990s functioned as an unnamed agreement and in July 2000 was introduced into the Civil Code. (*Ustawa z dnia 26 lipca 2000 r. o zmianie ustawy – Kodeks cywilny*).

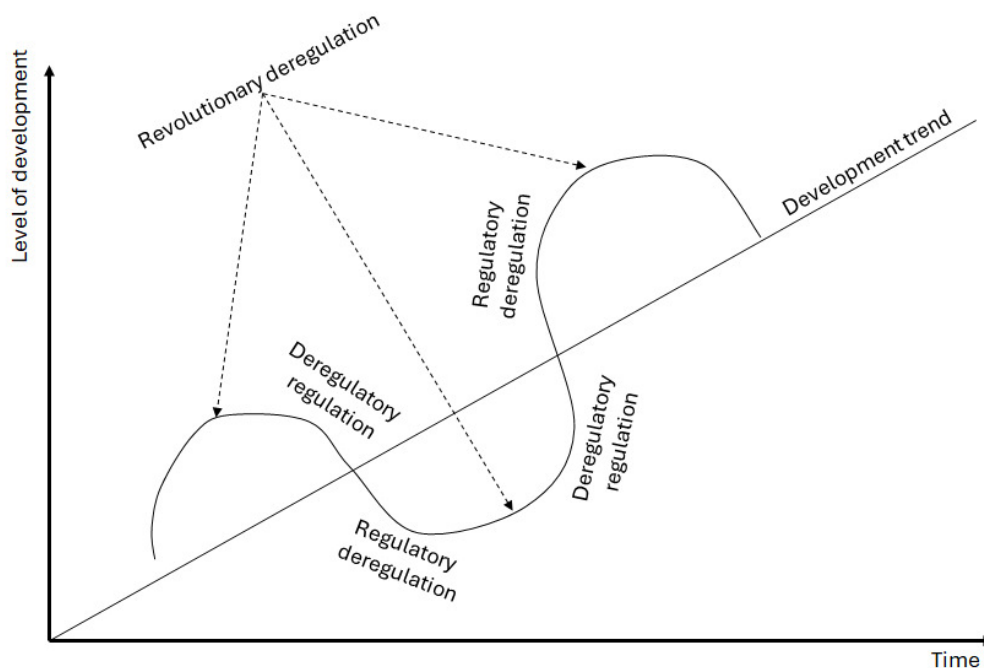


Figure 1. Phases of the regulatory-deregulatory cycle.

Source: Letkiewicz, 2013, p. 132.

Deregulatory regulation occurs after a revolutionary change in regulatory principles – revolutionary deregulation – and serves to clarify the regulators governing the functioning of economic entities to better and more efficient objectives achievement of the higher-order system (regulators in the institutional sense – the state). This concerns the imposition of social objectives on enterprises (e.g., social security for employees, corporate social responsibility, environmental objectives), or “tightening” the relationship between the state and economic entities. Due to the hierarchical nature of systems, a change in regulatory standards to the opposite – deregulation in higher-order systems will cause deregulation in lower-order systems – enterprises.

Regulatory deregulation is evident when economic operators cease to perceive the efficiency and effectiveness of state regulation objectives, or when it becomes possible to achieve those objectives in a more efficient manner. Regulatory deregulation can also be indicated when the system undergoes structural changes under the influence of external factors e.g., technological change or the emergence of substitutes. Due to the hierarchical nature of systems, deregulatory changes in lower-level systems will trigger deregulation in higher-level systems only if the process is consistent with the state's regulatory objectives set out in its policy or if the regulator (in subjective terms) decides to legally sanction phenomena that are common in economic transactions but not covered by legal rules.

3. Methods

This study adopts a qualitative approach, using a literature review method, to examine the formal and legal changes to the deregulatory package within the context of regulatory and deregulation theory. In this article, regulatory and deregulation theory is used as a framework to contextualize the changes proposed and implemented by the government in 2025, referred to as deregulation. Deduction was the primary method used to assess these changes and their place within the regulatory-deregulation cycle.

4. Results

According to the Prime Minister's statement, the government's work had been ongoing since the beginning of the term of office, but it only gained momentum in the spring of 2025, when Rafał Brzóska joined the social side of the work. After the social side submitted its proposals for changes, the government team decided that only 8% of the solutions were impossible to implement due to the security of the state budget, which means that out of over 13,000 proposals

for changes, almost 12,000 are feasible. Among the proposals submitted, 70% concern citizens and 30% concern business. From the point of view of a citizen who may also be an entrepreneur, the team of entrepreneurs identified seven key areas for simplification in the initial phase, relating to health, tax law, judiciary, digitization, energy, EU law, security and defense. (*Gospodarka bez zbędnych barier...*). In the final version, 13 thematic areas were developed during the government and social partners' work on deregulation/regulation. The detailed proposals included:

- social policy and health,
- digitalization,
- taxes and finance,
- business law,
- criminal law,
- family and civil law,
- labour law,
- administrative law,
- financial market,
- energy and climate,
- legislation,
- state registers,
- European funds.

In each of the areas indicated, detailed solutions were addressed that concerned changes in the law for citizens and entrepreneurs (examples of proposed changes are included in Table 1), as this process, according to the Prime Minister's declaration, is a key element of the government's strategy to stimulate the economy and improve business conditions through the simplification of regulations as a deliberate measure aimed not only at making it easier for entrepreneurs doing business, but also at reducing unnecessary bureaucracy for citizens. (*Raport o deregulacji...*).

Table 1.

Examples of activities undertaken by the team in specific areas

Area	Examples of actions taken
Social policy and health	Introduction of a catalogue of cases in which permanent disability certificates are issued, the ability to apply for a parking card online, and central e-registration of doctor visits
Digitalization	New services in the mObywatel application (including access to medical data and mEmerytura), integration of existing administrative systems in citizen services, digitalization of the judiciary, digital occupational health certificates
Taxes and finances	Presumption of taxpayer innocence in tax settlements, non-punishment of taxpayers and accountants for unintentional errors and mistakes, non-charging of default interest if the tax audit exceeds 6 months, abolition of the obligation to send the PIT-11 settlement
Entrepreneurs' law	Economic law, public procurement: including reducing the frequency of business inspections by half, raising the threshold for applying the Public Procurement Law, certification of public procurement contractors, modern craftsmanship

Cont. table 1.

Criminal law	Rationalization of penalties in business transactions, remote criminal trials
Family and civil law	Extrajudicial dissolution of marriage, increasing the upper limit of compensation for witnesses in civil proceedings, leasing agreements and transfers of copyrights in documentary form, extending the deadline from 3 to 24 months for submitting a declaration of return to the surname after divorce
Labor law	eKomunikacja with employees, employee representative in the Company Social Benefits Fund; electronic form of certificate of completion of occupational health and safety training
Administrative law	Increasing the accessibility of offices by changing their working hours, amending the Code of Administrative Procedure regarding the delivery of decisions in a hybrid form, prohibiting public administration bodies and courts from requesting data available in public registers, shortening the duration of the procedure enabling the removal of trees, remote hearings before the National Chamber of Appeal
Financial market	Limiting the obligations of the investment fund depositary, reducing the information obligations of issuers listed on the Warsaw Stock Exchange, reducing the number of reporting requirements for investment companies
Energy and climate	A simple electricity bill, easier connection of different energy sources in one electric hook-up, reduced licensing requirements for renewable energy sources
Legislation	Enforcement of the "European Union + zero" principle, longer <i>vacatio legis</i> – no more sudden tax changes for citizens and companies
State registers	Providing banks with data from the PESEL register, including the image, for the purpose of identity verification; the obligation to verify identity in the PESEL register when concluding third-party liability insurance contracts for Motor Vehicle Owners
European funds	Electronic documents for applications for EU funds, declarations instead of certificates in EU funds

Source: *Raport o deregulacji...*

In the context of the economy, the area of state-entrepreneur relations comes to the fore, in particular the relations between state institutions (control authorities) and those entrepreneurs who appear to be weaker in this relationship, i.e., small and medium-sized enterprises, which often do not have sufficient economic potential to hire specialized law firms and economic consulting entities, and therefore base their interaction with state authorities on their own knowledge and experience. In line with the measures taken, the focus is on simplifying the planned inspections of micro-entrepreneurs carried out by state administration bodies and shortening the duration of inspections from 12 to 6 days. The simplification of scheduled inspections of micro-entrepreneurs' activities results mainly from the introduction of a categorization of the risk of violating subjective and objective regulations (low, medium, and high - the method of analysis is determined by the control authority, which is required to publish information on the rules for assigning entrepreneurs to the appropriate risk category in the Public Information Bulletin on its website). The control authority may carry out a scheduled inspection of an entrepreneur who has been assigned to one of the risk categories in the event of (art 24 *Ustawy z dnia 21 maja 2025 r., o zmianie...*):

- low risk – no more than once every 5 years,
- medium risk – no more than once every 3 years,
- high risk – as often as necessary to ensure effective application of the relevant provisions, considering the high risk of irregularities and the measures necessary to mitigate it.

The proposed amendments also include exceptions - they apply to situations where ratified international agreements or directly applicable provisions of European Union law or separate provisions specify otherwise the frequency of inspections and controls and analyses falling within the competence of the National Revenue Administration, as well as inspections carried out on the basis of the Act of August 25, 2006, on the fuel quality monitoring and control system (art 24 Ustawy z dnia 21 maja 2025 r., o zmianie...). A detailed list of changes introduced in the area of business activity, made in the Entrepreneurs Law Act, is presented in Table 2.

Table 2.

List of changes introduced in the field of business activity, with an indication of the characteristics of deregulation

Area of change	Scope of change	Deregulation feature
Taking first steps in business	Easier ways to conduct business activities that don't require registration. It has been clearly decided that, as a general rule, individuals conducting unregistered business activities should use their PESEL number in business transactions	NO
Principles of business activity control	The maximum inspection time for micro-entrepreneurs will be shortened from 12 to 6 days	NO
	The frequency of planned inspections will be adjusted to the level of risk associated with the business's operations – the lower the risk category, the fewer the number of inspections. Bodies that conduct business inspections, such as the Social Insurance Institution (ZUS), the Trade Inspection, and others, will be required to publish information on the risk category assigned to individual businesses subject to inspection	NO
	Before starting the inspection, each authority will have to provide the entrepreneur with a preliminary list of information and documents that must be made available	NO
	Entrepreneurs will be able to object to inspection activities. This is possible if the authority improperly invokes circumstances justifying the non-application of inspection restrictions specified in the Entrepreneurs' Law, for example, due to suspicion of committing a criminal offense	YES
Rules for conducting business activity	It will no longer be necessary to submit a proxy or power of attorney document to the office if the authorization can be proven in public registers, e.g. the National Court Register	NO
	A change is being introduced to the definition of craft and craftsman, allowing craft entrepreneurs a wide choice of legally permissible forms of conducting business activity	NO
	So-called soft notices, which allow a claim to be filed with a trader without initiating legal proceedings, will be used more widely. This solution has been successfully used in consumer rights cases	NO
	Additional incentives are introduced to encourage mediation in administrative matters	NO
	The administrative body will not require the entrepreneur to use a stamp if such an obligation does not result from the regulations	YES
	Administrative bodies will be able to issue so-called hybrid decisions. If an administrative decision issued in paper form is to contain multiple attachments, these attachments – with the business's consent – may be provided on a durable medium	NO
	Proceedings before the National Chamber of Appeal will be electronically implemented. This will enable remote hearings before the National Chamber of Appeal	NO

Cont. table 2.

Possibility to conclude a leasing agreement in documentary form	The documentary form of a contract involves submitting a declaration of intent in the form of a document (e.g., email, PDF, SMS), which allows the identification of the person making the declaration and the review of its content. It does not require a handwritten signature but provides the same legal force as the written form. It is sufficient that the document allows for the reproduction of the content and confirmation of the parties' identities	NO

Source: own study.

To supplement the above list of changes, it should be added that the legislative changes concerning economic activity include a package of regulations relating to the law-making process. It covers the introduction of the principle of balancing administrative obligations, referring to the concept of “one in, one out.”, which means that when designing new obligations, the draftsman should strive to reduce the burdens resulting from regulations that are already in force in a given area. In addition, it has been established that laws imposing obligations on entrepreneurs will have to have a 6-month *vacatio legis* (art 24 Ustawy z dnia 21 maja 2025 r., o zmianie...), including in taxation.

The law-making process is the basis and foundation for establishing relations between the state and taxpayers in the specific area of taxation and control of proper reporting. The new regulations implement measures aimed at simplifying administrative tax obligations and mitigating penalties for fiscal offenses that do not result in direct tax losses. The most important change is that the new solutions are intended to strengthen the protection of taxpayers' rights and interests by introducing the principle of presumption of innocence. This means that in tax proceedings initiated *ex officio*, any facts causing doubts that cannot be removed will be resolved in favor of the taxpayer. Therefore, any doubts on the part of the tax office regarding the facts of the case will require the tax office to prove the taxpayer's guilt. This applies, for example, to situations where the tax office is not certain about the actual circumstances of an event, but the new regulations will apply to tax proceedings initiated *ex officio* and, accordingly, to verification activities, tax audits, and customs and tax audits.

Table 3.

List of changes introduced in the relationship between the entrepreneur, the taxpayer and the state, along with an indication of the features of deregulation

Area of change	Scope of change	Deregulation feature
Control proceedings	Presumption of taxpayer's innocence in <i>ex officio</i> control proceedings in a situation where the tax office is not sure what the actual circumstances of the event were in tax proceedings initiated <i>ex officio</i> and in verification activities, tax audits and customs and fiscal audits	YES
	The possibility of voluntarily submitting a correction to the tax return is given to the inspected entrepreneur, which partially involves errors detected during the customs and tax inspection	YES
	Possibility of submitting voluntarily a so-called initial declaration, i.e. one that has not been previously submitted, after the initiation or completion of a customs and tax audit	YES
	Cessation of charging default interest for the duration of a tax or customs and tax audit if the audit lasts longer than 6 months	NO

Cont. table 3.

Legislation of tax laws	6-month vacatio legis	NO
Penalties for fiscal offences of a formal nature	Reducing the limit on fines	NO
	Abolition of the penalty for violating the obligation of not appointing a tax collector	YES
Obligations to submit reports and statements	Abolition of the obligation for large taxpayers (income exceeding the equivalent of EUR 50 million and capital groups) to publish a report on the implementation of the tax strategy on their website and to inform the head of the tax office about it	YES
	Postponing by two years the so-called ESG reporting, which concerns the disclosure of information by companies, among others, on the impact of their activities on the environment, society and corporate governance.	NO

Source: own study.

Penalties for acts that do not cause direct tax losses (for formal fiscal offenses, e.g., failure to submit or delay in submitting mandatory declarations and information) will be reduced, as the planned solution is to come into force on January 1, 2026 - the legislative process is ongoing. The new limits on fines imposed by the court, adjusting the number of penalties to the actual harmfulness of the act, will be:

- 480 daily rates (PLN 29,862,336) instead of 720 rates (PLN 44,793,504);
- 120 daily rates (PLN 7,465,584) instead of 240 rates (PLN 14,931,168).

The obligations of the payer/collector to indicate people responsible for calculating, collecting, and paying taxes will be abolished. The penalty for violating the obligation to designate a tax collector will be eliminated. (*Projekt ustawy o zmianie ustawy - Kodeks karny.....*).

Significant changes introduced on October 1, 2025, also include a change in the control proceedings conducted by the Customs and Tax Administration. The new regulations allow the controlled entrepreneur to submit voluntarily corrections to the tax return — in particular VAT — which partially involves errors detected during customs and tax control. The adopted solutions clarify interpretative doubts raised by entrepreneurs regarding tax returns submitted after the initiation or completion of a customs and tax inspection, which allows for a faster completion of the inspection. In accordance with the solutions introduced, interest in late payment will no longer be charged in the case of payment of tax arrears resulting from a submitted return or correction of a return. If a tax return correction is submitted after the completion of a customs and tax audit, the audited entrepreneur may partially include the irregularities identified by the customs and tax office during the audit in the correction - previously, the audited party could submit only a correction that fully took into account the irregularities identified during the audit. In addition, the audited entrepreneur may submit a so-called original return, i.e., one that has not been previously submitted, after the initiation or completion of a customs and tax audit. (*Ustawa z dnia 24 czerwca 2025 r...*).

The legal changes also include a solution clarifying the calculation of interest in late payments during audits conducted by tax or customs and fiscal authorities. Interest for late payment will not be charged if the tax or customs and fiscal audit lasts longer than six months, according to the amendment to the Tax Ordinance passed by the Sejm on September 12, 2025, which is currently awaiting the signature of the President of Poland. However, this rule will not apply if the taxpayer or their representative has contributed to the delay, or if it is due to reasons beyond the control of the auditing authority. This regulation is intended to prevent abuse of the new provisions by deliberately prolonging audits in order to avoid paying interest. The period of suspension will not be included in the audit period. The rules for not charging interest for late payment in tax proceedings will not change if the decision has not been delivered to the taxpayer within 3 months calculated from the date of initiation of the proceedings (*Kontrola podatkowa bez odsetek...*).

The new deregulatory measures are also intended to relieve large taxpayers, i.e., taxpayers subject to personal income tax whose revenues exceeded the equivalent of EUR 50 million, and tax capital groups, - approximately 4,300 entities (*Koniec z obowiązkiem...*). Until June 26, 2025, they were required to publish a report on the implementation of their tax strategy on their website by the end of the twelfth month following the end of the tax year and to inform the head of the tax office about it. Failure to comply with this requirement was punishable by a fine of up to PLN 250,000. From the date of publication of the Act of June 25, 2025, amending the Corporate Income Tax Act, this obligation was abolished (Ustawa z dnia 25 czerwca 2025 r...), in particular because these reports were mostly laconic, even though, in principle, they were supposed to include information (excluding information covered by commercial, industrial, professional, or production process secrecy) about (*Koniec z obowiązkiem...*):

- procedures and processes used to fulfil tax obligations,
- the number of reports submitted on tax schemes (MDR),
- transactions with related entities,
- settlements in countries applying harmful tax competition,
- planned or undertaken restructuring activities,
- applications submitted for tax interpretations or binding rate information (WIS).

Like large companies, medium-sized and small entities listed on the stock exchange are also affected by the change regarding the introduction of mandatory ESG reporting. This involves a two-year postponement of ESG reporting, which requires companies to disclose information on, among other things, the impact of their activities on the environment, society, and corporate governance. The legislative solution established and signed by the President of the Republic of Poland (Ustawa z dnia 9 lipca 2025 r...) introduces the obligation of ESG reporting. The project of deregulation changes the date of reporting obligation. Consequently for large companies ESG reporting postponed from 2026 (reporting for the 2025 financial year) to 2028 (reporting for the 2027 financial year) and for small and medium-sized companies listed on the stock

exchange ESG reporting postponed from 2027 (reporting for the 2026 financial year) to 2029 (reporting for the 2028 financial year) (Projekt ustawy zmieniającej ustawę o zmianie ustawy o rachunkowości...).

5. Conclusions

The examples of changes in the legal system directly related to economic operators and located in the provisions on business activity and state-enterprise relations showed both strictly regulatory features (not changing the direction of the regulatory vector) and deregulatory measures. A list of deregulatory changes that meet the defined criteria for deregulation is provided in Table 4.

Table 4.

List of deregulation changes introduced and planned for introduction in 2025

Area of change	Scope of change
Principles of business activity control	Entrepreneurs will be able to object to inspection activities. This is possible if the authority improperly invokes circumstances justifying the non-application of inspection restrictions specified in the Entrepreneurs' Law, for example, due to suspicion of committing a criminal offense
Rules for conducting business activity	The administrative body will not require the entrepreneur to use a stamp if such an obligation does not result from the regulations
Control proceedings	Presumption of taxpayer's innocence in ex officio control proceedings in a situation where the tax office is not sure what the actual circumstances of the event were in tax proceedings initiated ex officio and in verification activities, tax audits and customs and fiscal audits
	The possibility of submitting voluntarily a correction to the tax return is given to the inspected entrepreneur, which partially involves errors detected during the customs and tax inspection
	Possibility of submitting voluntarily a so-called initial declaration, i.e. one that has not been submitted previously, after the initiation or completion of a customs and tax audit
Penalties for fiscal offences of a formal nature	Abolition of the penalty for violating the obligation of not appointing a tax collector
Obligations to submit reports and statements	Abolition of the obligation for large taxpayers (income exceeding the equivalent of EUR 50 million and capital groups) to publish a report on the implementation of the tax strategy on their website and to inform the head of the tax office about it

Source: own study.

The indicated cases of deregulation clearly changed the vector of regulation, introducing new rules that altered the characteristics of the regulator, as in the case of:

- the introduction of the possibility of objecting to control activities reverses the principle of ordering the hierarchy of systems – the state and the enterprise, making them equivalent and shifting regulations towards self-regulation;

- no need to use a stamp – the rule that a document is authentic and credible if it is stamped is changed; company stamps, payer stamps, employer stamps, name stamps, applicant stamps, letterhead stamps – these are just a few examples of the many types of stamps that entrepreneurs are required to use on application forms, statements, reports, protocols, and information forms and the lack of an appropriate stamp on a document submitted by an entrepreneur could contribute to the prolongation of the consideration of cases or, in extreme cases, to the refusal to accept an application, settle a case, or grant a right for formal reasons;
- the presumption of innocence in ex officio audit proceedings changes the principle of the state sanction policy towards the taxpayer; until now, it was the taxpayer who had to prove that the actual circumstances did not result in a violation of the law; the introduction of the principle of certainty of the authority regarding the violation of the law introduces the principle of “prove that I violated” instead of the principle of “prove that you did not violate”;
- in the case of the possibility of submitting a corrective declaration (full or partial) or an original declaration after the initiation of an audit, and in the case of the abolition of the penalty for violating the obligation to designate a tax collector, the principle of state sanctions policy stipulating that the penalty in the form of penalty interest for non-compliance with the law should be fully calculated until the decision is issued by the control authority, i.e. also the principle of maximizing state revenues from penalty interest – the voluntary submission of a corrective declaration is treated as an “admission of guilt and an act of repentance,” which has not been the case in the analyzed cases so far, and it was possible without an audit procedure;
- in the case of exemption from the obligation to publish a tax strategy and inform the head of the tax office about it, it changes the principle of distrust towards taxpayers, i.e., it departs from the principle of “prove that you are not cheating the tax authorities”.

The above-mentioned changes in regulatory principles – deregulation of the economic dimension of the socio-economic system – have the characteristics of regulatory deregulation, as evidenced by their direction (adapting changes to the general regulator – the free market economy) as well as the participation of a team of business representatives, and result from the premise of reducing the efficiency and effectiveness of the implementation of the economic objectives of enterprises without contradicting social objectives. Other changes in the area of business activity and state-taxpayer relations are regulatory in nature, as they do not change the direction of regulation, e.g. shortening the maximum duration of inspections for micro-entrepreneurs or reducing the limits on fines is merely a change in the scope of freedom of the regulator in the form of the state. In conclusion, it should be noted that the changes in the law made in 2025 under the banner of economic deregulation in most cases show the characteristics of regulation and only in a few cases the characteristics of deregulation as understood in regulation theory. It should also be emphasized that the changes made in 2025 fulfill only

a small part of entrepreneurs' expectations – reference can be made here to the report by the Lewiatan Confederation (*Czarna lista barier...*), in which the list of proposals includes 98 items in the field of tax law, 22 in the field of employment, 47 in the field of energy and the environment, 18 in the field of financial markets and corporate law, 32 in the field of healthcare and the life sciences sector, 11 in the digital field, and 14 in the field of media law.

6. Discussion

Economic theory has not yet been able to define methods for measuring the degree of regulation and the deregulation as well. The state, as a regulator, has difficulty recognizing where the economy is at a given point in the regulatory-deregulatory cycle. Economic policy can only estimate approximately whether the optimal degree of regulation has been achieved, although this raises the question of what “optimal” means. In principle, it should be the best under the given circumstances. This again raises the question of whose perspective - that of the regulator or the economic entity. There is therefore a lack of the basis needed to adopt the right strategy and provide an accurate answer to the question of whether to introduce regulation or deregulation (Bronk, 2009), so the participation of business representatives may be helpful.

Especially since the widespread and imprecise use of terms (in this case, regulation and deregulation) particularly by legislative bodies can create a false impression of the direction of change in the functioning of the socio-economic system, and thus hinder entrepreneurs from correctly interpreting and implementing self-regulatory changes and making the right decisions regarding their business activities. Consequently, entrepreneurs can perceive the state both - as, on the one hand, restrictive, and, on the other, entrepreneur-friendly, creating conditions for a rapid improvement in economic conditions (in the case of legislative actions in 2025), which in most cases is only a media phenomenon.

The analysis carried out is intended to organize the conceptual apparatus required in scientific discourse, which, in the author's opinion, is necessary because the literature on the subject contains statements that deregulation consists in limiting or even eliminating the administrative tools used by the state, and it is emphasized that this should primarily concern decisions on access to various types of economic activity (Ratajczak, 2000). A particular example of which is the “deregulation” of the accounting profession in 2014, which abolished the requirement to pass a state exam for those wishing to run an accounting office (Szczyba, 2014) or deregulation meaning the removal of restrictions on the free operation of the labor market (Gawrycka, 2017; Puzio-Waławik, 2009).

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THE PARADOX OF AUTONOMY IN VIRTUAL EXPATRIATION

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Purpose: This paper explores the paradox of autonomy–responsibility among virtual expatriates and develops a grounded model of performance with organisational inputs and leadership as factors moderating this relation.

Design/methodology/approach: The research adopts a qualitative approach. Data were collected through 15 semi-structured interviews. The respondents represent three perspectives: HR directors, line managers, and employees engaged in international virtual assignments across various sectors. Data were analysed using MAXQDA software and analysis was performed using open, axial, and theoretical coding to identify first- and second-order concepts and aggregate dimensions.

Findings: The final model integrates aggregate dimensions and second order concepts to illustrate the theoretical concept of the autonomy paradox in virtual expatriation and mechanisms moderating its relation to well-being and job performance. When virtual expatriates experience a high degree of self-direction and strong accountability for outcomes supported by organisational policies and leadership relational safety, their well-being results in high performance.

Practical implications: The study provides information on organisational practices that support the performance of virtual expatriates. Highlights the need to balance flexibility with accountability, strengthen relational trust, provide clear role definitions, and standardisation of the procedures tailored to the context of virtual expatriates.

Originality/value: This study contributes to the emerging phenomenon of virtual expatriation introducing the concept of autonomy paradox in virtual assignments. Organisational conditions and leadership support structure its dual nature. It extends the existing framework to the global virtual context and highlights the moderators of its relation. The study provides practical guidance for organisations to navigate the future of global virtual work.

Keywords: virtual expatriation, virtual global work, autonomy paradox, employee well-being, job performance.

Category of the paper: research paper.

1. Introduction

Global disruptions, the growing role of digitalisation and sustainable trends have changed the dynamics of global mobility (Mahadevan et al., 2025). Virtual assignments have been one of the most widely discussed research topics in recent years. Hybrid or fully remote work became the way to maintain business continuity and opened new opportunities to manage global travels. Virtual global mobility emerged as a mean to support business by replacing personal physical interactions for job purposes with virtual international interactions (Selmer et al., 2022). It allows employees to perform their tasks and take on operational responsibilities at different locations while remaining in their home country (Selmer et al., 2022). Global virtual teams could bring together the best talent regardless of team members' locations, and diversity of perspectives could speed up problem-solving, facilitate creativity, or drive innovation (Jimenez et al., 2017).

Virtual employees do the same job as assignees relocated to another country, but without physical relocation. Hence, the traditional understanding of expatriation evolved into a new concept of virtual expatriation. It gave organisations a new opportunity to rethink the way they operate their businesses in the context of sustainable trends. Relocation costs, family, immigration, and tax issues were no longer a risk; employees could continue their international careers and be open to new possibilities (Jimenez et al., 2017).

However, the complexity of international virtual assignments resulted in many challenges. Working in different time zones affected work-life balance, communication problems arisen due to reliance on teleconferences or online chats, language differences led to social categorisation and biases (Jimenez et al., 2017), and the risk of social isolation and stress increased (Vassiley et al., 2025). All these challenges damaged team dynamics and could amplify team conflicts. Managing employees in a virtual environment became increasingly complex as leaders are distant and hierarchy is blurred. The work environment enhanced greater autonomy and task authority (Lauring et al., 2024); however, significant operational decision-making power, limited strategic authority, and increased responsibility without real control emerged as consequences (Selmer et al., 2022; Vassiley et al., 2025).

In the context of virtual expatriation, autonomy is not unequivocally positive. On the one hand, it is a resource — it provides flexibility, motivation, a sense of competence, and decision-making power (Lauring et al., 2024). However, without organisational structures and leadership support, it becomes an emotional and cognitive burden (demand), leading to stress, isolation, and uncertainty about the role (Vassiley et al., 2025). The dual character of autonomy in the context of virtual expatriation shows that virtual expatriates experience autonomy, control, and responsibility, and these dynamics shape their performance and well-being. This tension between freedom and control creates a ‘paradox of responsibility’, a key phenomenon revealed in this study.

Although autonomy is recognised in the literature as an antecedent of motivation and performance, its paradoxical nature —both as a resource and a burden —remains unexplored in virtual expatriation contexts (Jaß et al., 2024). Although the autonomy paradox is well described, there is still little empirical evidence on how it operates in virtual arrangements when employees work across borders with a high level of responsibility (Mazmanian et al., 2013) and what are the consequences for employee well-being and performance in global teams (Fritsch et al., 2025).

Despite significant research on leadership in a virtual context, there remains a lack of research on the mediating role of leaders' influence on employee autonomy in virtual settings (Höddinghaus et al., 2024). Moreover, existing research does not reveal how leaders balance autonomy and accountability in virtual assignments (Brown et al., 2021) and how virtual expatriation depends on organisational context (Lauring et al., 2024). The study on virtual teams explains the psychological safety, however, it does not reveal which leadership practices model the autonomy paradox (Höddinghaus et al., 2024).

Although remote and hybrid work literature document the benefits of job autonomy, emerging studies reveal an autonomy–control paradox in which increased autonomy coexists with heightened demands, blurred accountability, and strain (e.g., longer hours, boundary erosion) (Vassiley et al., 2025). Yet, we lack process models explaining how this paradox unfolds in global virtual work, what are inputs for this concept, and which moderators buffer its negative effects on wellbeing and performance. Recent reviews of global virtual work call for multi-level, mechanism-orientated theories that link individual experience with organisational outcomes. This study addresses these gaps by theorising and empirically establishing a model in which leadership-mediated support converts autonomy into performance while mitigating responsibility overload.

2. Literature Review

2.1. Global virtual work and virtual expatriation

Digitalisation and global work have recently changed the way we work. In the past, multinational companies managed their international businesses based on traditional employee relocation.

Global work has been researched since the 1990s; however, it gained significant interest during the Covid-19 period (Jooss et al., 2022), when a new context of global mobility emerged (Donnelly, Johns, 2021). Global disruptions revolutionised modes of work and reorganised how people work and travel, redefining the boundaries between physical and virtual mobility (Mahadevan et al., 2025).

Global mobility and face-to-face contacts have been significantly reduced and replaced by virtual work, defined as being detached from fixed workplaces (Donnelly, Johns, 2021). Hence, new actors and new work contexts emerged, highlighting global employees, however, without physical relocation.

Global virtual work has become a fundamental means of operating cross-border activities. This shift has laid the foundation for virtual forms of mobility. Virtual expatriation emerged as a natural evolution of traditional mobility and international assignments. Remote work became a new organisational paradigm that gave the foundation for understanding virtual expatriation as a specific form of global virtual work (Donnelly, Johns, 2021). These challenges force organisations to reorganise organisational processes and develop a new approach to managing global mobility and organisational relations (Mahadevan et al., 2025). Remote work will continue to evolve, hence work transformation requires conceptualisation of organisational conditions to capture the novel phenomenon of virtual expatriation.

Recent research has emphasised that virtual expatriation is no longer just a concept but a real practice within multinational organisations. The ability of virtual expatriates to succeed depends largely on conditions provided by the organisation, such as organisational policies, leadership, and social conditions, hence, empirical and theoretical investigation of its structure is required (Lauring et al., 2024). In addition, Mahadevan (2025) points out the lack of empirically verified models for virtual expatriation and the emergence to conceptualise the novel context and roles in global virtual work.

2.2. Autonomy as a resource and a demand

Autonomy is a basic need at work. The concept is rooted in Self-Determination theory (SDT), which explains that the self-directed motivation of employee relies, among others, on autonomy (Ryan, Deci, 1985). Autonomy is essential for growth, integration, and social development. Autonomy determines employee personal well-being and performance (Ryan, Deci, 1985), it's a feeling of independence and individualism. Autonomy occurs when employees can choose their behaviour without being controlled by others. Autonomy is associated with positive outcomes and leads to better performance, engagement, and well-being (Ryan et al., 2022). The meta-analysis conducted by Ryan et al. (2022) provides empirical evidence for autonomy as a basic psychological need.

Autonomy and control on the job have traditionally been considered key factors in motivating employees to promote employee well-being and healthy working conditions (Pérez-Zapata et al., 2016). Undoubtedly, autonomy positively affects the meaningfulness of work (Vassiley et al., 2025). Employees can make decisions about their tasks and control their work and schedule.

However, if employees are under pressure to meet external expectations, they experience problems maintaining full engagement (Mazmanian et al., 2013). Their job performance depends on the clarity of organisational structures and support (Ryan et al., 2022). In virtual assignments, autonomy may not be adequately supported, leading to overload, personal,

and social disruptions (Ryan et al., 2022). SDT has practical implications for organisations, indicating that a disturbance in the sense of autonomy may lead to frustration and decreased well-being (Ryan et al., 2022).

Due to autonomy in virtual settings, employees are increasing their efforts to organise their work, for example, by working longer hours to adapt to different time zones (Pan et al., 2022). At the same time, they limit their independence through constant availability (Vassiley et al., 2025). Additionally, digital technology enhances prolonged availability, thereby burdening employees with their work (Mazmanian et al., 2013). Due to flexible work arrangements, employees blur the boundaries between their personal and professional lives, leading to greater anxiety and work-family conflicts (Björntoft et al., 2020). Autonomy can intensify work and lead to health problems and burnout (Pérez-Zapata et al., 2016).

Hence, the conflict arises from the attempt to gain greater freedom and independence while losing control and self-direction. SDT indicates that autonomy in the virtual expatriate environment may function as both a resource and a demand, depending on the conditions (Ryan et al., 2022). In addition, the Job Demands-Resources (JD-R) theory explains that autonomy can function as a resource but can also become a demand if not supported (Peretz, 2024).

This phenomenon, named the autonomy paradox, became a central issue in the context of virtual assignments (Vassiley et al., 2025). The autonomy paradox occurs when employees with a high degree of autonomy intensify their work and find it difficult to disconnect, which negatively affects their well-being (Vassiley et al., 2025). Employees are forced to shape their experience and develop self-management strategies to gain performance (Vassiley et al., 2025). The effect is intensified by technology that allows us to work from anywhere and maintain constant availability.

2.3. Leadership and organisational setting

In the context of virtual expatriation, the autonomy paradox arises when autonomy is granted without the positive support of leaders and organisational settings (Ryan et al., 2022). Hence, autonomy must be demonstrated situationally.

The dual nature of autonomy highlights conditions that moderate how autonomy results in well-being and greater performance. JD-R theory explains that job demands and resources influence employee well-being and performance (Bakker et al., 2025), hence organisational conditions or leadership support will play a significant role (Mazmanian et al., 2013; Ryan et al., 2022)

The lack of organisational frames for virtual context blur demands, and employees are transitioned towards self-management. Organisational inputs and leadership can reduce or intensify the autonomy paradox. The study of Ryan et al. (2022) indicates that autonomy will work if supported by organisational conditions and leadership that will enable its realisation. In addition, the JD-R model explains that work characteristics influence feelings of autonomy, which act as a key resource that enables self-management. Hence, leadership and organisational frameworks serve as contextual resources that foster a positive sense of autonomy (Bakker

et al., 2025). Additionally, distributed work arrangements, virtual communication, technological advancement, and external pressures will continue to increase the importance of leadership in virtual assignments (Höddinghaus et al., 2024).

In recent years, leadership in virtual settings has been the subject of extensive scholarly research (Höddinghaus et al., 2024). The use of digital technologies has transformed the way leaders communicate with employees, creating many challenges. The spatial distance between the leader and employees can decrease control and support and lead to changes in attitudes, feelings, thinking, behaviour, and performance (Höddinghaus et al., 2024). Due to reduced face-to-face contact, they struggle to foster positive relationships in the teams.

There are many styles of leadership in the literature; most of them can be categorised as task- or relationship-oriented. According to task-oriented leadership, including directive leadership, management by objectives, and transactional leadership, leaders coordinate and monitor work processes, define roles, assign tasks, set goals, and monitor performance (Brown et al., 2021). On the other hand, relationship-oriented leadership, such as LMX, participative leadership, shared leadership, and authentic or servant leadership, focuses on creating positive relationships with employees and building trust (Höddinghaus et al., 2024). Leaders inspire and motivate employees, develop and support them, and empower them to take initiative.

The results of a recent meta-analysis (Brown et al., 2021) revealed positive correlations of both types of leadership in a virtual context, such as job performance, job satisfaction (Brown et al., 2021). However, in virtual teams, relationship-based leadership may be harder for leaders to implement due to reduced information cues.

Studies on virtual assignments revealed that while working virtually, employees have higher autonomy, which requires self-management skills (Höddinghaus et al., 2024). Studies in virtual teams confirmed that leadership is a critical factor in helping employees overcome challenges while working virtually (Brown et al., 2021)

In virtual arrangements, leaders should ensure effective work while allowing psychological safety. Leadership in virtual settings requires different competencies, such as managing trust at a distance, enhancing relationships, and adapting tools to ensure effectiveness. Leaders should address the negative effects of digital technology by providing greater support, showing consideration for team members, and reducing uncertainty. On the other hand, leaders are expected to help employees execute tasks in a virtual environment, overcome the uncertainty and ambiguity of their roles, clarify requirements, expectations, and responsibilities, and finally establish structure to accomplish the task (Brown et al., 2021). This means there is no single style to adopt, and a new approach is needed.

However, many studies explore factors that moderate the relationship between leadership and performance in virtual context, but do not address how leadership moderates the relationship between autonomy and employee wellbeing in virtual assignments. Support from organisations and leaders can be an important factor in reducing the negative aspects of the autonomy paradox.

2.4. Employee well-being

The concept of well-being comprises a set of job characteristics that predict employee motivation, satisfaction, and efficiency (Bakker et al., 2025). Global disruptions, such as Covid-19, initiated a shift in how well-being is understood. Before then, well-being was associated with physical conditions and job satisfaction. However, disruptions and digital transformation introduced new conditions, including psychosocial risks, technostress, information overload, and challenges to work-life balance. These risks should be considered when discussing the concept of virtual expatriation. Mental-health programmes aim to provide holistic care to continue employee performance. Organisational experience has demonstrated that many organisations have begun to recognise the importance of developing dedicated mental health programmes, flexible work arrangements, and digital wellness policies (Duradoni et al., n.d.); however, the topic remains underdeveloped.

The job demands-resources (JD-R) theory integrates various job stress and motivational perspectives to explain how the organisational context may enhance or diminish employee well-being. A core assumption is that the physical, social or psychological aspects of the organisational environment influence employee health, behaviour, performance, and overall well-being (Bakker et al., 2025).

Knowledge of employee well-being in a virtual context is crucial not only for employee mental health but also for organisational long-term performance. Hence, investigating employee well-being in virtual context became a strategic need in achieving competitive advantage in the post-pandemic work environment (Mateen et al., n.d.).

Although SDT has robust empirical support (Ryan et al., 2022), its application to virtual global work — especially when autonomy interacts with increased responsibility without clear authority — remains underexplored. Hence, this study proposes leadership and organisational conditions as moderators of the relationships among autonomy, employee well-being, and job performance.

3. Methods

3.1. Research context

The empirical material for this study derives from 15 semi-structured interviews with polish HR specialists, line managers, and employees engaged in virtual global assignments within multinational organisations. The respondents were asked an open question; the interviewer did not suggest any possible answers, and the questionnaire itself used a cafeteria-style format. The interviewer had to classify the answer into one of the available response types, which facilitated processing and at the same time did not suggest any answers.

The participants represented diverse sectors, including the IT, banking, automotive, transport, and food industries, within international organisations (Table 1).

Table 1.

Formal interviewee characteristics

ID	Status	Gender	Age	Education	Industry	Company size
1	Manager	Male	30-40	Higher education	IT	More than 500
2	Manager	Female	40-50	Higher education	Transport	More than 500
3	HR Director	Female	40-50	Higher education	Food industry	More than 500
4	Manager	Male	40-50	Higher education	IT	More than 500
5	HR Director	Female	50-55	Higher education	Automotive	Less than 500
6	HR Director	Female	50-55	Higher education	Banking	More than 500
7	Employee	Female	20-30	Higher education	IT	More than 500
8	Employee	Male	20-30	Higher education	IT	Less than 500
9	Employee	Male	30-40	Higher education	IT	More than 500
10	Employee	Male	30-40	Higher education	IT	Below 500
11	Employee	Female	30-40	Higher education	IT	More than 500
13	HR Director	Female	30-40	Higher education	Banking	More than 500
14	HR Director	Female	40-50	Higher education	Food industry	More than 500
15	Manager	Male	30-40	Higher education	Transport	Less than 500

Participants were selected by purpose-sampling based on their international exposure and virtual assignments. Each interview lasted between 60 and 90 minutes and was conducted via online communication tools such as Microsoft Teams, Zoom, or Google Meet. The interviews were recorded, transcribed, and anonymised. Data were collected between November 2023 and September 2024.

3.2. Data analysis

Following the grounded theory approach (Goia et al., 2013), the author combined inductive coding with iterative abstraction. The process was supported by MAXQDA 2024 qualitative analysis software.

In the first stage, the open coding procedure was applied to identify first-order concepts, key phrases directly reflecting the voices of the participants (e.g., “Performance criteria vary by manager”, “Limited formal & informal integration rituals”, “Home office increases comfort and focus”). Next, through axial coding, conceptually similar statements were grouped into second-order themes to represent theoretical dimensions (e.g., “Relational safety buffer”, “Autonomy and responsibility”, “Equal opportunities”). This stage involved a continuous comparison across all statements to eliminate redundancy. In the third stage, the author clustered related themes into higher-level constructs to represent broader theoretical patterns, and finally aggregate dimensions were developed (e.g., “Leadership and rational safety”, “Mechanisms of Virtual Expatriation”) (Gioia et al., 2013).

The entire coding process was refined through peer debriefing and cross-checking to ensure credibility and consistency (Goia et al., 2013; Corbin, Strauss, 2015).

To enhance the trustworthiness of the findings, several strategies were applied:

- Triangulation of data sources (managers, employees, HR representatives) provided multiple perspectives.
- Iterative comparison between empirical data and emerging theory minimised researcher bias.
- Thick descriptions and representative quotations were retained to preserve the voices of the participants.
- Peer validation with qualitative experts and intercoder reliability checks in MAXQDA ensured analytical robustness.

This rigorous analytical process led to the identification of five aggregate dimensions and nineteen second-order categories for the entire study (Figure 1).

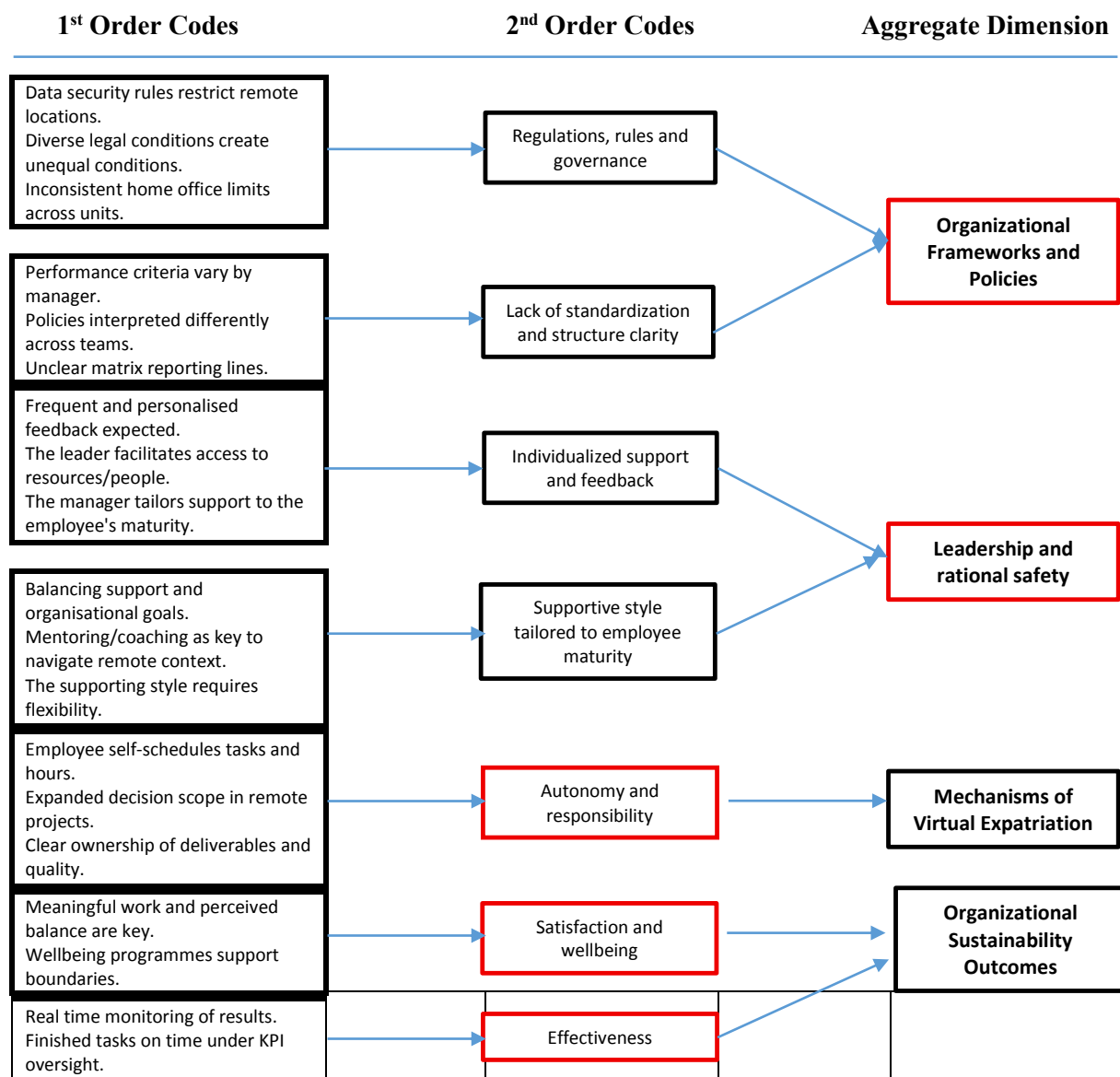


Figure 1. Coding scheme of selected concepts.

Source: Own resources.

The data presented in this article are part of a broader qualitative research project aimed at developing a model of virtual expatriation as a catalyst for organisational sustainability. In this article, the author focusses on selected codes and aggregate dimensions to explain how autonomy, responsibility, and support interact within virtual global work systems. The article presents five analytical dimensions to illustrate the autonomy paradox in virtual expatriates environment, two aggregated dimensions named Leadership and rational safety and Organisational frameworks and policies, as well selected 2nd order concepts, named Autonomy and responsibility as part of the Mechanisms of Virtual Expatriation, Effectiveness and Satisfaction and well-being as part of Organisational Sustainability Outcomes.

4. Results

4.1. Emerged codes and dimensions

Leadership and rational safety – this dimension reflects the role of leaders in creating the relational aspect of virtual work, balancing autonomy, providing personalised tailored feedback, and ensuring that employees remain connected to the organisation despite physical distance.

In interviews, employees described leaders as enablers and buffers: on the one hand, they empower people to make decisions and self-manage; on the other hand, they exacerbate isolation, stress, and communication breakdowns. Their unfair use of unrealistic performance monitoring caused poor mental health. Selected quotations are presented below:

- “The periodic assessment process should be supported by the line manager to gather comprehensive feedback” (MAN1).
- “I try to support the employee, but I also have to meet the objectives of the organisation - there is always a balance between the interests of the individual and the interests of the company” (MAN2).
- “Being there for employees – coaching, asking questions, offering support at every stage – that's what being a leader means to me” (HR3).

Organisational frameworks and policies – this dimension captures the formal and institutional structures and frameworks for virtual expatriation. It includes regulations, rules, governance, and the issue of structure clarity and standardisation of procedures. Provides the structural foundations for virtual assignments.

The interviews emphasised the lack of clear standards and policies for virtual assignments. Some organisations established rules defining eligibility for virtual work, such as financial regulations and compensation for home office expenses, while others relied on informal decisions. The absence of standardisation generated ambiguity among virtual employees. Selected quotes are presented below:

- “The regulations allow remote work for a maximum of twice a week or 24 days a year. In addition, there is an obligation to report the remote work location and a flat rate of thirty-odd zlotys per month” (HR1).
- “The supervisor has the authority to decide on remote work – it is up to them to decide whether someone can work remotely” (HR2).
- “The problem is the regulation of working hours, for example, from 11 am to 7 pm – and the lack of a specific duration for such tasks, which creates tension” (EMP4).
- “Feedback depends on the manager and the rules in the team – no specific regulations for remote work (HR1).
- “The methods are the same for everyone, regardless of the work system – there is no difference” (HR3).

Autonomy and responsibility – as part of the aggregate dimension named Mechanisms of virtual Expatriation, this concept captures how virtual expatriates organise their work, schedule tasks, make decisions in remote projects, and assume ownership of outcomes.

However, the respondents emphasised the high level of autonomy, while coexisting with high expectations of availability and productivity. In turn, it generated the paradox of autonomy, expressed as a tension between self-direction and accountability for performance. Selected quotes are presented below:

- “I am fully responsible for making decisions concerning my team – planning the work of the team, ensuring quality and timeliness. I am the one who assigns tasks and sets priorities” (MAN2).
- “I cannot decide which technology to use – architects impose this” (EMP2).
- “The biggest advantage of this role is the freedom to act; I have the opportunity to make decisions on how to run the project and how to solve problems” (MAN3).

Satisfaction and well-being – this concept encompasses the psychological and emotional outcomes of virtual expatriation, mainly well-being.

Some of the employees interviewed valued the organisation's flexibility, comfort, and well-being programmes. However, others experienced isolation and blurred boundaries between professional and private life. They found it difficult to disconnect from work, made worse by digital tools that provide constant access to job tasks, resulting in constant stress. Selected quotes are presented below:

- “They need to have self-discipline and good planning skills to avoid falling into the trap of having the laptop open from morning to night and being at work all the time” (HR3).
- “Remote work has allowed me to manage my time better and increase my focus. I have more time for my own pleasures, more private time, this is very valuable to me” (EMP4).

Effectiveness – this concept refers to achieving goals and ensuring performance. It includes real time monitoring of results and timely task completion under KPI oversight. Respondents noted that digital tools for coordinating tasks, clear goal setting, and mutual trust were critical to maintaining effectiveness without constant monitoring. Selected quotes are presented below:

- “Performance evaluation should be based on results and achievements, not just time spent at work. It should also include regular feedback and 360-degree evaluations” (EMP5).
- “The effectiveness of a virtual expatriate is determined by the success of the mission – e.g., implementing technology at the client's site or transferring an application to the client” (MAN1).

The study's results directly answer the research questions posed in this article. The study explores how autonomy is managed in a virtual context and highlights its dual nature (RQ1). Moreover, the author provides an exploration of mechanisms that influence the autonomy (organisational frameworks, leadership). The study explains how leaders can enhance employee well-being and job performance (RQ2). Finally, the study explains the consequences of the autonomy-responsibility dynamics for performance and wellbeing, both positively and negatively, and provides practical implications (RQ3).

4.2. Conceptual model and relationships

Based on the above dimensions, the model concept of autonomy paradox in virtual settings emerged. It is an interdependent model of organisational, relational, and individual mechanisms that shape the outcomes for the employee and the organisation. It is structured in the following interrelated levels:

1. Organisational frameworks as input.
2. Autonomy and responsibility as mechanisms of Virtual expatriation.
3. Leadership as a moderating mechanism.
4. Well-being and performance as outputs.

Organisational conditions create role ambiguity; hence, employee autonomy (freedom, flexibility) and responsibility (accountability, decision-making) may occur as a paradox (demand vs. resource). It is moderated by Leadership support, or its lack, which, in consequence, leads to a dual path of performance and wellbeing (empowerment and satisfaction vs. stress and work overload).

Based on the above discussion, the theoretical framework has been developed (Figure 2).

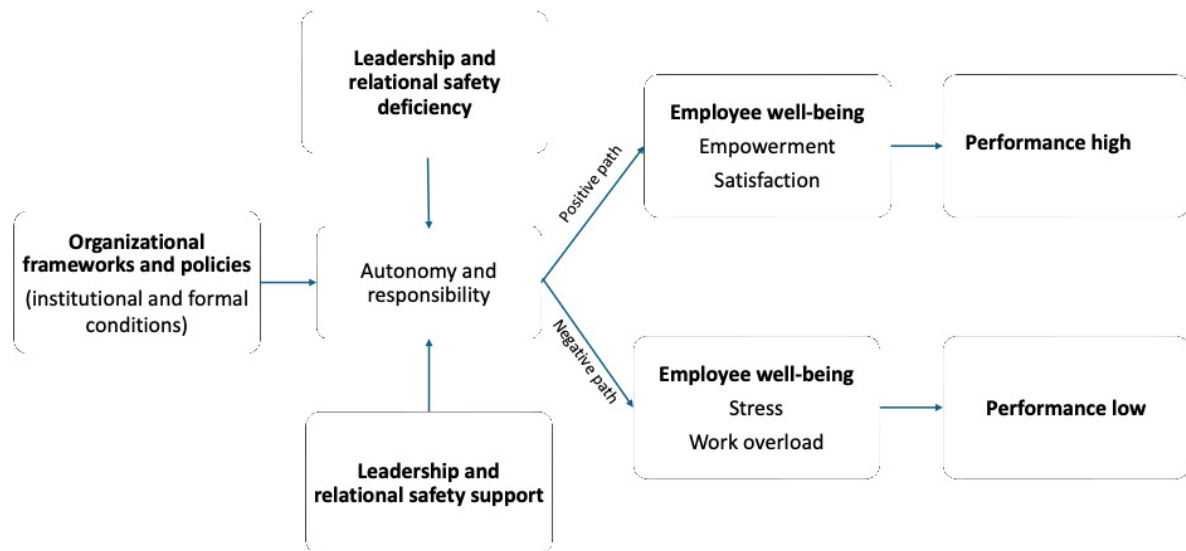


Figure 2. Emerged model of VE performance.

Source: Own resources.

4.2.1. Organisational conditions (input)

The organisational system plays a critical role in the virtual context and influences employees' mental well-being. Organisational frameworks—including regulations, rules, and governance, as well as standardisation and clarity of structure—define eligibility and support for virtual expatriates. The framework refers to rules that restrict virtual work, legal conditions, policies for virtual employees, and performance criteria. When these structures are clear and standardised in the context of virtual expatriation, employees can experience autonomy and focus on achieving results.

However, when standardisation is low or lacking, roles are not defined, processes are not adjusted to the virtual context of work, legal conditions are diverse, home office rules and performance criteria are unclear, it generates confusion, which directly influences perceived autonomy and, in turn, performance and well-being.

4.2.2 Mechanisms: Autonomy and responsibility as dual forces

The core of emerged model is constituted by 2nd order concept: autonomy and responsibility. It explains under what conditions perceived autonomy leads to well-being and higher performance.

In a virtual context, autonomy may be both a resource and a burden. VE gains freedom while having the opportunity to make decisions, organise tasks, and experience trust. It enhances self-discipline and accountability for your work, leading to higher performance. Autonomy may also lead to overload, stress, and role ambiguity if VE do not experience a supportive leadership style. The balance between autonomy and organisational control determines whether employees experience empowerment or overload. This equilibrium constitutes a micro-foundation of sustainable virtual work performance.

Hence, the negative path of the autonomy-leadership relationship will result in accountability without authority, decision constraints, and psychological tension. The positive path will determine self-organisation of tasks and time, flexibility, and focus.

However, this positive outcome depends on the clarity of organisational frameworks and leadership support. Determines whether virtual expatriation becomes a source of performance, stress, or disengagement.

4.2.3. Moderating mechanism: Leadership and relational safety

Within the organisational framework, leadership represents the relational and emotional infrastructure of virtual expatriation. When leaders demonstrate support through trust, provide constant, individualised feedback, and facilitate access to resources, virtual expatriates can experience greater empowerment. Moreover, leaders can enhance VE's flexibility and sense of belonging by applying a supportive, coaching style that balances support with organisational goals. It creates a psychological buffer that enhances well-being and productivity, and protects employees from the isolation and stress typical of the virtual environment. The supportive leadership style has been shown to improve motivation, trust, and psychological safety in a virtual environment (Carnevale, Hatak, 2020).

However, if these expectations are not fulfilled, VEs experience tension and difficulty sustaining in dispersed teams. Hence, leadership can either stimulate or reduce the autonomy paradox in virtual settings.

4.2.4. Well-being and performance as outcomes (output)

The final part of the model concerns the outcomes of perceived autonomy. The well-being of employees in virtual assignments emerges from the interaction among organisational frameworks, leadership, and perceived autonomy. It reflects how work conditions and leadership can support employee autonomy. Performance in virtual settings reflects how employees exercise autonomy to deliver the results of their work. Well-being and performance are interlinked outcomes that result in two possible paths.

The positive path of this relationship assumes that structured organisational frameworks and leaders' support encourage VE to demonstrate engagement, efficiency, high-quality results, and overall well-being. When organisational frameworks provide transparent expectations, clarity of role and structure, measurable work indicators, standardised procedures adjusted to the virtual work context, and supportive digital communication tools, VE are empowered to self-manage their tasks to achieve performance. In addition, leaders can improve autonomy by setting clear goals and evaluation criteria, providing constant support, and setting transparent expectations. It improves VE's sense of responsibility, often described as "the outcome depends on me," and leads to greater performance. This clarity reduces ambiguity and fosters employee well-being.

However, if autonomy is accompanied by a lack of managerial support and a blurred role, it generates stress and decreases performance. The negative path of this relationship results in overload, stress, isolation, role uncertainty, and reduced well-being. If performance

expectations are unclear, VE experience availability anxiety, expressed as a constant pressure to stay online and work beyond dedicated work time (Mateen et al., n.d.), as well as emotional exhaustion and decreased self-discipline.

When leadership and organisational frameworks align with the sense of autonomy and responsibility, VE will demonstrate stable well-being and high performance. When this mechanism misaligns, VE experience stress and detachment, and their well-being and performance decrease.

5. Discussion

The research resulted in the development of the framework for the effectiveness of virtual expatriates in the context of the autonomy paradox. The findings indicated that employees typically consider virtual assignments as a favourable mode of work. The level of overall well-being is satisfactory; however, employees highlighted the key role of autonomy and its dual nature. Autonomy may enhance well-being when supported by the organisation and its leaders. Employees expect flexibility in designing their work schedules with respect to their personal time. They highlight the need to disconnect when their mental state is threatened and expect adequate support. Recent studies also showed that when employees lose control over their time and conditions, it enhances their engagement and motivation (Pan et al., 2022). Hence, autonomy in the virtual context, as a positive phenomenon, is, however, moderated by many conditions.

Perceived organisational support proved to be a critical aspect of autonomy and well-being. Employees claim that managerial support, frequent individualised feedback, access to resources, coaching and mentoring practices, and well-being programmes allow them to navigate the virtual environment effectively. They expect expanded decision-making scope in virtual assignments, clear ownership of deliverables, and quality.

The study contributes to the literature on the dynamically evolving phenomenon of virtual expatriation, which remains underdeveloped. The study distinguishes virtual expatriation as a distinct concept among other forms of virtual work and places it within a clear conceptual framework. The author discusses conditions under which VE can achieve high performance.

In particular, the study adds to the literature on the autonomy paradox and puts it in the context of virtual expatriation. The study highlights that the autonomy is not universal but conditioned. Moreover, the study extends SDT and JD-R theory by explaining when autonomy shifts from a demand to a resource in virtual assignments, clarifying the conditions under which VE autonomy leads to well-being and high work outcomes. The model presents how unbalanced autonomy transforms into demands and decreases employee job performance.

The study highlights the critical role of the organisational framework and leadership to create favourable conditions for the effectiveness of virtual expatriates.

5.1. Limitations & future research

For this qualitative research, several limitations should be acknowledged. First, the limited number of interviews and a sampling in one country. The qualitative design, based on the Gioia methodology, provided a theoretical, rather than statistical, generalisation of the concept (Gioia et al., 2013). Therefore, the results offer conceptual framework for the virtual expatriate mechanisms and cannot be assumed to represent other organisational settings. Second, qualitative coding and interpretation can introduce researcher biases, although all strategies of constant comparison and transparent data structures were applied to ensure credibility (Chamraz, 2014). Finally, participants were selected based on their experience with virtual experiences from different points of view (HR directors, line managers, employees); their perspectives may also reflect subjectivity.

By considering the study's limitations, the author also identifies several new directions for future research. Although the author found clear evidence of moderators of the relationship between autonomy and virtual expatriates well-being and effectiveness, encourages future research to investigate the effects of additional moderators. Future research may focus on quantitative validation of the model by developing scales to assess different inputs and moderators of virtual expatriation effectiveness and testing them using structural equation modelling (SEM). In addition, future research may also focus on cross-industry comparison.

However, since the data presented in this article are part of broader qualitative and quantitative research aimed at developing a model of virtual expatriation as a catalyst of organisational sustainability, there is significant potential to identify other factors influencing the effectiveness of virtual expatriates within virtual global work systems.

5.2. Practical implications

The author introduces the paradox of autonomy as a foundation for the design of virtual work. HR plays a significant role in supporting organisations in building systems that define accountability and provide support for virtual expatriates. Organisations need to consider the specific nature of leadership in virtual environments, such as clear goals, frequent communication, and virtual rituals, which have direct implications for organisational settings (Höddinghaus et al., 2024). Knowing that leadership moderates the autonomy-responsibility paradox, organisations need to adapt their practices accordingly. Hence, organisations should develop mechanisms to support leaders in balancing autonomy with guidance, delegating, and empowering to ensure employee well-being, which will lead to high performance.

6. Conclusions

Given the growing significance of the concept of virtual expatriates, the study is particularly timely and important. The research found that virtual expatriates experience a paradox of autonomy at work and are aware of the conditions under which autonomy leads to general well-being and high performance. VE perceive organisational support as a protective buffer. Significantly reduces the risk of stress and poor performance. The study provides powerful evidence of the importance of an organisational framework and supportive leadership in transforming autonomy into a key driver of performance.

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APPLICATION OF IOT TECHNOLOGY IN PUBLIC TRANSPORT MANAGEMENT IN SMART CITIES

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Purpose: The dynamic development of modern information and communication technologies (ICT) and the increasingly widespread application of the Internet of Things (IoT) concept are one of the key elements in the transformation of modern cities into so-called smart cities. The growing demand for effective, safe, and environmentally friendly solutions in public transport makes IoT particularly important as a tool supporting sustainable development and improving the quality of life of residents. The aim of this article is therefore to examine the level of public awareness, perception of benefits, and potential risks arising from the use of IoT technology in public transport. The aim of the study was also to determine the extent to which respondents recognize the importance of IoT in improving the functioning of public transport, including punctuality, safety, travel comfort, and environmental protection. Another important aspect of the analysis was to identify potential concerns related to privacy and user data security, which is one of the main challenges of modern smart systems. Ultimately, the article aims to provide valuable insights for both practitioners and researchers involved in the field of smart cities. The research results can serve as a source of knowledge for planning and implementing IoT-based solutions in public transport, supporting the decision-making process of local authorities, transport system designers, and institutions responsible for sustainable urban development.

Design/methodology/approach: The research objectives were achieved by using a diagnostic survey method based on an online questionnaire. The approach to the topic is empirical and analytical, based on the theoretical assumptions of the Internet of Things (IoT) concept and its application in public transport in the context of smart city development.

Findings: The study found that most respondents had a positive view of the impact of IoT technology on the quality of public transport, especially in terms of improving safety and punctuality. The analysis of the results also confirmed a high level of public acceptance for the implementation of IoT-based solutions in smart cities.

Originality/value: The article brings a new perspective on the practical application of Internet of Things (IoT) technology in public transport, presenting users' opinions and expectations regarding smart urban solutions. Its value lies in providing up-to-date empirical data that can support local authorities, transport system designers, and researchers working on smart city issues.

Keywords: IoT, Management Smart City, Management Smart Mobility.

Category of the paper: Research paper.

1. Introduction

New technologies and new channels of communication affect not only the real economy and changes in the ways goods are produced and services are provided, but also work, housing, culture, value systems, etc. The transformations are so significant and so rapid that specialists are trying to analyze the consequences of these changes, find patterns, and create new theories. Automation has been around since the last two decades of the 20th century, and its widespread use did not bring about a breakthrough. Fundamental changes were brought about by networking, which was made possible by the digitization of various spheres of economic and non-economic activity. Increased efficiency was of fundamental importance for economic development. Networking broke down the barriers that existed in the traditional management process, in which each economic entity sought to rationalize the use of its resources. A similar development began to take place in the area of local government. This concerns the pursuit of new technological and organizational solutions, known as ICT, in the field of smart city development. Their implementation also has an impact on one of the six main sub-areas, namely smart mobility (Bitkowska, 2018; Łabędzki, 2022). The stages of transforming a city into a smart city, which were presented in Figure 1, are a natural consequence of the evolution of cities.



Figure 1. The evolution of the city towards the smart city concept.

Source: based on: Dewalska-Opitek, 2014.

The level of interactivity of urban areas is growing in parallel with the awareness of residents. Smart city elements are developing all over the world, including (Qonita, Giyarsih, 2023, pp. 481-483):

- Smart economy.
- Smart environment.
- Smart management.
- Smart living.
- Smart mobility.
- Smart people.

According to this transformation, they aim to transfer new technologies to the world, allowing them to live more comfortably. However, in Poland, the idea of smart cities may seem costly, but in the long term, it allows for significant savings at the local government level. When analyzing citizens' needs, local governments recognize the need to combine public

transport solutions with process management support dictated by the dynamically changing conditions of the urban environment, which cities of the future must meet, resulting from the implementation of adaptive measures (Bitkowska, 2018). More and more local governments recognize the need to implement a process management model that allows for the integration of the strategic and operational levels. There is a necessity to analyze the city's public transport processes, considering the relationship between individual internal and external elements. By definition, urban transport is one of the branches of the economy that most closely follows innovative solutions in the areas of vehicle resources used (including rail, road, and underground). In its efforts, it ensures effective travel for residents in three important relationships:

- home – work – home,
- home – school – home,
- home – destination – home.

In summary, the efficient functioning of public transport is crucial for the daily lives of residents and for the sustainable development of the city. The use of modern technologies, including solutions based on the Internet of Things concept, can contribute to increasing the efficiency of transport systems, improving their accessibility, and the quality of services provided. As a result, public transport becomes not only a means of transportation, but also an important element of a smart and resident-friendly city.

2. Literature review

Currently, there are many definitions of a city. Urban centers and related concepts are classified according to population size, type of functions performed, buildings or regardless of these factors, municipal rights (Manik, 2024, pp. 3-4). Definitions of cities have evolved (Noori, et al., 2025, pp. 14-15). Initially, defensive strongholds with their suburbs or commercial settlements were considered cities. However, cities with their definitions along with the development of civilization, the functions of settlements, their population and the nature of their buildings have changed. Table 1 presents an overview of current definitions of smart city.

Table 1.
Selected definitions of the smart city

Definition	Autor's
The smart city has been proposed as a way to develop sustainable cities by improving efficiency and better optimizing processes in the urban system.	Clement et al., 2023
A smart city is characterized by intelligent, heterogeneous devices that cooperate with each other through the regular exchange of small amounts of data in the context of IoT in an urban area.	Murroni et al., 2023

Cont. table 1.

A smart city is perceived as an agglomeration of cooperating systems, in which each physical system is connected and synergistically integrated with the surrounding urban environment.	Tricomi et al., 2024
Smart cities, which are a modern and efficient model of cities, digital solutions are implemented in various areas. It is embedded in sustainable development, striving for ecosystem balance and a new quality of life for residents.	Wolniak et al., 2024
A smart city is a new approach to urban development that goes beyond traditional models and is based primarily on information technology.	Chen et al., 2024
A smart city is a city structure based on new-generation information technologies and the progressiveness of a knowledge-based society.	Chen et al., 2025

Source: Author's own study.

The term Internet of Things (IoT) was first introduced in 1999 by Kevin Ashton, who described the emerging global architecture of internet-based information services (Mishra et al., 2016, p. 1332). Today, this concept refers to a network connecting devices, applications, and services through the Internet. These elements are equipped with sensors and microprocessors, enabling them to communicate with one another and exchange data in real time. As a result, it becomes possible to create intelligent systems that automatically collect and analyze information, make decisions, and perform specific tasks. IoT technology is applied on many fields, including industry, transportation, healthcare, energy, and agriculture, allowing for process automation, optimization, and the improvement of people's quality of life. Table 2 presents an overview of current definitions of IoT.

Table 2.

Selected definitions of the Internet of Things (IoT)

Definition	Autors
The Internet of Things, a revolutionary and rapidly developing technology that could change the way we interact with our surroundings.	Li et al., 2024
The Internet of Things has revolutionized information technology and sensors in various fields, providing widespread coverage and creating opportunities and challenges in the present day.	Ahakonye et al., 2024
The Internet of Things is gaining popularity, and with the development of technology, the Internet, and big data, the networks created are used in every branch of people's everyday lives.	Sharma et al., 2024
The Internet of Things (IoT) can be defined as a global network infrastructure consisting of connected devices that use detection, communication, networking, and information processing technologies.	Xiaoshao, Antwi-Afari, 2024
The Internet of Things (IoT) enables connection, interaction, and data exchange between a large number of diverse devices, while maintaining security standards.	Ashfra et al., 2025
The Internet of Things (IoT) is a network of connected devices whose task is to communicate and exchange data via the Internet.	Azad et al., 2025

Source: Author's own study.

The Internet of Things (IoT) has been increasing popularity (Kieltyka, 2019, p. 39), finding wide application within the concept of smart cities. This idea involves the development of solutions such as smart homes, where all components are connected to the Internet and can interact with one another. In most cases, IoT communication relies on wireless technologies, enabling the creation of integrated networks of devices capable of exchanging information (Burg et al., 2018, p. 39).

Such systems allow for the automatic control and monitoring of various elements of everyday life – from waste bins and household appliances to lighting – significantly improving both efficiency and user comfort. The Internet of Things can be defined as a network of physical objects (“things”) equipped with electronics, software, sensors, and communication modules that enable them to collect and exchange data. This makes it possible to remotely detect and control objects using the existing network infrastructure. As a result, IoT fosters the direct integration of the physical world with computer systems, enhancing efficiency, accuracy, and delivering tangible economic benefits.

Each device is uniquely identifiable through a built-in address, while still being able to operate within the global Internet infrastructure. According to forecasts, the number of devices connected to IoT was expected to reach nearly 20.7 billion in 2024, with projections indicating growth to 50 billion by 2030 (Law, 2024). Currently, companies developing IoT technologies emphasize that some concepts and solutions can already be implemented, while others remain within the scope of forecasts and long-term visions (Malucha, 2018, pp. 53-54).

The literature review was directly linked to the topic of the article through an analysis of existing research on the application of Internet of Things technology in public transport and the concept of smart cities. The publications cited by the author provided the basis for identifying key research problems and the appropriate selection of variables analyzed in the empirical part. This provides a coherent link between the two parts, generating a uniform background for the research and facilitating the interpretation of the results obtained. This connection also allows the conclusions of the article to be placed in the broader context of current trends and directions in urban transport development.

3. Methods

The study used simple random sampling, which involved randomly selecting respondents without dividing them into strata or using a fixed selection scheme. The sample was selected from the population of city residents using public transport, regardless of gender, age, or professional status. This approach made it possible to obtain a diverse research group, reflecting a cross-section of public transport users. The sampling method used helped to reduce bias and increased the reliability of the results obtained. To achieve the research objectives, the method of direct interviews was adopted and carried out between August and September 2025. This technique made it possible to gather in-depth opinions and individual experiences of respondents regarding the functioning and potential of the Internet of Things (IoT) in public transport. The choice of this method was driven by the need to collect qualitative data that not only reveal the level of public awareness of IoT but also help identify expectations, concerns, and suggestions for the practical implementation of new technologies.

The interviews were organized in a semi-structured format, meaning that the researcher used a pre-prepared set of questions while leaving space for open responses and further exploration of relevant topics. The questions focused on, among others:

- knowledge and understanding of the Internet of Things,
- perceived benefits of its application in public transport (e.g., route optimization, improved punctuality, enhanced safety),
- potential risks and barriers to implementation (e.g., data privacy issues, investment costs, system reliability),
- assessment of the community's readiness to adopt such innovations.

Respondents were selected purposively to include diverse perspectives of public transport users. Participants represented different age groups, occupational backgrounds, and frequencies of using public transport. This approach ensured that the collected opinions reflected a broad cross-section of the community.

The qualitative data were then categorized and subjected to thematic analysis. Based on recurring opinions and themes, the main areas of interest were identified and used to formulate research conclusions. The results were presented in graphical form-through charts, tables, and infographics-which allowed for clear and visually engaging presentation. Such visualization facilitated the comparison of individual categories of responses and provided a quick overview of the dominant trends within the surveyed group.

The combination of interviews and graphical data presentation made it possible to obtain comprehensive insights into public perceptions of the Internet of Things in public transport, as well as to identify factors that may support or hinder the implementation of such solutions in the future.

4. Results

The distribution of respondents' answers regarding their perception of Internet of Things technology in public transport, their level of knowledge about IoT, and their readiness to use smart solutions is presented. The results are presented in tabular form, which allows for a clear presentation of data for the reader. This part of the study is limited to describing the results of the survey, while the interpretation and evaluation are discussed later in the article. The survey was conducted in August–September 2025 on a group of 70 randomly selected respondents. The aim was to obtain opinions on awareness and perception of the applications of the Internet of Things (IoT) in public transport. A diagnostic survey method was used, employing a questionnaire prepared in Microsoft Forms, which enabled efficient data collection and subsequent quantitative and qualitative analysis. The results are presented in Table 3.

Table 3.*Demographic characteristics of respondents*

Education	Results
Basic	3%
Secondary (technical school, high school)	24%
Higher	70%
Basic vocational	3%
How often do you use public transportation?	Results
Every day	40%
Several times a month	21%
Several times a week	16%
Once a week	10%
Rarely/never	13%
How would you rate your knowledge of Internet of Things (IoT) technology?	Results
Very good	11%
Good	37%
Low	20%
Average	31%
Age	Results
18-24	10%
25-34	26%
34-44	30%
45-54	27%
55-54	6%
>64	1%
Gender	Results
Woman	51%
Man	45%
No answer	4%
Age	Results
18-24	10%
25-34	26%
34-44	30%
45-54	27%
55-54	6%
>64	1%

Source: Author's own study.

Based on the data presented, it can be seen that a diverse group of respondents took part in the survey, with a majority of them having higher education (70%). The most numerous age groups were people aged 34-44 (30%) and 45-54 (27%), which indicates a predominance of professionally active people who are potentially more likely to use public transport. The majority of participants in the study were women (51%), while men accounted for 45% of the sample. Forty percent of respondents declared that they use public transport regularly, and another 16% use it several times a week, which confirms the importance of public transport in the daily lives of residents. The level of knowledge of Internet of Things technology was most often rated as good (37%) or average (31%), which indicates growing public awareness of modern technological solutions. These results suggest that the respondents have a basic knowledge of IoT, but there is potential for further education and popularization of this topic.

The questionnaire consisted of a personal details section and a set of questions about the level of knowledge about IoT technology, perceived benefits, potential risks, and readiness to use smart transport solutions. Respondents were selected at random, which allowed for a diverse research sample in terms of age, education, and frequency of public transport use. The information obtained forms the basis for drawing conclusions about the social perception of modern technologies in the context of smart city development. The answers to all questions are presented in Table 4.

Table 4.
Research details

Question No.	Name	Results
1	How do you assess the importance of IoT technology for improving the quality of public transport?	
	Very large	59%
	Small	10%
	Moderate	31%
2	Which aspect of IoT application in public transport do you consider the most important?	
	Passenger safety	33%
	Traffic flow and punctuality	57%
	Convenience and comfort of travel	10%
3	To what extent do you think that the introduction of IoT in public transport will contribute to environmental protection?	
	To a large extent	44%
	To a small extent	14%
	To a moderate extent	41%
4	How do you assess the potential risks related to data privacy when using IoT in public transport?	
	Very high	33%
	Low	19%
	Moderate	49%
5	Would you use a mobile application based on IoT that provides information about delays and the location of public transport vehicles?	
	Yes	63%
	No	37%
6	Do you think that the use of IoT can increase passenger safety in public transport?	
	Yes	87%
	No	13%
7	Do you think investing in IoT solutions for public transport should be a priority in smart cities?	
	Yes	83%
	No	17%

Source: Author's own study.

Based on the results obtained, it can be concluded that respondents generally assess the importance of Internet of Things (IoT) technology in the context of public transport development positively. As many as 59% of respondents considered that the impact of IoT on improving transport quality is very significant, while 31% assessed it as moderate, which indicates a high level of acceptance for this technology. The most important aspect of IoT application in public transport was considered by the participants to be traffic flow and punctuality (57%), followed by passenger safety (33%).

A significant proportion of respondents (44%) believe that the use of IoT can greatly contribute to environmental protection, mainly through route optimization and reduced emissions. At the same time, respondents also see potential threats – 49% assess the risk of data privacy breaches as moderate, and 33% as very high, which indicates the need for appropriate system security measures.

Most respondents (63%) declare their willingness to use IoT-based mobile applications that provide information about delays and vehicle locations, and as many as 87% believe that these solutions can increase passenger safety. The vast majority of respondents (83%) also emphasize that investing in IoT technologies should be a priority in the smart city development strategy. These results confirm the positive reception of the IoT concept and indicate public support for the implementation of smart solutions in public transport.

5. Discussion

The survey allowed us to determine how public transport users perceive the importance of Internet of Things technology in the context of improving the quality of transport services, safety, and the efficiency of the system. Unlike previous studies, which focused mainly on the technical and organizational aspects of IoT, the analysis provides up-to-date empirical data based on the opinions of end users. The results obtained are largely consistent with the literature on the subject, confirming the importance of IoT for the development of intelligent transport, but they also reveal stronger concerns among respondents about data privacy. It can be concluded that the implementation of IoT solutions requires not only technological development, but also information and education activities. The results of the study confirmed the hypothesis about the positive perception of IoT technology in public transport. In the future, it is planned to expand the study to a larger sample and to deepen the analysis by using qualitative methods, such as individual interviews.

The results obtained are consistent with the findings presented in studies by Zanella et al., who indicate that Internet of Things technologies significantly contribute to improving punctuality and safety in public transport, which is also confirmed in this study (Zanella et al., 2014). Similarly, Bibri emphasizes that IoT is a key element in the development of smart cities, especially in the area of urban mobility and traffic management, which corresponds to the high level of acceptance of investments in such solutions among the respondents (Bibri, 2018).

At the same time, compared to previous studies, respondents' concerns about privacy and data security are more noticeable, which indicates growing public awareness in this area. These differences may result from the dynamic development of digital technologies and the increasingly frequent public debate on the processing of personal data. The results of the study therefore confirm the general trends described in the literature, while providing up-to-date empirical data from the perspective of public transport users.

6. Summary

The implementation of sustainable urban management objectives is increasingly based on the concept of a smart city, in which modern technologies, including the Internet of Things (IoT), play a key role. Implementing this idea requires not only appropriate technological solutions, but also the creation of new organizational structures consisting of qualified and properly trained employees capable of effectively managing complex urban systems.

Economic issues are an important aspect of the implementation process. Local authorities often focus on initial costs, assuming that the expenses associated with the maintenance and development of systems will be passed on to future administrations. However, this approach can lead to a lack of continuity and limit the long-term effectiveness of the solutions implemented. A truly smart city is not created solely through technological investments, but above all through sustainable planning, responsible resource management, and continuous improvement of infrastructure.

According to the smart city concept, all activities should be focused on the needs of residents. Technologies, including IoT-based solutions in public transport, are designed to improve the quality of life, increase the comfort of everyday functioning, and reduce the negative impact of humans on the environment. The effective implementation of intelligent communication systems can contribute to improving urban mobility, reducing traffic jams, optimizing energy consumption, and increasing the safety of public transport users.

Ultimately, creating a smart city requires a long-term strategy based on cooperation between public administration, the private sector, and residents. Only then will technologies such as the Internet of Things be able to fully realize their potential, becoming a tool that supports the development of sustainable, modern, and socially friendly urban spaces.

The development of new technologies and increasingly easy access to information will enable real-time city management in the future. Smart cities leverage the growing potential of information and communication technologies (ICT) to perform tasks that provide authorities with access to effective and modern solutions. Through the use of ICT and advanced data analysis, these cities strive to achieve three key objectives: strengthening social cohesion, supporting sustainable development, and increasing the efficiency of urban space.

These goals can only be achieved through close cooperation between city authorities and residents, as well as through detailed analysis of data obtained from sensors installed in urban infrastructure, such as traffic lights, bus stops, and users' mobile devices. This data forms an integrated information network that allows for continuous monitoring of processes taking place in the city and supports decision-making based on real and up-to-date information.

Smart city systems require constant supervision, and the data they collect should be systematically processed, analyzed, and made available. This process forms the basis for initiating new activities and development projects that lead to an improvement in the quality of life of residents and increase the innovation and efficiency of the city's functioning.

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GENERATION X REPRESENTATIVES AS A BASE FOR BUILDING COMPETITIVE ADVANTAGE IN CONTEMPORARY SMES

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Purpose: The paper aims to outline the primary characteristics of Generation X as customers and a source of competitive advantage for SMEs.

Design/methodology/approach: The paper is based on a critical literature evaluation presenting international research on Generation X, as well as a review of the practitioner-oriented insights published by different Polish marketing agencies.

Findings: The paper surveys and synthesizes published research on Generation X customer behavior with providing information on the background and possible reasons that shape their purchase behavior. It presents the overall picture of Polish customers aged 50-65 and identifies research gaps in the area.

Research limitations/implications: As a part of the paper is based not only on scientific papers, but also on research of marketing agencies, it may raise some discussion, but that source of information was chosen intentionally as it presents synthetic knowledge about customers and provides an overview of how to reach them with marketing tools.

Practical implications: The paper can be a source of information for SMEs on how to reach Polish customers aged 50 to 65. If they are given attention, they can be a valuable and stable source of income and information for businesses.

Social implications: The Gen X is perceived by some authors as 'neglected' as the attention of marketers and researchers is focused on younger generations at the moment. As active, willing to learn new things, loyal and more resilient customers they should be more recognized and appreciated by marketers.

Originality/value: At the moment, most of scientific research and also practitioners' attention is focused on Generation Z customers and younger, while Gen X is characterized mainly as employees and a part of comparative studies, not analyzed as an independent cohort. The knowledge presented in the paper can be used not only for researchers but also for businesses to address their offers and communication in more effective ways to utilize the potential of the group of customers.

Keywords: Generation X, customer behavior, generation marketing.

Category of the paper: General review paper.

Introduction

The concept of generation was introduced in 1952 by K. Mannheim. J. Pilcher analysed generations as ‘different birth cohorts who share the same and unique understanding due to their shared experience in a socio-historical context that they were born and lived in. (...) Different motivators are assessed differently depending on birth cohorts and cultural generations’ (Raišienė et al., 2021, p. 2). Generation usually covers the period of 20 years (Maloni et al., 2019), and as ‘cohorts are typically constructed by external systems such as research, the military, and the education systems (...), imagined by researchers and made by systems, generations are constituted by actors who become aware of their history’ (Burnett, 2020, p. 3). The events the generation experiences result in values that remain relatively unchanged throughout their lives and provide a bond for members of generations (Schewe, Meredith, 2004). Howe and Strauss indicated three conditions defining a generation: perceived awareness of membership in a group, shared beliefs and behaviors accelerated by the group, and shared history about significant historical events (Goldring, Azab, 2020).

Interesting discussion on the generations can be found in Polish literature, where, for some authors, in marketing and pop culture, the tendency to ‘create generations’ can be observed and it can even be described as ‘tracing generations’ tendency (Koseła, 2008). As B. Fatyga and K. Szafraniec indicated there are some ‘generations’ created and later their descriptions are developed (e.g. JPII generation) because the concepts can be easily communicated and they are attractive to catch readers attention (Przybylski, 2023).

Generation is one of the concepts that allows for more effective segmentation of customers, because it is not only based on age but provides all sorts of characteristics of cohorts of customers based on social, cultural, and economic characteristics that enable more effective adjustment of marketing tools to the expectations of that group. Dividing customers based on their age, with strong recognition of different factors that shape their behavior in the market, can be very useful when designing the marketing mix concept and developing offers adjusted to the expectations of a particular group. Although it cannot be indicated as the only criterion for dividing customers, their age and the moment of their birth provide researchers with a wide range of information about the values, beliefs, attitudes, and hidden motivators that make customers perform in a particular way.

Generation X, which is discussed in the paper, is the cohort of people who are described as the ‘neglected’ generation and the one that seems to be ignored in marketing nowadays. They are too young to be treated as seniors, although, as being over 50, they can be discussed in the ‘silver economy’ context due to the European Commission recommendations (European Commission, 2018, p. 6). At the same time, they are too old and too different to be reached out with the tools prepared for Gen Y or younger.

The term Gen X was popularized by D. Coupland, who presented representatives of the generation as ones who grew up in the economic decline, 'having less' perspectives and sources as their parents, searching for their own identity against societal expectations (Hansen, 2025). D. Barnett indicated them as a group working hard and playing hard (Brown, Martson, 2018). In the literature, they are also described as *Slacked Generation*, *MTV Generation*, *Twentysomething Generation*, *Post-Boomers*, *Middle Child Generation*, *Baby Bust Generation* (in contrast to *Baby Boomers*) (Przybylski, 2023), or as a *Sandwich Generation*.

Gen X is researched as employees and as an element of working environment (e.g.: Benson, Brown, 2011; Cogin, 2012; Lub et al., 2016; Duxbury, Ormsbee, 2017; Dust et al., 2019; Raišienė et al., 2021; Dutta, Misra, 2021; Jankowiak, Czerwińska-Lubszczyk, 2024; Martyniak, Kammel, 2024), tourists (Cooper et al., 2018), game players (Brown, Martson, 2018) and in a marketing perspective as a part of comparative studies indicating differences between generations in variety of areas – mainly related to digital, modern technologies and forms of communication just to cite the recent research: Nataraj, Shivanna 2024; Gurunathan and Lakshmi, 2004 and 2025; Tavdishvili, Maglakelidze, 2025; Zaidi, 2025; Nazarova et al., 2025; Anada et al., 2025; Conley, 2025; Koczy et al., 2025.

The reason for the study is to summarize and analyse the knowledge about Generation X as active participants of the Polish market and a possible resource for businesses to make them more resilient, as they can base on loyal customers, demanding but willing to cooperate and share their opinions. As more and more attention of scientists and different types of researchers is put into younger generations, it seems beneficial to draw the attention of marketers to the generation that generates high revenues when effectively looked after by tenders but feels ignored due to, as it seems, not enough attention put into understanding their specific features and expectations. What seems significant, at the moment one fifth citizen of EU is at the age of 46-59 (Ipsos, 2025a).

Another important aspect that is also covered in the paper is the strong need for recognizing specific characteristics of generations from different nation's perspective. 'Simple reproduction of generational labels in countries with varying levels of technological and economic development, other political and axiological systems, or, more broadly, fundamentally different types of cultures, is risky and raises legitimate doubts' (Przybylski, 2023, p. 39). Thus, there is a need to analyse generations upon the specific conditions of their existence in the national context, which can provide a wider perspective and better understanding of the groups, which, in consequence, may lead to more effective adjustment of communication tools, which is crucial for the effectiveness of marketing strategies.

Generation X – overview

Generation X is a cohort of customers born between 1965 and 1980, but some authors would indicate 1961 as a moment of Xers' birth or even 1971 (Przybylski, 2023). In the group of Gen X, there are two main groups: older representatives who share similar values and opinions as Baby Boomers and younger ones whose buying behavior is similar to the Millennials' (Semcore, 2022). Often they are described as connectors between Baby Boomers (their parents) and Millennials represented by their children (Zajkowska, 2022). W. Wrzesień would even claim that in Poland, there had never been Generation X; it should be discussed as *Pokolenie Końca Wieku* [Turn of the Century Generation] that includes: *Pokolenie 89* ['89 Generation] – born between 1964-1970, *Dzieci transformacji* [Children of the Transformation], born between 1971 and 1976, and *Maruderzy końca wieku* [Stragglers of the turn of the century], born between 1977 and 1982 (Wrzesień, 2007). That approach towards Polish Generation X representatives provides us, marketers, with an even more interesting area for further research. Exploring very different behaviours of the three sub-groups from different marketing perspectives may be attractive for researchers.

As different research results reveal 'many Gen X'ers revel in the untrammelled independence they had as children and teens. (...) This lack of supervision, combined with being the last generation with a foot firmly in the physical world, made Gen X what it still is today – tough and resilient' (Twenge, 2023, p. 165). They demonstrate higher resilience, better skills to cope with change, new situations and unexpected challenges (Harari et al., 2023). Being brought up by parents committed to full-time jobs and constantly absent, Gen Xers became independent and nonconformist (Goldring, Azab, 2020). In consequence, the Gen X representatives value: self-reliance sourced in handling situations appearing in their lives and their savings; being good parents and friends, being able to balance work and non-work related priorities (Erickson, 2000, p. 63).

At the moment, they are in their 50s or 40s, usually with children, with a stable financial and professional position. They earn more money than younger generations, have inherited or will soon inherit from their parents. In a global perspective, 'they yield a good degree of power in the family and in the boardroom and are very much the quietly powerful generation we shouldn't ignore' (Ipsos, 2025a). They treasure values as work, career, family, life comfort, loyalty, health, and ecology (Paduszyńska, 2019; Fita, 2025). Care for natural environment is probably related in their case with the love for their homeland they were brought up in and also with the sense of responsibility for others they were taught (Jasion, 2020) but this aspect is the one of the areas that needs to be research deeper, as from one hand - ecological assets of products, and their sustainability is increasingly important for modern customers (PwC, 2025) and 72% of Gen X declare that they do all they can to save the environment (Ipsos, 2025) but at the same time only 30% of the Generation X representatives are ready to pay more for ecological products (PwC, 2025).

A significant part of Xers have worked in one place all their lives. They are more detached and reserved in comparison to younger generations. As Jurkiewicz (2000) indicates, a sense of belonging, feedback, and security are the most important for them. They treasure work-life balance, they can use new technologies, but they are still interested in traditional media. They are loyal towards employers and the brands they know well, they tend to read and watch manuals, and they are susceptible to manipulative techniques (Kukliński, 2024).

Polish Generation X – the marketing perspective

As mentioned, Generation X is not ‘fashionable’ at the moment and overlooked in media stories and research projects what seems a significant opportunity missed by businesses (Ipsos, 2025a). Moreover, discussion on generations on a global level may not be efficient, because various countries, their characteristics, local customs, and events shaping customers' behaviors and representatives of specific generations may vary significantly (Ting et al., 2018). These two premises make it reasonable to analyze Generation X, also in terms of marketing, as the Polish market participants.

As ones who grew up in the traditional media era (radio, TV) and were also exposed to the rapid technological development of other forms of communication can be reached through many different channels (Pawluczyk, 2024). They use TV and social media as primary sources of information, even if 30% perceive traditional media as outdated (Kohai, 2022). Xers use social media intensively and spend about 32 hours searching for information about new offers and different contests (Jasion, 2020). Most of them spend more than 6 hours online (40%), while 31% spend 4-5 hours online a day. Interestingly, at the same time, nearly 40% declare that they suffer from information overload (Kohai, 2022). Most frequently, they visit Facebook, followed by information portals (Wp.pl and Onet.pl, Interia.pl), Youtube, and Allegro.pl. Rarely Instagram - it was indicated by 13% of respondents in the Kohai survey. They browse news portals, social media such as Facebook, for social purposes and YouTube for entertainment (Fita, 2025; Paduszyńska, 2019). They eagerly share their opinions and different content on the internet. As the results presented in Table 1 reveal, they prefer video content. While online, they listen to the radio and search for entertainment (memes, quizzes, audiobooks). Their behaviour, analyzed from this perspective do not vary significantly from other generations (Table 1), and as the cited research was conducted on the representative groups in the research panel, it may be interpreted as a tendency.

Table 1.
Preferred forms of content in different generations

	Generation X	Baby Boomers	Millenials	Generation Z
Video	68%	67%	66%	68%
Radio online	28%	26%	29%	24%
Memes	28%	22%	37%	46%
Blogs	23%	18%	29%	26%
Quizzes	21%	26%	25%	18%
Podcasts	21%	20%	17%	30%
E-books/audiobooks	20%	12%	21%	20%
Webinars	17%	14%	18%	18%

N = 1005; Polish citizens, aged 18-65, CAWI.

Source: Kohai Content, 2022, p. 65.

When discussing ways to reach that group with communication, some main tendencies can be observed. Firstly, they expect authentic, expert, humorous, sentimental communication highlighting safety, timesaving, and ecological aspects (Fita, 2025). In communication with that group, it is beneficial to use nostalgia marketing. They prefer new content, educational more than entertaining (28% to 23%) (Kohai, 2022). In the case of Gen X, in the opinion of experts, promotion should be based on positioning, Google adverts, and text messages informing about discounts (Semcore, 2022). The cohort should be provided with testimonials, systems of product customer scales, or USG (Kohai, 2022). Additionally, in the case of that group, a fan page seems necessary. It would enable Xers' verification of the reliability of a brand, searching for expert content, and remarketing as they detailly analyse offers before purchasing (Fita, 2025), which they perceive as a form of their autonomy (Goldring, Azab, 2020). They actively use e-mails, read and respond to them, which is why this tool is an effective way of communication with the group (Fita, 2025).

Polish Xers shop online intensively. More than 74% of them are customers of sales platforms, and they are the most numerous group of customers of that type of service (Kohai, 2022). 53% read reviews on the internet, which is the highest result of all the generations (Kohai, 2022). They usually search for more expensive, durable products, and they consider their impact on the natural environment (Jasion, 2020; Pawluczyk, 2024; Kohai, 2022), although they are not willing to pay more for ecological products (PwC, 2025), as mentioned.

They represent a unique perspective on technology – they use digital tools for everyday tasks, but they know their limitations (Kamber, 2017).

They do not trust authorities, including influencers-celebrities (Jasion 2020), but they consider opinions of younger generations (Pawluczyk, 2024) and experts (Fita 2025). They are described as well-informed, cautious, skeptical, but still open to new experiences if beneficial (Fita, 2025). They expect honest and direct messages (Pawluczyk, 2024) and trustworthy, reliable content (Kohai, 2022) to create relations (Semcore, 2022; Jasion, 2020). On the internet, they search for knowledge and look for valuable and reliable sources of information (Fita, 2025; Kukliński, 2024; Kohai, 2022).

Significantly, research indicates that 54% of Polish Xers feel frustrated because they believe brands keep ignoring them (Jasion, 2020). At the same time, they are loyal and eagerly use different discounts, perks, and other savings they obtain as a form of reward for their loyalty (Kohai, 2022).

As the American researchers revealed, due to their experiences with different economic downturns, Xers are price-sensitive with a short-term orientation (Goldring, Azab, 2020). At the moment, their financial situation is stable, and some of them own their own businesses. When analysed from the economic perspective, Xers prefer stability and stable returns. They avoid loans and unnecessary spending. When investing large amounts, their decision is analyzed thoroughly (Tolani et al., 2020). There is a lack of information about this aspect in Polish scientific literature, which leaves an interesting gap for further research.

Discussion

Generation X is not very popular as a subject of scientific research and discussion recently. While Baby Boomers, Millennials, and Gen Z are described in detail and are given a lot of attention, Gen X is often referred to as a 'forgotten generation' and is ignored (Kukliński, 2024). Quite unjustifiably, as it is a lucrative market for a very wide range of products and services represented by people who often hold significant power as family members, politicians, leaders, or businessmen (Tolani et al., 2020; Ipsos, 2025a).

As argued by Ting et al. (2018) and Przybylski (2023), the uncritical transfer of generational labels across countries may obscure important differences resulting from political, economic, and cultural conditions. The Polish case illustrates that clearly – Polish Xers and Western European ones differ, and as Wrzesień (2007) indicated, could be interpreted as 3 different groups/cohorts.

The reviewed literature and research results enabled the creation of a 'portrait' of customers representing Gen X. They are resilient, autonomous, and pragmatic as shaped by early independence and economic uncertainty (Goldring, Azab, 2020; Twenge, 2023; Harari et al., 2023). These characteristics are reflected in their buying behaviour, in their cautious approach to buying products, searching for durable and higher – quality products, reliance on experts rather than influencers (Jasion, 2020; Fita, 2025). Xers treasure security, feedback, and a sense of belonging. They are loyal towards brands if listened to and appreciated. The research results indicate that Xers combine intensive digital media use with using traditional channels such as television and radio. They are technologically competent yet critically aware of digital tools' limitations. They reported information overload, and at the same time, they are spending long hours online searching for information and entertainment. They require clarity, relevance, and credibility in communication. The tendency of Polish Xers to carefully analyse offers,

consult online reviews, and loyalty towards trusted brands indicates long-term relationship orientation. For SMEs, this aspect of their behaviour may translate into a competitive advantage. At the same time, the frustration over being ignored by brands reveals a paradox that despite their loyalty and power as customers, Xers perceive themselves as marginalized in marketing communication. They are also marginalized in some research reduced to a comparative background rather than examined as an independent consumer cohort.

Summary

Marketing, in its core, is related to the needs of potential customers and their satisfaction through valuable offers. The Generation X (next to Generation Y) has the strongest influence on the contemporary market (Tolani et al., 2020). Thus, marketing campaigns to the specificity of that group to create the field for solid and lasting relationships between business and young silver clients (Fondevila-Gascón et al., 2024).

Realizing that generational labels cannot be transferred recklessly from one country to another without considering cultural and historical context that shape specific collective experiences (Probst, Atkinson, 2025), make researchers provided with a vast range of opportunities to create effective methodologies and to perform research supporting understanding of Generation Z as a valuable source for businesses.

The Generation Z characteristic which was presented in the study, prepared basing on secondary sources of information including scientific papers and content published by marketing agencies, does not exhaust the topic. Different groups within the generation, their expectations towards businesses, expected ways of effective cooperation may be indicated as areas worth further, closer analysis and discussion. Xers seems to be customers, who are stuck between the generations of their parents and children in mental, as well as marketing aspect. With their power discussed from social but also economic perspective, representing high level of loyalty and resilience they can be reckon as a significant, but still not fully utilized potential source of income and information for SMEs that can be used to increase competitive advantage in the times of economic turbulence that entrepreneurs have been facing recently.

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THE ORGANISATIONAL DIMENSION OF DIGITAL MATURITY IN PUBLIC AND PRIVATE INSTITUTIONS

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Purpose: The paper aims to answer the following questions: what is the level of organisational maturity in public and private institutions, and how does the size of these institutions affect the level of their organisational digital maturity?

Methodology: This goal will be achieved by presenting the results of a study conducted in 308 public and private institutions. The survey was carried out using the online survey technique (CAWI) at the end of 2024 and the beginning of the 2025 year.

Findings: The results showed that private institutions have a statistically significantly higher overall level of organisational digital maturity and its subdimensions than public institutions. In turn, the size of the institutions surveyed proved to be a factor that did not significantly differentiate the level of their organisational digital maturity. The only significant differences were found in the level of the subdimension of 'organisational culture'.

Research limitations: Only the organisational dimension of digital maturity was analysed. In the future study, other dimensions of digital maturity in public and private institutions should be considered, as well as factors that may influence them.

Practical implications: The results indicate that public institutions need to intensify their digitisation processes. Today, customers of public and private institutions expect high-quality services. The pressure to reduce costs also forces high operational efficiency. A high level of digital maturity within the institution is an important prerequisite for meeting these demands.

Originality: Only a few studies on the level of digital maturity in public and private institutions clearly indicate differences between them. The presented research attempts to assess and compare the organisational dimension of digital maturity in private and public institutions, pointing to the differences between them not only in the overall level of the organisational dimension but also in its subdimensions.

Keywords: digital maturity, organization, private institutions, public institutions.

Category of the paper: Research paper.

1. Introduction

The development of digital technologies is one of the most important factors driving changes within public and private institutions. Although digital technologies have become omnipresent, institutions often lack the ability to utilise opportunities they offer (Ziemba, Karmańska, 2021). The digital transformation of organisational processes in public and private institutions is a response to the challenges posed by the environment that arise, e.g., from the rapid development of information technology (Pieriegud, 2016). This phenomenon results in a number of opportunities and threats for public and private institutions.

On the one hand, digital technology accompanied by digitalisation and automatization of organisational processes enables public and private institutions to decrease costs, enhances transparency of operations and their control, increases access to information, and as a result improves efficiency and quality provided services. For these reasons, the digitalisation of institutions, especially public ones, has become an important element of the Polish state's digitalisation strategy and the creation of a modern information society (Minister of Digital Affairs, 2017). On the other hand, in practice many institutions still find this process one of the most challenging to introduce and manage due to their limited resources compared to large companies, as well as specific organisational obstacles such as hierarchical structure, authoritarian leadership, low flexibility of action, reluctance to change, etc., that are characteristic for public institutions.

The success of the institution in facing the challenges and threats brought about by changes in the contemporary economy is largely based on its digital maturity. Digital maturity is a multidimensional concept that covers different areas of the functioning of public and private institutions related to both their technological assets as well as its management and organizational processes, leadership, and organisational culture (Hauke, Perechuda, Cieśliński, 2022). The digital maturity of public and private institutions is also characterised by their ability to transform their performance by introducing IT technologies into organisational processes. As a result, new organisational and management tools are being developed. It also influences the requirements for employees, organisational culture, leadership, organisational cooperation network, and protection of personal data. In this context, the organisational dimension of the digital maturity of public and private institutions has gained great importance for their further development under new conditions of performance in the digital economy. Today, awareness of the opportunities and risks of digitisation, as well as knowledge of the organisational aspects of this process, is essential for the effective management of public and private institutions (Ziemba, Karmańska, 2021).

Rapid technological changes and the need for digital transformation mean that it is essential for researchers and practitioners to assess the digital maturity level of organisations and identify the factors that impact it. However, despite the growing popularity of this topic, there is still

little empirical research dedicated to organisational dimensions of digital maturity in the private and public institutions.

Therefore, the paper tries to answer the following questions: what is the level of the organisational maturity dimension in public and private institutions, and does the size of these institutions measured by the number of employees differentiate level of their organisational digital maturity? This goal will be achieved by presenting the results of a survey conducted in 308 public and private institutions.

2. Theoretical background and hypotheses development

The concept of institution is understood in a number of ways in various scientific disciplines. Pioneer of institutional economics, North (1990) defined an institution as the rules of ‘the economic game in society’, emphasising the influence of institutions on economic processes and development. In turn, in public management, institutions are usually associated with public administration entities that carry out specific public duties. In the classical management approach, the concept of an institution is usually equated with that of an organisation, i.e., a group of people with resources that work together to achieve certain objectives (e.g., Pszczółowski, 1978; Zieleniewski, 1976). It should be noted, that the term of public institution is more clearly defined than private institutions generally and means organised structures that are created for the management of public affairs (Giucă et al., 2022). However, changes in public management and the emergence of new public management and governance approaches (Gorzelański, 2025), along with the tendency to transfer the delivery of many public services to the private sector, have resulted in the blurring of boundaries between public and private institutions in many areas of their actions.

Consequently, today the term of both public and private institution can be understood as an organisation equipped with resources, not an enterprise that provides specialised services to society, contributing to optimising its functioning and development (e.g., hospitals, schools, libraries, community centres, social welfare centres, financial and insurance institutions) (Wilkin, 2009). Their activities and tasks are broad and diverse (e.g., education, science, health, environmental protection, social welfare, culture, sport). These institutions, based on specific norms and values depending on the economic and sociocultural context (often of a legal nature), regulate social behaviour in areas that are particularly important for the society and the well-being of its members (Neale, 1987). The fundamental difference between public and private institutions is how they are financed: public institutions are funded by the state, whereas private institutions are funded by private sources and have private owners.

In the context of the dynamic development of the digital economy, it has become increasingly important for institutions to adapt to the new conditions by digitising various areas of their performance. An institution's digital maturity is determined by the extent to which it has digitised its activities. The literature contains many different conceptualisations of the relatively new concept of digital maturity. Generally, it can be viewed as adaptation of an organisation to the digital environment (Adamczewski, 2019). Digital maturity is also defined as the organisational ability to respond adequately to changes by using digital capabilities (Sándor, Gubán, 2021). In the opinion of Berghaus and Back (2016), digital maturity is the set of organisational skills and resources that enable the effective implementation of digital transformation processes. In turn, Teichert (2019, p. 1635) indicates that digital maturity 'reflects the status of a company's digital transformation'.

In recent years, numerous models of its assessment, covering various dimensions of digital maturity, have been proposed by experts on this topic (e.g., Schallmo, Williams, Boardman, 2017; McKinsey Digital, 2016; Deloitte, 2018; Petzolt et al., 2022). The majority are theoretical and qualitative in nature and they have not been tested in empirical studies. Considering the contribution in the digital transformation process, they frequently cover dimensions such as: IT infrastructure and governance, strategy and vision, employee skills and competencies, organisation, leadership, culture, products and services, etc. (Teichert, 2019; Nerima, Ralyté, 2021). However, particular attention should be paid to the model proposed by Petzolt et al. (2022), since it is one of the few models that has been validated in an empirical study. This model encompasses several dimensions of digital maturity, but unlike other models, in addition to the dimensions related to IT infrastructure, it also emphasises the importance of the organisational dimension. This dimension includes five subdimensions, i.e., leadership, data privacy, organisational culture, internal collaboration/networks, and employees that determine the organisational digital maturity.

Numerous factors which can differentiate the level of digital maturity are mentioned in the literature, e.g. kind of activity, resources, technologies used and management, etc. (Skrzypek, 2022; Hauke, Perechuda, Cieśliński, 2022). They refer to public and private institutions. However, in the public sector, other specific factors related to this sector can also impact the digital maturity of public institutions. These factors include, e.g., e-government strategy and policy, IT governance, specific legal regulations concerning public institutions, their hierarchical and complex structures, as well as the relatively low flexibility of public organisations and the lack or limited competitive pressure (Kafel, Wodecka-Hyjek, Kusa, 2021). They may hinder the digitisation process in the public institutions. Therefore, the following research hypothesis was formulated:

H1: The level of the organisational dimension of digital maturity is higher in private institutions than in public ones.

An important factor determining the ability of an institution to digitise is often its resources, particularly financial, technological, and human resources. Previous studies indicated that IT solutions are more likely to be applied in larger organisations, and they tend to have more positive outcomes than the latter (Tansley, Newell, 2007). Small and medium-sized institutions typically have fewer financial and human resources, which can lead to a lower level of digital maturity of the organisational dimension compared to larger institutions (Rudnicka, Chrupala-Pniak, Pollak, 2017). This leads to the following research hypothesis:

H2: The size of the institution (measured by the number of employees) differentiates the level of the organisational dimension of the digital maturity.

3. Method

An empirical study of public and private institutions was conducted using the online survey technique (CAWI). It was carried out at the end of 2024 and the beginning of 2025. The survey was part of a research project entitled 'Digital Maturity of Market Entities in Poland'. A purposive sampling method was used. The key criterion was the type of entity and its activities. Then, after a preliminary interview with their top management, the typical entities were chosen.

The final research sample consisted of 308 institutions, 242 (78.6%) of which were public and 66 (21.4%) of which were private. In terms of type of activity, the sample structure can be described as follows: 3.6% were publishing, audiovisual, and broadcasting institutions; 3.2% were financial and insurance institutions; 3.6% were administrative and support services institutions; 67.2% were public administration, defence, and compulsory social security institutions; 1.6% provided healthcare services; 3.6% directed social work and social welfare activities; 11.7% were arts, entertainment, sports, and recreation institutions; 2.6% were educational institutions; and 2.9% conducted other professional, scientific, and technical activities.

The structure of the sample by the number of employees was as follows. 1.3% of the institutions examined had up to 9 employees, 32.5% employed between 10 and 49 people, 33.4% employed between 50 and 249 people, and 32.8% employed more than 249 employees.

The study was attended by representatives of the management of the institutions surveyed. A total of 176 women (57.1%) and 129 men (41.9%) participated in the survey. Three participants identified their gender as the other. The average age of the respondents was 43.61 years (median 44 years). Most of the participants had a university-level education (89.6%), while 10.4% had secondary education.

The organisational dimension of digital maturity was measured with the scale developed by Petzolt et al. (2022). This scale encompassed its five subdimensions, that is, ‘leadership’ (4 items), ‘data privacy’ (2 items), ‘organisational culture’ (6 items), ‘internal collaboration/networks’ (3 items), ‘employees’ (6 items). In total, it included 21 items. The overall level of organisational digital maturity was measured as the average of the five subdimensions.

All scale items of the scale were categorized, and the respondents indicated the number on the seven-point Likert scale ranging from 1 (I strongly disagree) to 7 (I strongly agree). The Cronbach alpha coefficients of the subscales were: 0.86 for ‘leadership’, 0.74 for ‘data privacy’, 0.88 for ‘organisational culture’, 0.72 for ‘internal collaboration’, and 0.88 for ‘employees’ subdimension. These findings indicate a high internal consistency of the subscales, which attests to the reliability of their measurement.

4. Results

The results of the analysis showed that the respondents mostly highly rated the organisational dimension of digital maturity in the institutions examined (Table 1). The average general rating of the organisational dimension of digital maturity was 4.58 on the 7-point Likert scale (median 4.72). The ratings of the subdimensions of organisational digital maturity were generally at a similar level. However, the highest rated of its subdimension was ‘data privacy’ (mean 5.36) (Table 1). The lowest rated subdimension was ‘employees’ (mean 4.25).

Table 1.

Descriptive statistics of organisational dimension and its subdimensions of digital maturity

Variables	Mean	Median	Std. Deviation	Minim.	Max.
Leadership	4.56	4.75	1.11	1.00	7.00
Data privacy	5.36	5.50	0.94	1.00	7.00
Organisational culture	4.47	4.67	0.95	1.00	7.00
Internal collaboration/networks	4.27	4.33	1.04	1.00	7.00
Employees	4.25	4.33	0.97	1.00	7.00
Organizational digital maturity (overall)	4.58	4.72	0.83	1.00	7.00

Source: own developed.

Then, the average level of organisational digital maturity was compared between private and public organisations (Table 2). Generally, private institutions had a higher average level of digital maturity than public ones. This difference was particularly evident in the ‘internal collaboration’ and ‘employees’ subdimensions. The average level was only slightly higher in public institutions for the ‘data privacy’ subdimension.

Table 2.

The level of organisational dimension and its subdimensions of digital maturity in public and private institutions

Dimensions		N	Mean	Std. Deviat.	Std. error	95% confidence interval for the mean		Min.	Max.
						Lower boundary	Upper boundary		
Leadership	Private	66	4.93	0.78	0.10	4.74	5.12	2.25	7.00
	Public	242	4.46	1.16	0.07	4.32	4.61	1.00	7.00
Data privacy	Private	66	5.28	0.56	0.07	5.14	5.42	4.00	7.00
	Public	242	5.38	1.01	0.07	5.24	5.50	1.00	7.00
Organisational culture	Private	66	4.87	0.54	0.07	4.72	4.50	3.33	7.00
	Public	242	4.37	1.00	0.06	4.24	4.49	1.00	7.00
Internal collaboration	Private	66	4.72	0.61	0.08	4.58	4.88	2.00	7.00
	Public	242	4.14	1.09	0.07	4.00	4.28	1.00	7.00
Employees	Private	66	4.65	0.57	0.07	4.51	4.79	3.33	7.00
	Public	242	4.14	1.02	0.07	4.01	4.27	1.00	7.00
Organizational digital maturity (overall)	Private	66	4.89	0.47	0.06	4.77	5.00	3.15	7.00
	Public	242	4.50	0.89	0.06	4.39	4.61	1.00	7.00

Source: own developed.

The significance of the differences in mean scores across the subdimensions studied in public and private institutions was then tested. Since the distribution was close to normal, a Levene's test was performed to check the homogeneity of variance assumption. If the test is statistically insignificant and the assumption of homogeneity of variance is met, a Student's t-test could be used to analyse the significance of the differences for independent samples. Since the variances in the groups were heterogeneous for all dimensions, a Student's t-test with Welch's correction was used to check for significant differences in the means (Table 3).

Table 3.

The results of the Levene's test and the t-test for equality of means for independent samples for public and private institutions

Dimensions	Levene's test for homogeneity of variance		T test for equality of means					
	F	Sig.	t	df	Sig.		Difference in means	Std. error of the difference
					one-tailed test P	two-tailed P		
Leadership	9.859	0.002	3.83	152.18	<0.001	<0.001	0.467	0.122
Data privacy	14.236	<0.001	-1.01	191.30	0.158	0.316	-0.096	0.095
Culture	19.339	<0.001	5.30	196.33	<0.001	<0.001	0.494	0.093
Collaboration	25.866	<0.001	5.70	189.75	<0.001	<0.001	0.587	0.103
Employees	17.699	<0.001	5.20	188.34	<0.001	<0.001	0.501	0.096
Organizational digital maturity (overall)	25.776	<0.001	4.81	203.84	<0.001	<0.001	0.391	0.081

Note. The significance level is 0.05.

Source: own developed.

The results revealed that private institutions had a statistically significantly higher overall average level of organisational digital maturity than public institutions. Private institutions also demonstrated significantly higher levels of particular subdimensions of digital organisational

maturity than public ones, except for the 'data privacy' dimension. However, in the case of the 'data privacy' dimension, which was higher in public organisations, these differences were found to be statistically insignificant.

Next, to test hypothesis H2, the averages of the examined subdimensions and the overall organisational digital maturity were compared across institutions of different sizes, measured by the number of employees.

Three groups of institutions were examined: small institutions with 1 to 49 employees (104 institutions); medium institutions with 50 to 249 employees (103 institutions); and large institutions with more than 249 employees (101 institutions). First, the mean level of the studied subdimensions and the overall level of organisational digital maturity were calculated for each group (Table 4).

Table 4.

Descriptive statistics of the subdimensions of organisational digital maturity in small, medium and large institutions

Subdimensions	Institution (size)	N	Mean	SD	Std. error	Minim.	Max.
Leadership	small	104	4.48	1.01	0.10	1.00	7.00
	medium	103	4.54	1.25	0.12	1.00	7.00
	large	101	4.68	1.05	0.10	1.00	7.00
Data privacy	small	104	5.37	0.88	0.09	2.50	7.00
	medium	103	5.44	1.01	0.10	1.00	7.00
	large	101	5.25	0.91	0.09	1.00	7.00
Culture	small	104	4.53	0.88	0.09	1.50	7.00
	medium	103	4.28	1.09	0.11	1.00	7.00
	large	101	4.60	0.84	0.08	1.00	7.00
Collaboration	small	104	4.23	0.99	0.10	1.00	7.00
	medium	103	4.13	1.10	0.11	1.00	7.00
	large	101	4.45	1.00	0.10	1.00	7.00
Employees	small	104	4.24	0.90	0.09	1.00	7.00
	medium	103	4.11	1.11	0.11	1.00	7.00
	large	101	4.41	0.84	0.08	1.00	7.00
Organizational digital maturity (overall)	small	104	4.57	0.76	0.07	1.57	7.00
	medium	103	4.50	0.95	0.09	1.00	7.00
	large	101	4.68	0.78	0.08	1.00	7.00

Source: own developed.

To determine whether an ANOVA analysis could be performed, Levene's test for homogeneity of variance was performed. This revealed the homogeneity of variance for all subdimensions (p-value greater than or equal to 0.05). Therefore, an ANOVA analysis was then performed to test whether the differences in the mean level of the examined were statistically significant (Table 5).

Table 5.*Results of ANOVA analysis: subdimensions of organisational digital maturity*

Subdimensions		Sum of Squares	df	Mean Square	F	Sig.
Leadership	Between Groups	2.075	2	1.038	0.842	0.432
	Within Groups	375.751	305	1.232		
	Total	377.826	307			
Data privacy	Between Groups	1.861	2	0.930	1.059	0.348
	Within Groups	267.960	305	0.879		
	Total	269.821	307			
Culture	Between Groups	5.550	2	2.775	3.132	<u>0.045</u>
	Within Groups	270.298	305	0.886		
	Total	275.848	307			
Collaboration	Between Groups	5.330	2	2.665	2.497	0.084
	Within Groups	325.505	305	1.067		
	Total	330.835	307			
Employees	Between Groups	4.888	2	2.444	2.651	0.072
	Within Groups	281.194	305	0.922		
	Total	286.081	307			

Note. The significance level is 0.05.

Source: own developed.

ANOVA analysis revealed that the observed differences in the levels of organisational digital maturity across the investigated subdimensions were only significant in the case of 'organisational culture' when comparing institutions of different sizes. Therefore, a post-hoc analysis was performed using the Tukey test for this subdimension (Table 6).

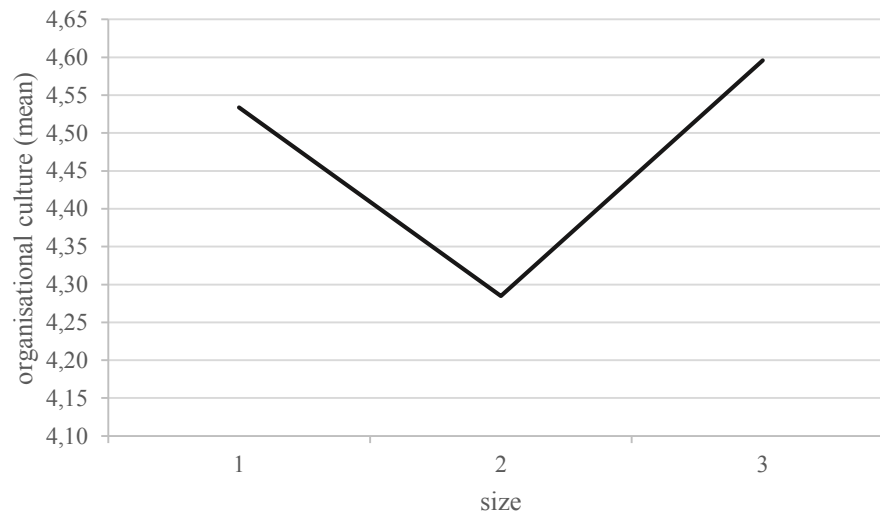
Table 6.*The results of comparisons between the institutions examined: 'culture' subdimension (Tukey's test)*

(I) size	(J) size	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
small	medium	0.249	0.131	0.140	-0.059	0.557
	large	-0.062	0.132	0.885	-0.372	0.248
medium	small	-0.249	0.131	0.140	-0.557	0.059
	large	-0.311	0.132	<u>0.050</u>	-0.621	-0.000
large	small	0.062	0.132	0.885	-0.248	0.372
	medium	0.311*	0.132	<u>0.050</u>	0.000	0.621

Note. The significance level is 0.05.

Source: own developed.

A post-hoc analysis revealed that there were statistically significant differences in the level of 'organisational culture' between medium-sized and large institutions (Figure 1).



Note. 1 – small institutions, 2- medium institutions, 3 – large institutions.

Figure 1. Differences in the level of organisational culture between medium-sized and large institutions.

Source: own developed.

Next, the level of digital maturity of the overall organisational dimension was examined in small, medium, and large institutions. Since Levene's test revealed heterogeneity of its variance, the nonparametric Kruskal-Wallis test was used for this purpose (Table 7).

Table 7.

Statistical significance of differences between the average levels of the overall organisational dimension of digital maturity in small, medium, and large institutions

Null hypothesis	Test	Test statistic	Significance	Decision
The distribution of the organizational dimension is the same across institutions	Independent samples Kruskal-Wallis test	3.299	0.192	Accept the null hypothesis

Note. Asymptotic significances are displayed. The significance level is 0.05.

Source: own developed.

The analysis showed that the differences are statistically insignificant. Therefore, there are no significant differences in the level of overall organisational digital maturity between the institutions surveyed of different sizes.

5. Discussion and Conclusions

According to the results obtained, there is no reason to reject the first hypothesis (H1). The analyses revealed that the overall level of organisational maturity, as well as the levels of its subdimensions, were statistically significantly higher in private institutions than in public ones. The only exception was the 'data privacy' subdimension, which was higher in public institutions, though this difference was not statistically significant.

These findings indicate that private institutions are more effective in dealing with the organisational aspects of digitisation. It also suggests that public institutions are not fully exploiting the opportunities created by digitisation in the organisational dimension, despite the fact that information resources are strategically important to these institutions and IT systems are essential for their performance and execution of their basic tasks. It should be noted that the results obtained correspond to the findings of the previous study conducted in the Polish public sector, which showed a moderate level of digital maturity of public institutions (Kafel, Wodecka-Hyjek, Kusa, 2021). The relatively high level of organisational digital maturity of public institutions observed in this study can be explained by a strong emphasis on the digitisation of public institutions in recent years, resulting in its increase. However, this remains lower than that of private institutions, suggesting the need for public institutions to accelerate their digital transformation further. It must be stressed that today public institutions face challenges related to growing expectations about the quality of services, and the need to increase the effectiveness of their performance, and digitisation makes it possible to meet these requirements.

Regarding the second hypothesis (H2), the results obtained provide grounds for rejecting this hypothesis, since the differences between small, medium, and large institutions were statistically significant only in the 'culture' subdimension. It should be noted that organisational culture is the dimension of digital maturity that has been examined most frequently in studies (Teichert, 2019). The results revealed that in medium-sized institutions, such important characteristics for the digital maturity of organisational culture as support for entrepreneurial actions, openness to new ideas and technological changes, and willingness to take risks were rated lower than in small and large institutions.

This finding shows that the culture of medium-sized institutions is not conducive to enhancing their organisational digital maturity. These differences can be attributed to the fact that often large institutions tend to prioritise change and risk taking, while small institutions, with their frequently clan culture, foster an environment that encourages experimentation and the tolerance of potential mistakes and failures (Frączkiewicz-Wronka, Marzec, 2015). In practice, this means the need for a cultural change in medium-sized institutions and the development of an entrepreneurial culture that encourages innovation and risk taking.

The study also has other significant practical implications. To properly plan and implement digitalisation in public and private institutions, the initial level of their digital maturity must first be assessed to take appropriate action. These results clearly show that public institutions need to intensify their digitisation processes, because despite the declared policy of digitising the public sector (see Ministry of Digital Affairs, 2024), the level of their organisational digital maturity is still significantly lower than that of private institutions. Increasing the level of digital maturity of public institutions is essential to improve their efficiency, reduce costs, and improve service quality. However, it also requires ensuring additional public funding and resources for these activities.

In this context, it is pertinent to mention the limitations of the conducted study, which define potential directions for future empirical research. First and foremost, the study was limited to analysing differences in the level of organisational digital maturity and its subdimensions between public and private institutions, as well as between institutions of different sizes. In further research, other dimensions of digital maturity of public and private institutions need to be analysed. Other characteristics of institutions that may differentiate the level of organisational digital maturity should also be taken into account. This concerns in particular characteristics of public organisations, such as complex structures, rigid organisational hierarchies, and financial resources, all of which can influence the level of their digital maturity. Furthermore, no causal relationships were examined; the focus was only on comparing the levels of maturity between the selected groups of institutions. An analysis of causal relationships can explain how the digital maturity of institutions evolves. It is also important to identify the characteristics of the organisational culture that may hinder their digitisation process. In the future study, the institutional or regulatory conditions that may affect the level of the subdimensions examined within the organisational dimension of digital maturity should be identified. This is particularly relevant for the subdimension of 'data privacy', which was rated the highest among the subdimensions examined in the surveyed institutions. Furthermore, it should be noted that the sample was nonrandom; hence, the results of the study cannot be generalised to the entire population. In the future, it would be worthwhile to repeat the study on a larger scale using a random sampling method.

In conclusion, a high level of digital maturity is essential for modern public and private institutions to perform effectively. In the digital economy, it is a basic condition for their survival and development. An increasing number of public and private institutions are pursuing digital transformation because only those that are digitally mature can cope with the challenges posed by an unpredictable and rapidly changing organisational environment.

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MEASURING ENERGY POTENTIAL IN THE CONTEXT OF ENVIRONMENTAL TRANSFORMATION – PROPOSED METHODOLOGY, PROSPECTS AND CHALLENGES

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Purpose: The theoretical goal of this article is to present a model for measuring countries' energy potential based on the definition of potential derived from physics. The empirical goal is to conduct analyses assessing the dynamics of changes in Poland's energy production structure and the state of Poland's energy balance, to calculate Poland's energy potential for 2018-2024, to critically assess Poland's energy self-sufficiency, and to draw conclusions and recommendations regarding Poland's energy security in the coming years given the threats of the modern world.

Design/methodology/approach: A time-dependent concept of a country's energy potential was defined, allowing for the analysis of the availability of domestic and foreign energy resources. A model for measuring energy potential was proposed and its advantages and disadvantages were discussed. The empirical analysis was based on source data for Poland for the years 2018-2024.

Findings: Energy potential was defined based on a physical formula and using the concept of economic potential (income and population). The terminology was adapted to the energy market. The value of the potential depends on the adopted measure. The research results can be applied to analyses of the country's energy resources, the diversification of energy sources, and energy security.

Practical implications: The formula allows for calculating a country's energy potential and analyzing its energy security, categorizing its own energy security and its dependence on other countries in a given period. It can be used to assess a country's energy security, assess the diversity of energy sources, and assess energy self-sufficiency.

Originality/value: The methodology described in this article is innovative when applied to the energy market. It proposes a formula for measuring energy potential. Physical concepts are adapted to the topic of energy security. The advantages and disadvantages of this method, as well as research limitations, are outlined.

Keywords: economy, management, energy market, energy potential, energy balance, energy security.

Category of the paper: Research paper.

1. Introduction

Energy generation is a crucial and irreplaceable element of every country's economy. Depending on geographic location, availability of energy resources, and technological progress, energy generation varies. Some countries are self-sufficient, energy independent, and able to obtain energy from their own natural resources. However, not all countries are self-sufficient in this regard. Some countries are dependent on other entities, and Poland is in this situation as well.

With the development of technology and environmental awareness, the structure of energy sources is also changing. In many countries, fossil fuels were the primary energy source for many decades. However, with technological advances and an awareness of environmental pollution, the approach to energy generation and environmental issues has changed significantly in the 21st century.

Energy security is a key topic of public debate in the 21st century, as the entire global economy relies on energy resources. This is particularly important in the European Union, whose member states are largely dependent on imports of these resources. The reliability and security of these imports will underpin the future development of these economies, which is why analyzing the energy balance of the European Union as a community and of each country individually is so crucial. EU member states' dependence on energy imports is not uniform. A growing demand for energy is noticeable.

To a large extent, the economies of many countries are shifting away from fossil fuels in favor of ecological energy sources, including nuclear power. This approach justifies environmental protection as one of the factors of a sustainable and responsible economy.

Given geopolitical and military threats and armed conflicts, diversification of energy sources is also crucial. Climate change, the increasingly visible environmental pollution and its impact on public health, and technological advancements imply changes in energy sources. The share of renewable and nuclear energy is increasing, while the share of energy obtained from fossil fuels is decreasing.

2. Theoretical background

Much attention is paid in the literature to the issue of energy security as the foundation of the functioning of the state in a dynamically and stochastically changing economic environment.

The literature can be divided into three subgroups. In macroeconomics, the importance of energy balance in the economic development of countries has been discussed by Baldwin (2022), Baldwin and Forslid (2023), Begg, Fischer, and Dornbusch (1992). Particular attention was paid to energy self-sufficiency in the works by Campling and Selwyn (2018), Diebold and Yilmaz (2015), Fronczek (2018), Gorynia (2019), while dependence on foreign suppliers and the related problems were described in the works by Hegerty (2016), Kocot (2007), and Kołodko (2003). Rynarzewski and Zielińska-Głębocka (2006), Trautwein, H.-M. (2022) strongly emphasize the importance of self-sufficiency, including self-sufficiency in the energy market in competition, in the global economy at all levels of cooperation.

Another group of studies includes methodological works that model selected economic variables Beckmann and Czudaj (2014), Diebold and Yilmaz (2009), explain concepts Mastalerz-Kodzis (2018), define correlations, and examine dynamics Greene (2003) and Silvennoinen and Thorp (2013).

The third group encompasses works on the energy market, its laws, trends, and regulations. These include works by Abdelradi and Serra (2015), Cabrera and Schulz (2016), and Izadyar, Ong, Chong, and Leong (2016). These are works in the field of energy acquisition, its processing and use in the economy: Marques, Fuinhas and Pires Manso (2010), Mensi, Hammoudeh, Nguyen and Yoon (2014), Mensi, Beljid, Boubaker and Managi (2013) and Drożdż and Mróz-Malik (2020).

The energy policies of countries and their natural resources are also an important issue, as this significantly influences the structure of energy production. Discussions on energy policy can be found in the works Papież, Śmiech and Frodyma (2021), Bijańska and Wodarski (2024).

The aim of this article is to derive a formula for measuring the country's energy potential, analyze the dynamics of changes in the structure of energy production in Poland, and calculate Poland's energy potential for 2018-2024. The paper also presents a critical assessment of Poland's energy self-sufficiency and draws conclusions and recommendations regarding Poland's energy security.

3. Methods

3.1. Territorial unit potential – definition and measurement methodology

Originally, the concept of potential comes from physics, then it was used by economists in Geographical Economics, and in this work, based on physical concepts, the methodology for measuring energy potential will be presented.

3.2. Potential as a physical concept

In physics, potential is a quantity used to describe a physical field. A field of physical quantities is a set of functions characterizing points in space and other parameters. For a given system of physical units, the partial potential P_{ij} is used to analyze the interactions of units $(i, j = 1, \dots, n; n \in N)$. For any two units, it is determined according to the formula:

$$P_{ij} = \alpha_0 \frac{P_i P_j}{d_{ij}} \quad (1)$$

The value of the partial potential is interpreted as the amount of energy between units i and j per unit mass, P_i, P_j is the mass of the units, d_{ij} the distance between the units, α_0 and is a parameter.

3.3. Economic potential

Potential is defined in economics as the resource of capabilities, possibilities, or performance that can be assigned to a given territorial unit. As early as 1970, G. Dutton introduced the concept of income and population potential and their quotient, which has become a measure of socioeconomic development. The potential of a region, area (territorial unit), or state is a multidimensional concept, as it depends on many different, often interdependent factors. Potential defines an entity's capabilities based on the abilities, competencies, and efficiency possessed by a given organization, and also measures the ability to use these resources and those of its environment.

Based on the definition of partial potential, the concept of the potential of a territorial unit (e.g., a state) is constructed. It is assumed that the territorial division system consists of n objects – spatial units $(n \in N)$. The potential of each unit is dependent on all other units, albeit to varying degrees. The model of the potential of the i -th spatial unit $(i = 1, 2, \dots, n, n \in N)$ in a given time period (year, quarter, month) is written as:

$$V_i = \alpha_0 \sum_{\substack{j=1 \\ j \neq i}}^n \frac{B_j^{\alpha_{1,j}} P_j^{\alpha_{2,j}}}{d_{ij}^{\beta}} \quad (2)$$

where:

B_i - weight of the i -th spatial unit,

$\alpha_0, \alpha_{1,j}, \alpha_{2,j}$ - structural parameters of the model,

β - distance parameter, remaining symbols as above.

According to the spatial potential model, the capabilities of a territorial unit (state) depend on the condition of the unit itself, but also on the unit's location within the considered space and the adopted metric. This can be a geographical space, in which the distance between units is

measured as the Euclidean distance between the geographical coordinates of distinguished points. Road distance (shortest, fastest) can also be considered, as can the availability of connections between units. Another interesting approach is to consider the metric as an economic quantity.

The components of the above formula can have an economic interpretation.

In geographical economics, the mass of a unit can be considered as production, GDP, population, employment, foreign trade turnover, and investment volume. The mass weight of a given spatial unit can be the occupational structure of the population, age, gender, income, or investment volume per capita. Weights can be adopted arbitrarily or calculated based on statistical data. Distance metrics between units include temporal, physical, Euclidean, and economic distances. Model parameters are determined using the least squares method.

The dependent variable V_i is interpreted as the total impact on the i -th spatial unit, while the total potential of the i -th unit is the sum of the partial potentials of all units in the system. Economic potential can be interpreted as the intensity of the impact of all states (regions) of the system on a selected state (region). Potential is the sum of two components: the system's own potential and the potential of the surroundings. Geographic location has a significant impact on the value of the surroundings' potential. In economics, the following spatial potential models can be distinguished: income, population, and location (accessibility of the region to residents of other regions). These models of geographical economics are described in detail in Mastalerz-Kodzis (2018).

3.4. Energy potential

For the purposes of this article, a country's energy potential is defined as its ability to generate energy from available sources, but also in the context of obtaining energy from other countries. This paper proposes a methodology for determining energy potential, taking into account fossil fuels, renewable energy (wind, photovoltaics), and nuclear energy, and incorporating the time parameter into formulas for calculating countries' energy potential.

Let us assume the following notations:

$EP_i(t)$ - total energy potential in the i -th territorial unit in period t ,

$E_i(t)$ - value of energy produced in the i -th territorial unit in period t (own potential),

$Z_i(t)$ - total energy consumption in the i -th territorial unit in period t ,

d_{ij} - distance between units i and j ,

$\sum_{\substack{j=1 \\ j \neq i}}^n \frac{E_j(t)}{d_{ij}}$ - energy potential of the surroundings of the i -th territorial unit (ambient potential).

In practice, a metric can be binary. If a given country is neighboring the country under study, the value in the distance matrix is 1; if it is not neighboring, the value is assigned to 0. It can also be a binary matrix when considering agreements between countries regarding the

purchase and sale of energy or its carriers. In general, the greater the distance between countries, the more expensive the transmission, meaning the lower the profitability of buying and selling energy. The concept of a metric can also be applied to the distance between countries. Of course, the value of the potential depends on the adopted metric.

Total energy potential is defined as the sum of the internal and external potentials:

$$EP_i(t) = E_i(t) + \sum_{\substack{j=1 \\ j \neq i}}^n \frac{E_j(t)}{d_{ij}} \quad (3)$$

Potential is a measure of a region's spatial accessibility. It determines the intensity of interactions between regions, taking into account economic values and distances between regions. In formula (3), it is divided by the distance between units, as the greater the distance, the smaller the impact on the analyzed characteristics. Energy storage facilities are not included in the formulas. In order to meet a country's energy needs, its total energy potential should be higher than its consumption. A country is safe when its total energy potential is greater than its demand in a given period of time.

The ratio of the i -th unit's own potential in period t to the demand is given by the formula:

$$EE_i(t) = \frac{E_i(t)}{Z_i(t)} \quad (4)$$

If the value $EE_i(t)$ is greater than 1, it means that the country's total energy potential is greater than its energy demand in a given time period, meaning the country is self-sufficient. If the value $EE_i(t)$ is less than 1, the demand exceeds consumption, meaning the country is dependent on other entities.

In turn, the quotient

$$FE_i(t) = \frac{EP_i(t)}{Z_i(t)} \quad (5)$$

provides information about energy availability, taking into account the surrounding environment. If this quotient is greater than one, it means that the capacity to produce and obtain energy exceeds consumption, so consumption can be covered by the country's own resources and those of other territorial units. However, if the value were less than one, it would indicate a critical situation in which the country lacks sufficient energy resources, and even assistance from neighboring (or further) countries would not solve the energy shortage. This is a critical situation.

Potential is a measure of a region's spatial accessibility. It determines the intensity of interactions between regions, taking into account economic values and distances between regions. Energy storage facilities are not included in the formulas. This value $EE_i(t)$ changes over time, so it is possible to consider the dynamics of changes in the energy potential of countries and assess whether changes in the energy generation structure are positively impacting the energy independence of territorial units.

4. Results and discussion

4.1. Energy transformation in Poland – changing the structure of energy production in the years 1970-2024

For decades, hard coal was the primary energy source in Poland. Since the 1980s, hard coal extraction and consumption have been steadily declining (Figure 1). Until 2009, extraction exceeded consumption, but since 2010, consumption has exceeded extraction. A significant decline in hard coal consumption in the Polish economy has been recorded. Compared to 2023, the decline is 14%, and compared to 2015, it is a staggering 33%.

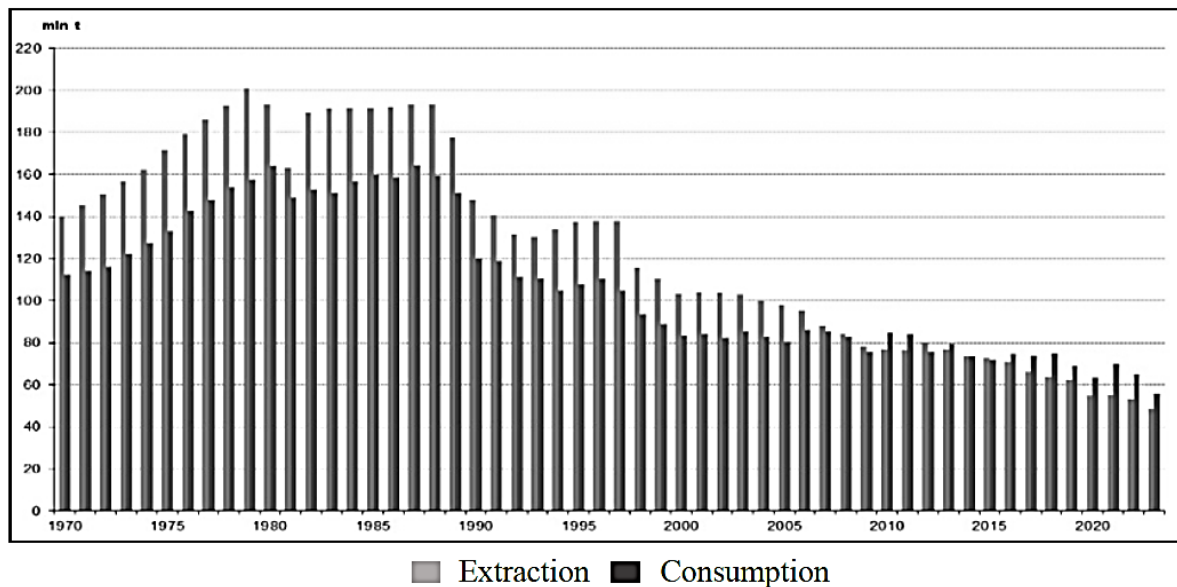


Figure 1. Hard coal extraction and consumption in the years 1970-2024 (mln t).

Source: Own elaboration.

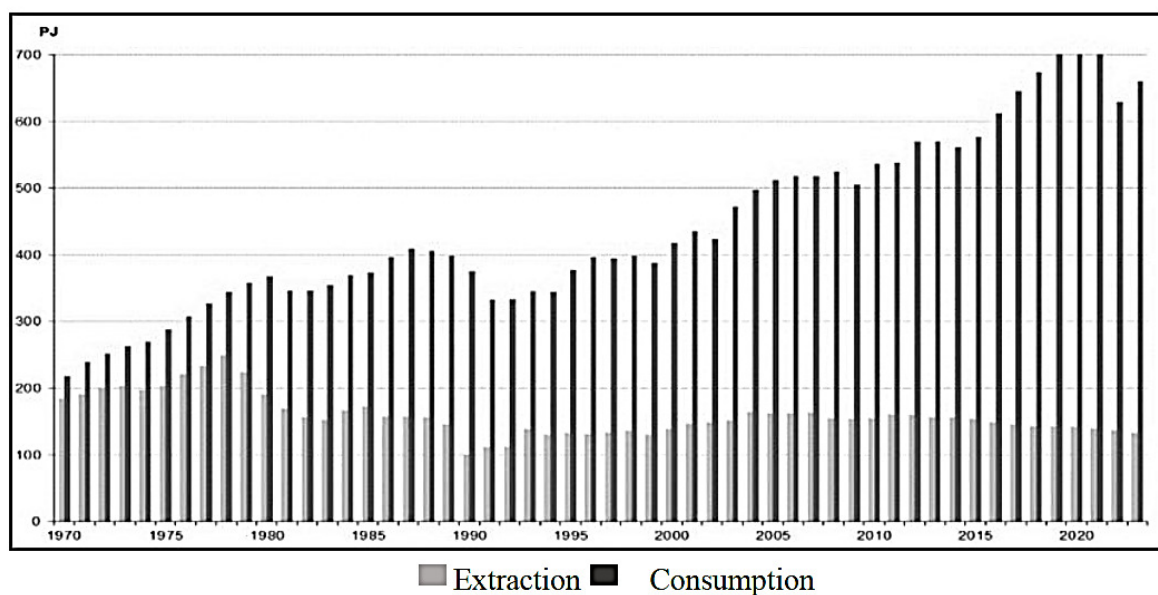


Figure 2. Production and consumption of natural gas in the years 1970 – 2024 (PJ).

Source: Own elaboration.

The total share of coal in electricity production is declining. In 2024, it reached 56.2%, a 4.3 percentage point decrease compared to 2023. Meanwhile, gas consumption is steadily increasing. Dependence on renewable energy imports (primarily biofuels and biomass) hovers around zero (Figure 2).

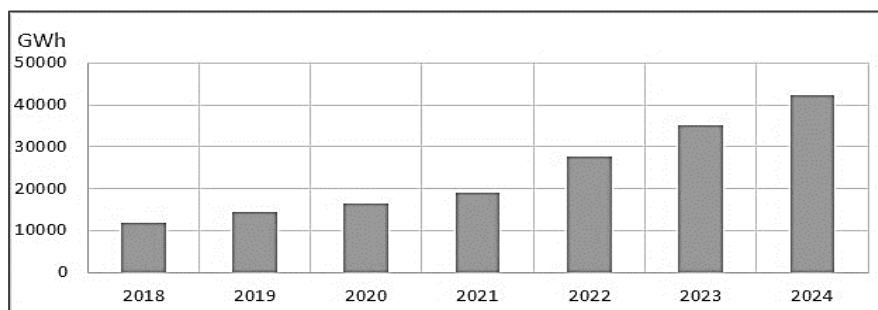


Figure 3. Renewable energy production in 2018-2024 in Poland (GWh).

Source: Own elaboration.

In the 20th and early 21st centuries, renewable energy sources received little attention. It wasn't until the 1920s that significant changes were made. Renewable energy from various ecological sources is becoming increasingly important (Figure 3).

4.2. The structure of energy production in Poland in 2024

Electricity is produced primarily by utility power plants. In 2024, these facilities generated 124,781 GWh, representing almost 75% of total production. The remainder came from wind farms and other renewable energy sources (42,208 GWh) – data are included in Table 1 and Figure 4. It's worth noting that the percentage of installed capacity from commercial and renewable sources is not the same as their percentage of electricity production. Green sources account for 44.08% of installed capacity, but only 25.3% of production.

Table 1.

The structure of energy production in Poland in 2024

Energy source	GWh
hard coal-fired power plants	69 112
hard coal power plants	35844
gas power plants	16768
wind farms and other renewable energy sources	42208
hydroelectric power plants	3057

Source: Own study based on data.

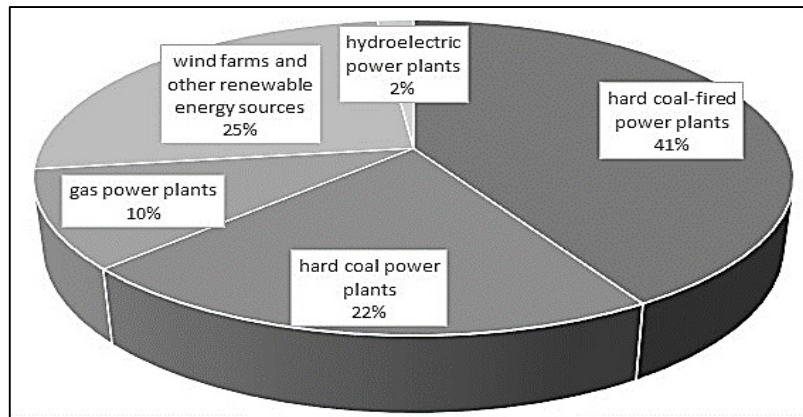


Figure 4. Share of energy production in Poland in 2024.

Source: Own elaboration.

However, the share of coal in energy production is still significant, accounting for over 57 percent (Figure 5).

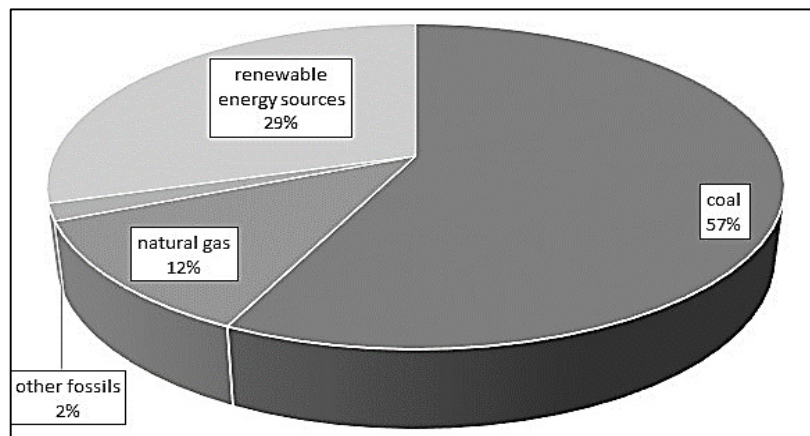


Figure 5. Energy mix in Poland in 2024 year.

Source: Own elaboration.

The 2024 report prepared by the Energy Forum shows a gradual shift in the share of coal-fired sources in Poland's energy mix. Last year, they accounted for 57.1% of electricity production, marking a record low for the combined share of hard coal and lignite in total energy generation. At the same time, the share of renewable energy sources increased again, reaching a historically high 29.6%.

4.3. Poland's energy dependence

Currently, Poland is energy dependent on other countries. Figure 6 shows energy production and consumption from 1970 to 2024. Energy dependence is visible in 1988-1989, in 2014, and since 2016 (Figure 6).

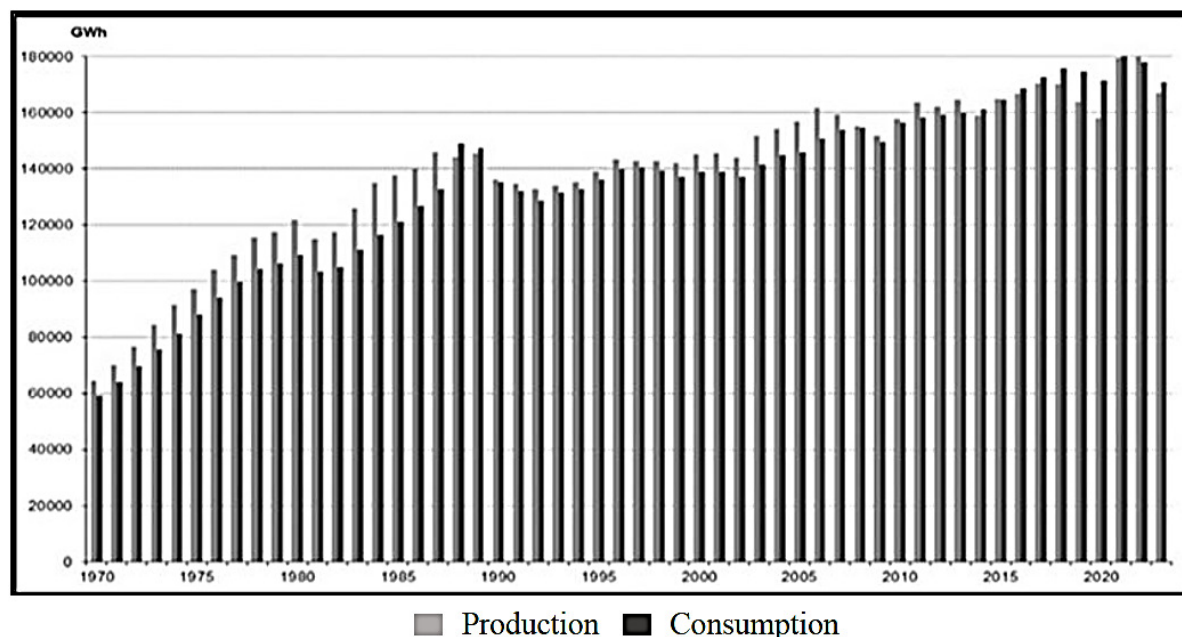


Figure 6. Electricity production and consumption in Poland 1970-2024 (GWh).

Source: Own elaboration.

Poland's dependence on raw material imports is steadily growing, primarily due to the increasing share of oil and its derivatives in the structure of raw material consumption (Figure 6, Figure 7). In 2023, the total dependence reached 45%, compared to 29% in 2014. However, supply diversification, necessary for national security, is taking place. The total cost of raw material imports in 2024 was approximately PLN 112 billion. Since the beginning of the Russia-Ukraine armed conflict, Poland's dependence on raw materials from Russia has steadily declined. By the end of 2024, Poland completely cut off its fuel and raw material supplies from Russia. Poland paid the most for fuel and raw materials from Saudi Arabia (29%), Norway (18%), and the United States (17%).

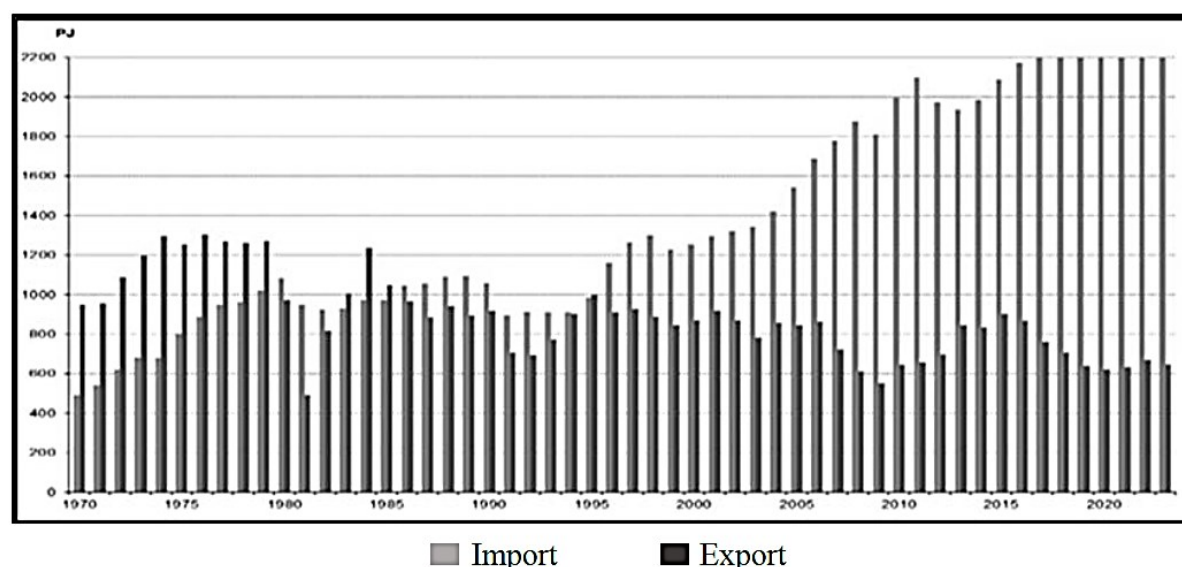


Figure 7. Total energy in Poland - import and export in the years 1970-2024 (PJ).

Source: Own elaboration.

The Polish economy's dependence on energy imports increased from 29% to 45% between 2014 and 2023. For years, the highest import dependence has been observed for crude oil. As much as 96-97% of the oil consumed in Poland comes from abroad. In 2024, dependence on natural gas imports reached 82%. This is 2 percentage points more than in 2023 and 9 percentage points more than 10 years ago. Thermal hard coal imports in 2024 covered 10% of domestic consumption. The decrease compared to 2023 is due to record low consumption of this raw material. Over the past decade, dependence on thermal hard coal imports has increased by 13 percentage points.

Poland's energy deficit is recorded in Table 2 and shown in Figure 8.

Table 2.
Energy deficit in Poland in 2018-2024 (in GWh)

Year	Electricity production	Electricity consumption	Energy consumption deficit
2018	165214	170932	-5718
2019	158767	169391	-10624
2020	152308	165532	-13224
2021	173583	174402	-819
2022	175157	173479	1678
2023	163629	167518	-3889
2024	166990	168956	-1966

Source: Own elaboration.

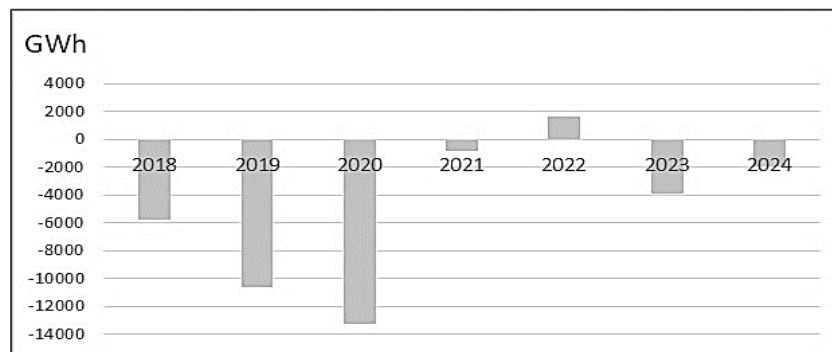


Figure 8. Energy deficit in Poland in 2018-2024 (in GWh).

Source: Own elaboration.

In summary, electricity production in 2024 was lower than domestic consumption. Consequently, the foreign exchange balance amounted to 1,966 GWh. Poland was dependent on foreign suppliers. EU energy import dependency rate stood at 58.4% in 2023. The energy deficit is covered by exports. Exports depend on the metric defined in point 3.4

4.4. Poland's energy potential in 2018-2024

Based on the data, Poland's domestic energy potential was calculated for the years 2018-2024.

Table 3.*Poland's domestic energy potential for the years 2018-2024*

Year	$EE_i(t)$
2018	0,967
2019	0,937
2020	0,920
2021	0,995
2022	1,010
2023	0,977
2024	0,988

Source: Own elaboration.

Only in 2022 the value was greater than 1, so only in this period was Poland energy self-sufficient. In other years, dependence on other countries (not just those within the European Union) was significant. This is a very dangerous phenomenon for the Polish economy and for Poles.

4.5. Energy independence of the European Union. Impact of energy transformation on climate and environmental change – prospects and challenges

The European Union imports more than half of the energy it consumes – primarily in the form of fossil fuels such as oil and natural gas, which generate the majority of its energy. Nuclear energy accounts for 13%, and over 15% of its energy comes from renewable sources. For several years, the popularity of renewable energy has been steadily increasing in both Poland and the EU.

Energy transformation allows for a reduction in the use of fossil fuels in overall energy production. This has a positive impact on the environment, resulting in less pollution and reduced climate change (global warming). Further research plans to include the "energy storage" variable in the energy potential formulas in theoretical and methodological analyses, as well as modify the metric to account for long-term contracts and commitments regarding energy procurement from external entities, as well as the CO₂ environmental pollution variable. The authors believe that taking these factors into account will allow for a more precise determination of countries' economic potential and will also enable potential forecasts for future periods. This is a crucial element of countries' energy security and influences their stable and sustainable development.

The goal should be to achieve a situation in which the total energy potential exceeds demand. If the country's own potential does not meet demand, the country's energy policy should be adjusted so that the surrounding potential covers the remaining portion necessary for the proper functioning of the country. Selecting the metric can be a challenging optimization problem when there are many options for obtaining energy from external sources. Such an optimization task will pose a challenge for the authors in further analyses.

The issue of energy security in European Union countries, particularly in the face of the Russia-Ukraine war crisis, is a particularly significant topic in the current literature. Works by Brodny and Tutak (2023), Dunlop and Völker (2023), Kaczmarek (2022), and Loewen (2022) highlight the importance of energy independence and a balanced energy policy. Studies by Pietrzak et al. (2021), Ahn et al. (2021), and Bowen and Saha (2023) highlight the importance of diversifying energy sources in the 21st century, while works by Brzóska et al. (2022), Kaczmarek et al. (2022), and Jonek-Kowalska (2022) demonstrate a shift away from fossil fuels towards renewable and nuclear energy. It is clear that this course of action is optimal in today's global economic reality.

Another interesting and important aspect for Poland's sustainable and stable economic development is determining the economic potential of its surroundings in the long term. However, this potential depends on metrics (distance, transmission costs, agreements between suppliers, and sanctions imposed on countries). Such an analysis would undoubtedly provide a broader perspective on energy independence for Poland and other countries. This will undoubtedly be the subject of future research and analysis.

5. Summary

The energy potential of each country is a factor influencing its security in the rapidly changing economic environment and the very difficult political situation currently prevailing worldwide. Dependence on other countries can adversely affect security, especially in the face of armed conflicts and the associated restrictions on the flow of goods, including energy resources.

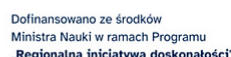
Every country should strive for energy self-sufficiency. However, this is sometimes impossible due to the unavailability of energy resources and the inability to switch energy sources, such as nuclear power plants, wind farms, or photovoltaics.

Measurement of energy potential is a crucial element of a country's development strategy. However, the measurement methodology leaves researchers with many parameters, such as the distance matrix. Depending on its value, relationships, agreements, and availability, the values of countries' energy potential may vary. However, analyzing the dynamics of change allows for an assessment of the direction of change and the provision of guidelines and recommendations for the energy security of the country and its inhabitants.

The direction of further analyses is to compare the energy potential of European countries, show the possibilities of cooperation in the exchange of energy resources and energy itself, and provide recommendations for further strengthening Poland's energy position in Europe.

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HARNESSING NEW TECHNOLOGIES TO PREVENT THE MIGRATION OF CRAFTSMEN

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Purpose: This article combines three issues: new technologies, migration, and crafts, analyzed from the perspective of people training in craft professions in centers located in the Opole Region (Poland). It aims to find answers to the question how does the implementation of new technologies in the craft professions affect the likelihood of abandoning intentions for labor migration?

Design/methodology/approach: The article presents the results of a survey conducted among 166 students of vocational schools located in the cities of Kędzierzyn-Koźle, Opole, and Nysa. The research was conducted using a quantitative method based on a structured questionnaire that included questions concerning the respondents' vocational training profile, plans to start working in Poland, intended country of work, age, sex, and nationality.

Findings: The research reveals that although most vocational school students plan to pursue employment in Poland, limited migration interest, enduring gender-based occupational patterns, and prevailing labor market uncertainty highlight the need for enhanced vocational guidance and greater exposure to international labor opportunities. The results further indicate that while vocational school students recognize technological innovation as a driver of efficiency and the modernization of craft professions, migration intentions remain primarily shaped by economic conditions and individual motivations.

Originality/value: This article provides a comprehensive examination of the interplay between emerging technologies and migration, specifically within the context of the craft sector, thereby addressing and filling a previously identified gap in the existing body of research.

Keywords: craft, new technologies, cultural economy, migration, sustainable development, craft resilience.

Category of the paper: Research paper.

1. Introduction

New technologies refer to recently implemented innovations or observed advances. They can be improvements on existing technologies across various sectors (Cobrief, 2025). The concept of new technologies refers to technologies that were created or launched relatively recently, often associated with innovative tools, systems, or methods. Technological innovations are playing an increasingly important role in the growth dynamics of leading economies. This category is also referred to as ‘emerging technologies’, ‘future technologies’, or ‘breakthrough technologies’. According to the McKinsey Technology Trends Outlook report, 13 technology trends with significant potential for business transformation can be identified. These include: Agentic AI, AI, Application-specific semiconductors, Advanced connectivity, Cloud and edge computing, Immersive reality technologies, Digital trust and cybersecurity, Quantum technologies, the Future of Robotics, the Future of Mobility, the Future of Bioengineering, the Future of Space Technologies, and the Future of Energy and Sustainability Technologies (McKinsey & Company, 2025). In migration processes, emerging technologies include: the Internet of Things (IoT), Artificial Intelligence (AI), cloud computing, Big Data technologies, blockchain, automation, and biometric technologies (Nalbandian, Dreher, 2022), as well as virtual reality and information and communication technologies (ICT), including social media (Arya, Nardon, Riyadh, 2022). The perception of new technologies is not always clear-cut, depending on factors such as age group, place of origin/residence, and the industry represented.

Technology has always played an essential role in migration processes, in the context of movement (travel), contact with people from the home and host countries, or transferring money (Ros et al., 2007). Digital connectivity via mobile phones, in particular, is impacting every aspect of migration (Gelb, Krishnan, 2018). New technologies are transforming the labor market in various segments, including migration-related. As Barišić et al. (2024) noted, implementing new technologies can alter labor demand. Their findings, limited to the implementation of robots and based on an analysis of the literature, indicate, among other things, that the use of robots positively impacts overall employment growth. In contrast, using robots in the manufacturing sector may affect the labor market for immigrants. Generally, because workers adapt to changes in the workplace, robots do not increase the number of unemployed. Furthermore, automation and robotization do not lead to the displacement of humans in low-skilled manual work in the service sector. However, they may provide a solution to problems resulting from labor shortages.

The impact of new technologies on the labor market in the manufacturing sector involves examining the role of patents, robot adoption, digital assets (capital in computer hardware, capital in communications equipment, and capital in computer software and databases), and total factor productivity in the growth of migrants relative to the total workforce. Among

other things, it can be observed: 1) the differential impact of digital assets, 2) the impact of robots (as elements displacing people from the labor market) is greater among native workers than migrants, while 3) the impact of total factor productivity concerns migrant workers (Ghodsi, Stehrer, Barišić, 2024). These studies indicate that innovations: 1) can benefit migrant workers, 2) there is a potential complementarities between migrant work and robotization in some sectors (Barišić et al., 2024). The factors discouraging immigration include higher digital resources per employee in the target country. In comparison, the factors that attract immigration include a higher level of robots per employee in the target country (Ghodsi, Landesmann, Barišić, 2024). Research conducted in Germany, focusing on the impact of industrial robots and artificial intelligence on the labor market, indicates that the use of robots does not significantly affect migration flows. Still, it does affect wages, increasing for the native population and decreasing for the immigrant population, particularly in the manufacturing sector, where robots are most frequently used. Demand for artificial intelligence, on the other hand, favors the influx of new immigrants but negatively impacts the native population and already settled migrants (Giesing, Rude, 2022).

Martínez Torán et al. (2017) note the following trends in contemporary crafts: going glocal, focusing on sustainable intelligence, personalizing products and services, sharing experiences, engaging consumers in design and promotion, and digital craft – an area closely linked to new technologies. The evolution of craft design also reveals three main trends: 1) diversification of production to meet new needs resulting from technological progress, 2) shifting responsibility from product design to action design, and 3) blurring the boundaries between industries, disciplines, and participants (Zhou et al., 2022). The growing impact of digital technology on the skills-based economy has long been highlighted in reports on contemporary crafts. The crafts sector is constantly evolving, and this is happening in an environment of changing economic, cultural, technological, and social conditions. Online sales are increasing, and new technologies are opening up new creator opportunities (BOP, 2012). New technologies are also identified as having the potential to re-elevate the prestige of various artisan products, contributing to the preservation of traditional skills and their popularity among younger generations of artisans. These technologies can also support and increase productivity and product quality (AGNIi, 2023). In the transformation towards a knowledge-based economy, traditional, established knowledge resources retain their importance and can effectively coexist with new forms of knowledge. Crafts are a sector that can benefit from the integration of new technologies, particularly given the current democratization of: 1) design (free exchange and consumer engagement in co-creation), 2) production (the possibility of supervision, even by micro-entrepreneurs), and 3) innovation (free access to information via the Internet, software development, and the formation of online communities). Their use does not diminish the value of the final product. On the one hand, new technologies enable simplifications in manufacturing, marketing (including product presentation and establishing stakeholder relationships), sales, and product distribution, among others (CEARTE, 2017), on the other

hand, the craft-based design methodology through manufacturing with technology embodies authenticity and is relevant to the 'culture of personalization' in production and consumption (Bunnell, 2004).

The study aims to explore the opinions of vocational school students in the Opole Region regarding the use of new technologies in crafts in the context of their migration plans. This article seeks to determine whether new technologies in crafts are perceived as a factor influencing the decision to abandon plans for economic migration.

2. New technologies in the context of migration

The issues of migration and new technologies are perceived from many perspectives, primarily in the context of the following research: 1) knowledge-based economy operating in the conditions of international competition, 2) digital labour platform, 3) the impact of migration on technological changes, 4) educational tools addressed to migrants, 5) the use of advanced digital technologies in the management of immigration and asylum systems, including migration research and border management, and 6) digital nomadism.

2.1. Knowledge-based economy

The first approach highlights aspects of the knowledge-based economy, international competition, and the consequences of highly skilled migration. These topics are examined from different perspectives: 1) negative consequences—declining economic growth in sending countries; 2) return migration of highly skilled migrants (compensating for outflows); and 3) the benefits of mobility for both sending and receiving countries (Rashidi, Pyka, 2013).

2.2. Digital labour platform

Digital labor platforms enable migrants to find work immediately upon arrival in the host country. Their use is associated with, among other things, lower entry barriers. However, offering lower-quality positions poses a different set of challenges. Research conducted by Zwysen & Piasna (2024) indicates that this type of work is not typical "migration" work. Migrants, however, are more likely to work through digital labor platforms due to the limited number of employment options available. These researchers point out, among other things, that taking up work through platforms is a symptom of labor market integration problems for migrants (Zwysen, Piasna, 2024).

2.3. The impact of migration on technological change

The third approach, explored by, among others, Andersson, Karadja and Prawitz (2022) and involving the analysis of historical data (concerning mass migration from Europe to the United States in the 19th century), indicates that emigration influences the growth of innovative activity (patent applications) and the increase in capital intensity related to new technologies (Andersson, Karadja, Prawitz, 2022). Highly skilled migrants residing in high-income countries, in particular, contribute to technological innovation and research and development. Like diasporas, migrants constitute an important channel for technology transfer, including back to the country of origin (through direct technology and knowledge transfer, investment and remittances supporting economic growth and transformation in source countries, and fostering entrepreneurship in source countries), including technology diffusion (Gelb, Krishnan, 2018). This diffusion is defined as a key factor driving productivity growth and economic progress, and migration as a process supporting the flow of knowledge to the countries of origin of migrants (CentrePiece, 2025).

2.4. Educational tools

Digital technologies enable various groups (including migrants) to access education. However, online training should be inclusive, meaning it should be tailored to the cultural specificity of a given migrant group. Furthermore, it should be designed in collaboration with migrants to ensure its practical application, based on technologies already used by migrants. It should also consider migrants' privacy and security, and include assessment and certification management (Unwin, Harindranath, Ghimire, 2021). Within this group of issues, new technologies also enable the mobilization, expression of claims and strengthening of migrants' identity (Nedelcu, Soysüren, 2022).

2.5. Managing immigration, asylum systems, and borders

The use of advanced digital technologies in immigration management is the most common research topic within migration and new technologies. Researchers emphasize the need to monitor the use of new technologies (especially AI) in international migration management (Baranowska, Szoszkiewicz, 2021). This topic covers new technologies in researching migration, e.g., using social networking sites to establish contact with migrant respondents or computer-aided research (Pötzschke, Rinken, 2022). Within border management, the dominant technologies are IoT, Big Data, automated decision-making systems, predictive analytics, drones (aerial surveillance), and biometric technologies. These are discussed from two perspectives: 1) risk to the host country (dominant approach encompassing national security aspects) and 2) to the migrant. Within the first perspective, new technologies are primarily used to track, identify, and control individuals crossing and departing from designated borders, as well as to forecast migration and capture satellite imagery. Forecasting migration flows may be related, for example, to emerging disasters or economic crises, or to incorporating migration

into epidemiological models to counteract the spread of diseases (Fournier-Tombs, Castets-Renard, 2022). International migration is considered the most difficult demographic change element to forecast (Wiśniowski, 2021). In the second perspective, innovative technologies are analyzed from the point of view of supporting migrants' experiences - protection and support tools under challenging situations, especially in the framework of migration risk analysis, accelerating identification and registration processes, improving service provision, facilitating settlement and integration (Nalbandian, Dreher, 2022). Some of these solutions speed up decision-making and reduce the risk of bias and discrimination. Still, they may also have negative aspects, including transparency, proportionality, personal data security, and respect for fundamental rights (Ozkul, 2023; Khoury, Hendow, 2025; ENNHRI, 2024; Fournier-Tombs, Castets-Renard, 2022), including encouraging the creation of e-borders (Nedelcu, Soysüren, 2022). Automated processing of massive data sets doesn't always allow for the reconstitution of the decision-making process. This is referred to as the "black box problem" in the context of the issue under analysis, which prevents investigation or questioning of the decisions made (Castelvecchi, 2016). Amnesty International (2023) emphasizes that digital technologies that facilitate rights violations at and around borders are also used to criminalize life.

2.6. Digital nomadism

The last of these topics concerns remote workers traveling the world. Generation Y primarily represents this group, educated individuals who experience uncertain economic conditions in their home countries while also having the opportunity to travel to developing countries. This lifestyle is being publicized on social media. It is fostered by the growing tourism industry, which offers long-term shared and coworking accommodations, internet cafes, and networking events (Thompson, 2024).

To sum up the above, despite the scientific community's interest in new technologies and migration, there is a clear research gap covering the group of craftsmen and people training in crafts.

3. Material and Methods

The article presents the results of the first research stage conducted among the young generation of craftsmen/ skilled tradespeople – undergoing vocational training in vocational schools of the first and second degree located in the Opole Region.

Data were obtained from a survey conducted between April and June 2024. The schools selected for the study were the largest vocational education centers in the region. The schools were sent a letter requesting their consent to conduct the study. After receiving this consent,

the online survey was sent twice (Google Form). The response rate was 166 forms submitted from three centers: 1) Academy of Crafts and Entrepreneurship at the Opole University of Technology (in Polish: Akademia Rzemiosła i Przedsiębiorczości Politechniki Opolskiej), 2) Center for Vocational and Continuing Education in Nysa (Centrum Kształcenia Zawodowego i Ustawicznego), and 3) School Complex No. 1 named after the Silesian Insurgents in Kędzierzyn-Koźle (Zespół Szkół nr 1 im. Powstańców Śląskich).

The study aimed to examine the professional aspirations and employment intentions of vocational school students, with particular attention to whether they plan to work in Poland or abroad. It also sought to identify differences in intentions based on the use of new technologies in the educational process, as well as vocational profile, gender, age, and nationality.

The research was conducted using a quantitative method based on a structured questionnaire. The survey included questions concerning the respondents' vocational training profile (type of craft), plans to start working in Poland, intended country of work, age, sex, and nationality (national or ethnic identity).

Figure 1a-d summarize the key demographic characteristics of the surveyed vocational school students. The study sample consisted of 166 students attending various vocational schools. The mean age was approximately 16.44 years, while the median age was 16, indicating that half of the participants were aged 16 or younger. The youngest respondent was 14 years old, and the oldest was 19 years old. Average Age was 16.7 years. This age distribution confirms that the study focused on adolescents and young adults at the stage of early career decision-making, which is typical for vocational education settings.

In terms of gender distribution, female students accounted for 49% of the sample, and male students also made up 51%, indicating a balanced gender structure.

Regarding nationality, the vast majority of respondents (95%) identified as Polish, while a small share were of Ukrainian (4%) and German (1%) origin. This reflects the growing presence of students with migrant backgrounds in Polish vocational education, although the group remains predominantly national in composition.

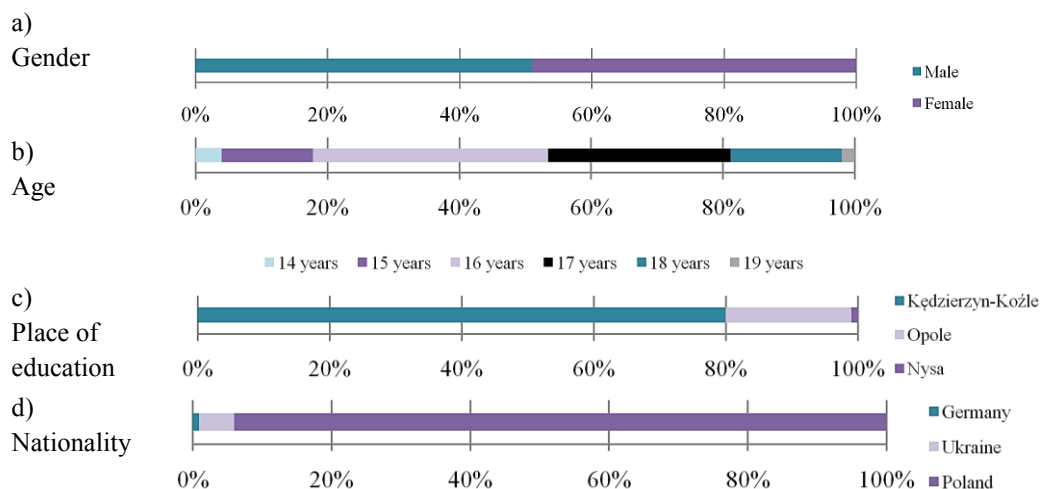


Figure 1a-d. Demographic composition of the respondents [%].

Source: own study.

Table 1 presents the distribution of the surveyed students according to their vocational training profile. The largest group consisted of automotive mechanics (23%), followed by hairdressers (20%), cooks (16%), and salespersons (15%). Together, these four professions accounted for more than three-quarters of all respondents, indicating that technical and service-oriented trades dominate among vocational students.

Smaller groups included locksmiths (6%), interior finishing workers (3%), interior finishing installers (2%), and confectioners (2%) and carpenter (2%). Several other professions, such as carpenters, hotel service workers, tailors, electricians, photographers, and IT technicians, were represented by only one or two students each, corresponding to about 1% of the total sample.

Overall, the table highlights the strong representation of practical, hands-on professions that are in high demand in both the Polish and European labour markets, especially in the automotive and personal services sectors.

Table 1.
Distribution of respondents by vocational profile

Vocational training profile	Number	%
Automotive Mechanic	39	23%
Hairdresser	34	20%
Cook	27	16%
Salesperson	25	15%
Locksmith	10	6%
Interior Finishing	5	3%
Interior Finishing Installer in Construction	4	2%
Confectioner	4	2%
Carpenter	3	2%
Logistics Warehouse Worker	2	1%
Hotel Service Worker	2	1%
Tailor	2	1%
Sanitary Installation and Network Installer	2	1%
Photographer	1	1%
Waiter	1	1%
IT Technician	1	1%
Electrical Technician	1	1%
Car Painter	1	1%
Panel Beater	1	1%
Baker	1	1%
All	166	100%

Source: own study (n = 166).

Table 2 shows the distribution of female and male students across various vocational specializations. The data reveal a clear gender-based differentiation in vocational choices. Female students were strongly represented in service-oriented and customer-focused professions, particularly hairdressing and sales. In contrast, male students dominated the technical and construction-related specializations, such as automotive mechanics, locksmithing, and carpentry, accounting for more than 90% of participants in those fields. This pattern corresponds with broader trends in vocational education, where gender still plays a significant role in determining occupational preferences and pathways.

Some professions, such as hotel service worker, tailor, and logistics warehouse worker, show almost balanced gender distribution (49% female, 51% male), suggesting that these roles attract both genders equally.

Table 2.
Gender distribution by vocational profile

Vocational training profile	Female	Male	All
Automotive Mechanic	1	38	39
Baker	0	1	1
Car Painter	0	1	1
Carpenter	0	3	3
Confectioner	4	0	4
Cook	17	10	27
Electrical Technician	1	0	1
Hairdresser	33	1	34
Hotel Service Worker	1	1	2
IT Technician	0	1	1
Interior Finishing	0	5	5
Interior Finishing Installer in Construction	0	4	4
Locksmith	1	9	10
Logistics Warehouse Worker	1	1	2
Panel Beater	0	1	1
Photographer	1	0	1
Salesperson	20	5	25
Sanitary Installation and Network Installer	0	2	2
Tailor	1	1	2
Waiter	1	0	1
All	82	84	166

Source: own study (n = 166).

Overall, the data highlight a persistent pattern of gender segregation in vocational education, with women gravitating toward service and creative fields, while men dominate in technical and industrial professions. Despite this, a few mixed-gender occupations indicate a gradual diversification of vocational choices among young people. The dominance of automotive mechanics and hairdressers is clearly visible, highlighting the popularity of these professions among vocational youth. Technical trades attract a large proportion of male students, whereas service and aesthetic fields remain predominantly female. This imbalance suggests that, despite increasing gender equality in education, traditional gendered divisions of labour continue to shape vocational career choices.

The data were collected and organized in Microsoft Excel, which was also used for data cleaning, coding, and statistical analysis. Descriptive statistics were applied to calculate frequencies and percentage distributions for each categorical variable. Cross-tabulations were used to explore relationships between vocational profile and employment intentions, as well as between gender and occupational choice. These analytical procedures allowed for a structured examination of how demographic and educational characteristics influenced students' career plans and migration aspirations.

The analysis focused on identifying general patterns, gender differences, and levels of certainty in career decision-making among vocational students.

4. Results

Employment intentions were examined to assess whether vocational school students plan to start working in Poland or abroad. As presented in Figure 2, 41% of respondents expressed their intention to work in Poland, 12% declared a desire to work abroad, while 47% remained undecided. The relatively high proportion of undecided respondents indicates a degree of uncertainty in career planning typical for this age group. At this stage of life, many students are still completing their education, gaining work experience, or exploring various career paths, which makes it difficult for them to make firm employment decisions. Moreover, their choices are often influenced by factors such as family expectations, the opinions of peers, and the perceived attractiveness of working abroad compared to domestic opportunities.

The large share of undecided respondents may also reflect limited knowledge of the labour market or uncertainty about future economic conditions. Young people may not yet have sufficient information about wages, job stability, or career advancement opportunities in their chosen profession. Additionally, fluctuations in labour demand, regional differences in job availability, and the possibility of further education can also delay final career decisions.

Therefore, the high level of indecision among students should not necessarily be interpreted as a lack of ambition or interest in employment, but rather as a natural stage in the process of career orientation. Future migration and employment trends in this group are likely to depend on external conditions such as wage differentials between Poland and other EU countries, the accessibility of quality jobs locally, and the ease of international mobility.

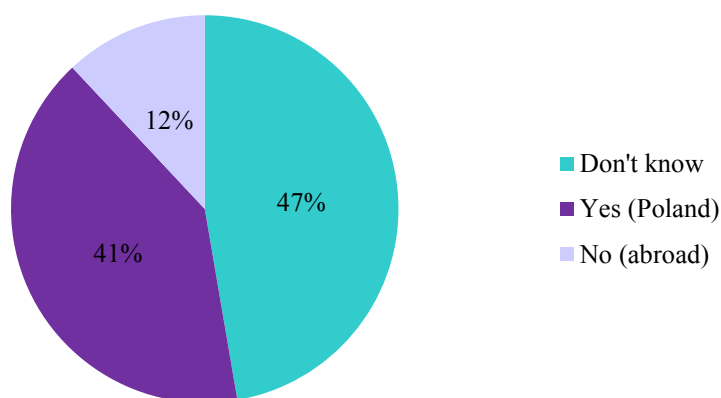


Figure 2. Employment intentions (work in Poland vs abroad).

Source: own study (n = 166).

Table 3 indicates that the majority of vocational school students declared an intention to commence employment in Poland upon completion of their vocational education. The largest proportion of affirmative responses (“yes”) was observed among automotive mechanics (21 respondents), hairdressers (15 respondents), and cooks (9 respondents). These vocational profiles are likely associated with a relatively stable demand for skilled labour in the Polish labour market, particularly within the service and manufacturing sectors, where opportunities for immediate employment are more accessible and entry barriers remain comparatively low.

Nevertheless, it is noteworthy that a considerable number of respondents within these same professions expressed indecision regarding their post-graduation employment plans, specifically, 15 hairdressers and 17 cooks selected the “don’t know” option. This pattern suggests the presence of a significant degree of career uncertainty among students in these vocational tracks. Such uncertainty may stem from several factors, including limited information about labour market prospects, insufficient career guidance, or perceived instability in the respective sectors. Consequently, these findings highlight the need to strengthen vocational counselling and labour market orientation within vocational education frameworks to support informed career decision-making among young professionals.

Table 3.
Plans to start working in Poland

Vocational training profile	Don't know	No	Yes	All
Automotive Mechanic	12	6	21	39
Baker	1	0	0	1
Car Painter	1	0	0	1
Carpenter	0	1	2	3
Confectioner	1	0	3	4
Cook	17	1	9	27
Electrical Technician	0	0	1	1
Hairdresser	15	4	15	34
Hotel Service Worker	1	0	1	2
IT Technician	0	0	1	1
Interior Finishing	4	0	1	5
Interior Finishing Installer in Construction	1	2	1	4
Locksmith	7	2	1	10
Logistics Warehouse Worker	2	0	0	2
Panel Beater	0	1	0	1
Photographer	0	0	1	1
Salesperson	14	3	8	25
Sanitary Installation and Network Installer	0	0	2	2
Tailor	1	0	1	2
Waiter	1	0	0	1
All	78	20	68	166

Source: own study (n = 166).

When analysing migration preferences (Figure 3), vocational school students most frequently mentioned Germany, Switzerland, Spain, Austria, the Netherlands, and Norway as their intended destinations for work abroad. These countries are well-established labour markets for Polish and Central European workers, particularly in technical and construction

professions. It should be emphasized, however, that this question differed from the previous one. In the earlier question, students were asked in general terms whether they planned to work in Poland or abroad. In that case, 41% declared an intention to work in Poland. In contrast, in the follow-up question, where respondents were asked to indicate specific countries in which they would like to work, Poland was chosen by as many as 74% of them, while 11% of respondents answered “don’t know”.

This discrepancy suggests that the second question was interpreted somewhat differently by the respondents. When asked to choose a country rather than to make a firm decision about their employment plans, many vocational school students selected Poland as a natural or default option, even if earlier they had been uncertain or open to working abroad. For some, choosing “Poland” in this context did not necessarily indicate a strong commitment to domestic employment but rather reflected a lack of concrete migration plans or a tendency to associate the start of their careers with their home country.

The presence of 11% of undecided respondents (“don’t know”) further confirms a general sense of uncertainty among young people regarding future employment destinations. Many of them are still in the process of career exploration and may not yet possess sufficient information about labour market conditions, job availability, or wage differentials abroad.

The observed differences between the two questions highlight the fluid and context-dependent nature of students’ migration intentions. While most express attachment to Poland and see it as a likely place to begin their careers, many remain open to future mobility depending on economic conditions and professional opportunities in other European countries.

However, the “don’t know” category was notably large, particularly among younger respondents aged 15-16. This uncertainty suggests that many students are still exploring their career options and may reconsider migration as they gain professional experience or encounter economic pressures.

It is worth to add, that nationality also played a role in migration preferences. While the majority of respondents identified as Polish, a small number of Ukrainian students expressed stronger intentions to work in Poland rather than return to their home country, indicating that Poland may serve as both a training and destination country for them.

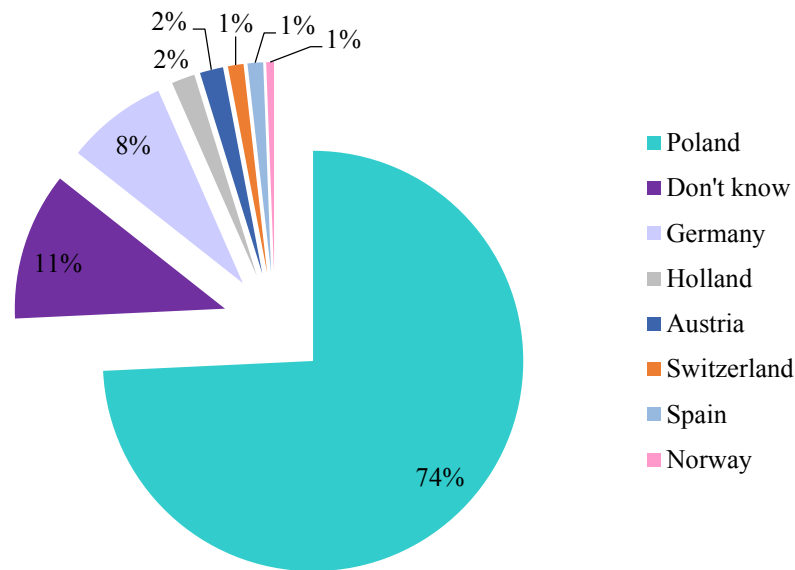


Figure 3. Migration preferences.

Source: own study (n = 166).

The cross-tabulation of vocational profiles and employment plans (Table 4) provides deeper insight into how professional orientation influences students' intentions to work in Poland or abroad. The data clearly demonstrate that the type of vocational training significantly shapes employment aspirations and potential migration decisions.

As shown in the table, vocational school students from technical fields, especially automotive mechanics, were the most determined to work in Poland, with almost two-thirds declaring such an intention (29 out of 39). This result may reflect the strong demand for skilled technical workers in the domestic labour market, where automotive and mechanical services remain stable and accessible career paths. At the same time, this group also contained the highest number of respondents considering migration, mainly to Germany and Switzerland. These two countries are traditional destinations for Polish mechanics and technicians, offering higher wages and attractive working conditions, which makes international mobility a realistic alternative rather than a distant prospect.

Among service-oriented professions, such as hairdressing and sales, the pattern was slightly different. Nearly half of these students expressed plans to work in Poland, while a comparable proportion remained undecided. For instance, eight hairdressing students and one salesperson responded "don't know," suggesting that uncertainty about labour market opportunities or plans to continue education may still influence their choices. Service professions are often more dependent on local demand, personal networks, and customer relationships, which may explain why students in these fields are less inclined to migrate immediately but remain open to future changes.

The findings also reveal that in smaller professional groups, such as cooks, confectioners, or carpenters, the overwhelming majority preferred to work in Poland. This could be due to the availability of employment opportunities in local businesses, restaurants, and small enterprises,

where such skills are directly applicable. On the other hand, a few individuals from construction-related fields (e.g., locksmiths or interior finishers) indicated plans to work abroad, reflecting the long-standing tradition of labour migration in the construction sector.

It is also worth noting that 19 respondents (11%) declared that they “don’t know” yet where they would like to work. This group of undecided students represents an important segment of the population entering the labour market. Their hesitation may stem from a lack of practical experience, uncertainty about wage levels, or insufficient information about foreign labour markets. Furthermore, some students may still be considering further education before making long-term employment decisions.

However, the results presented in Table 4 highlight a dual trend among vocational students: strong local attachment combined with openness to migration. While most young people intend to start their professional careers in Poland, particularly in technical and service occupations, the appeal of working abroad, especially in Western Europe, remains significant. This suggests that future migration flows among vocational graduates will likely depend on domestic job availability, wage competitiveness, and the accessibility of international employment channels.

Table 4.

Vocational profiles and employment plans

Vocational Training Profile	Austria	Germany	Holland	Norway	Poland	Spain	Switzerland	Don't know	All
Automotive Mechanic	1	4	0	0	29	1	1	3	39
Baker	0	0	0	0	1	0	0	0	1
Car Painter	0	0	0	0	1	0	0	0	1
Carpenter	0	0	0	1	2	0	0	0	3
Confectioner	0	0	0	0	3	0	0	1	4
Cook	0	1	0	0	23	0	0	3	27
Electrical Technician	0	0	0	0	1	0	0	0	1
Hairdresser	0	2	0	0	23	1	0	8	34
Hotel Service Worker	0	0	0	0	2	0	0	0	2
IT Technician	0	0	0	0	1	0	0	0	1
Interior Finishing	0	1	0	0	3	0	0	1	5
Interior Finishing Installer in Construction	0	0	0	0	4	0	0	0	4
Locksmith	2	2	1	0	4	0	0	1	10
Logistics Warehouse Worker	0	0	0	0	2	0	0	0	2
Panel Beater	0	0	0	0	0	0	0	1	1
Photographer	0	0	0	0	1	0	0	0	1
Salesperson	0	3	2	0	18	0	1	1	25
Sanitary Installation and Network Installer	0	0	0	0	2	0	0	0	2
Tailor	0	0	0	0	2	0	0	0	2
Waiter	0	0	0	0	1	0	0	0	1
All	3	13	3	1	123	2	2	19	166

Source: own study (n = 166).

One fifth of students (21%) declared using new technologies during classes at school, while almost half (49%) during practical vocational training (Figure 4).

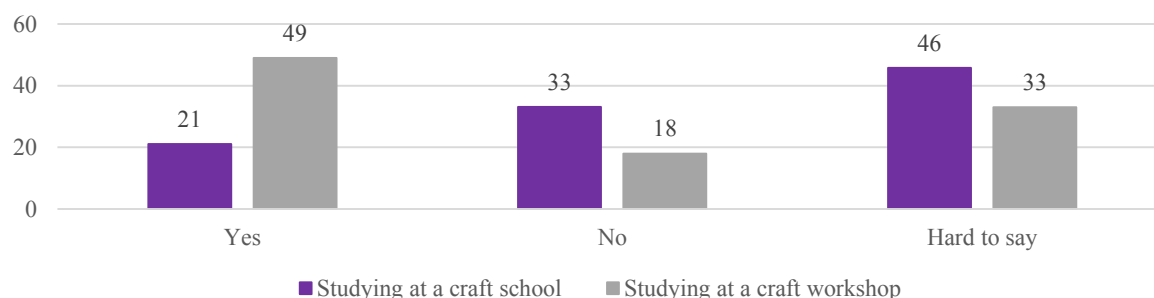


Figure 4. Using new technologies while learning a craft [%].

Source: own study (n = 166).

The analysis revealed statistically significant relationship between using new technologies while learning in craft school and students' migration intentions ($p < 0.05$), but at the same time no statistical significant relationship is shown between using new technologies while the practical process of learning a profession (during vocational training or other activities related to the practical aspects of vocational education) and students' migration intentions ($p > 0.05$). Details are shown in Table 5 and 6.

Table 5.

Using new technologies during school classes

Answer	Observed			Expected			p-value
	Plans to work outside Poland	Work plans in Poland	Hard to say	Plans to work outside Poland	Work plans in Poland	Hard to say	
Yes	1	23	11	4,2169	14,3373	16,4458	0,0067
No	9	22	24	6,6265	22,5301	25,8434	
Hard to say	10	23	43	9,1566	31,1325	35,7108	

Source: own study (n = 166).

Table 6.

Employing new technologies throughout vocational training and associated practical activities

Answer	Observed			Expected			p-value
	Plans to work outside Poland	Work plans in Poland	Hard to say	Plans to work outside Poland	Work plans in Poland	Hard to say	
Yes	10	42	29	9,7590	33,1807	38,0602	0,0634
No	4	9	17	3,61445	12,2892	14,0964	
Hard to say	6	17	32	6,6265	22,5301	25,8434	

Source: own study (n = 166).

Although 39% of respondents believe that new technologies influence young people's career choices, in a question focused on the advantages and disadvantages of new technologies in the context of crafts, none of the students noted their impact on migration plans, both in terms of pushing them into foreign markets and retaining them in the Polish market. The advantages of using new technologies included: 1) impact on productivity and efficiency, 2) more thoughtful production and management processes, 3) adaptability to the demands of modern consumers, 4) influence on the selection of less environmentally harmful materials or minimizing the use of rare materials, and 5) perception of the enterprise as modern. The disadvantages of new technologies in crafts included: 1) high implementation costs, 2) the risk of job cuts, and 3) the need to implement changes within the enterprise and the resulting reluctance of employees to change/learn new things.

Similarly, among the observed changes related to the introduction and application of new technologies in crafts (in the workplace/practice setting), no changes were identified associated with preparing, adapting, or enabling work abroad. However, the following elements were appreciated: 1) more flexibility in working hours, 2) faster performance of professional tasks, 3) easier communication within the company and with the external environment, and 4) positive impact on the natural environment.

5. Discussion

Our study focuses on a group of students of vocational schools, and it is not only oriented on the education period (preparation for a profession), but also career and migration plans after completing the education process. Other research conducted in the context of learners within the selected subject area focuses primarily on educational migration (full-time study abroad or shorter academic exchanges). Examples are presented in Table 7. It is worth emphasizing that this research does not concern the space of craftsmen or craft professions.

Table 7.
Examples of research combining the issues of new technologies and migration focused on people in education

Source	Respondents/ area	Main characteristic
Brunner, Tao (2024)	Students	Managing international students using AI and automation, among other things, to assess study permit applications. The risks of using them in this regard are related to the complex and subjective decision-making system (aspects of systemic racism and discrimination, as well as border surveillance/imperialism) and the consequences of errors, the costs of which are borne by those temporarily residing in the destination country.

Cont. table 7.

Masud (2020)	Students	The use of communication media by migrant students for higher education to maintain transnational social networks and relationships.
Collin, Karsenti (2019)	Students	International students' use of technology before and after migration in the context of integration.
Leek, Rojek (2022)	Students, teachers, researchers and administrative staff	Digital learning within international online mobility.
Podgórska (2022)	Students	Research on the use of new technologies in communication by educational migrants in the context of the use of social networks.
Kukulska-Hulme (2019)	Projects and applications designed by migrants	Innovative projects and mobile language learning applications designed for migrants that students can also use.

Source: own study.

There is a lack of scientific publications that link the topic of migration with issues related to new technologies and crafts. Available studies focus, among other things, on analyzing the impact of digital transformation on job mobility. The results of Qiao and Ao's (2024) research suggest that digitalization can facilitate increased mobility of workers from rural areas, particularly in regions with lower levels of economic development. The use of modern technologies influences the structure of labor demand, leading to transformations in the required competencies and remuneration levels of individual employee groups. Consequently, technological progress can have both positive and negative impacts on migration patterns (Barišić et al., 2024).

The results of this study provide valuable insights into the professional aspirations and migration intentions of vocational school students in Poland. The findings indicate that although international mobility remains an important consideration, the majority of respondents currently envision their professional future within the domestic labour market. This tendency likely reflects both the improving economic conditions in Poland and the growing demand for skilled workers in sectors such as automotive services, gastronomy, and retail.

The predominance of technical and service-oriented profiles among respondents demonstrates that vocational education continues to fulfil its key role in preparing young people for practical, skill-based occupations. Automotive mechanics and hairdressing remain particularly popular fields, likely due to their relatively stable employment prospects and the ease of entering the job market. However, the limited representation of emerging professions such as those related to digital technologies, logistics, or renewable energy suggests that vocational curricula may not yet fully align with structural transformations occurring in the modern economy. Updating training programs to better reflect new market realities could therefore strengthen the relevance of vocational education.

Migration intentions reveal an interesting combination of moderate mobility and notable uncertainty. While only 12% of respondents expressed a clear desire to work abroad, almost half remained undecided. This level of ambiguity indicates that many young people are open to migration in principle but have not yet made firm decisions. Several factors may contribute to

this hesitation, including limited knowledge of foreign labour markets, language barriers, or the perception that working abroad entails greater preparation and financial risk. Similar findings have been reported in other studies of youth labour mobility, where migration intentions often remain aspirational rather than leading to concrete action.

The gender distribution confirms the persistence of traditional gender patterns in vocational education. Male students continue to dominate in technical and mechanical fields, while female students are concentrated in service-oriented and aesthetic professions. This division reflects enduring social norms and stereotypes concerning male and female occupations. Although overall gender parity has been achieved in vocational education enrolment, equality across occupational specializations remains limited. Addressing these imbalances may require targeted interventions in career counselling, mentorship, and public education to promote greater gender diversity across all vocational domains.

The considerable proportion of students who remain uncertain about their future employment plans suggests that career guidance and counselling services in vocational schools could be further developed. Early exposure to both domestic and international labour markets through internships, student exchange programs, or career fairs could help students make more informed career choices. Furthermore, initiatives that encourage entrepreneurship and self-employment may strengthen the confidence and independence of those still unsure whether to pursue careers locally or abroad.

Finally, the relatively low rate of declared migration intentions should not necessarily be interpreted as a lack of interest in mobility. Rather, it may reflect Poland's current socioeconomic stability and rising wage levels, which reduce the need for migration, particularly among low- and mid-skilled workers. Nonetheless, as European labour markets continue to evolve, future cohorts of vocational students may once again experience stronger migration pressures, especially in response to wage differentials or labour shortages abroad.

The high proportion of undecided responses is a limitation of this research. The large number of respondents who chose a neutral option or avoided expressing a clear opinion may result, for example, from limited knowledge of the issue being analysed or a low level of engagement with the topic. Therefore, some of the results obtained may reflect a lack of a clear position or uncertainty.

In conclusion, this study underscores both the strengths and challenges of vocational education in preparing young people for an increasingly dynamic labour market. While most students plan to remain in Poland, maintaining flexibility and awareness of international opportunities will be essential for their long-term employability. Promoting gender balance, modernizing vocational curricula to include emerging industries, and expanding access to career guidance can further enhance the readiness and adaptability of Poland's future vocational workforce.

6. Conclusion

The study provides an overview of the employment and migration intentions of vocational school students, revealing that most respondents plan to work in Poland while only a small proportion express definite plans to seek employment abroad. The results highlight the enduring popularity of traditional technical and service professions and the persistence of gendered occupational choices. Uncertainty among many respondents suggests the need for stronger vocational guidance and exposure to both domestic and international career pathways. Although migration is not currently a dominant goal, the openness of some students to mobility, especially toward nearby European countries, indicates potential for future international engagement.

Respondents generally recognized the importance of technological innovation for improving work efficiency and the attractiveness of craft professions. Exposure to or awareness of new technologies does not appear to have the only direct impact on students' migration decisions. This finding suggests that factors other than technological modernization, such as wage expectations, working conditions, or personal aspirations, may play a more decisive role in shaping the migration intentions of future craftspeople.

However, integrating modern tools, digital solutions, and innovative production techniques into vocational training can make local industries more attractive and competitive. By modernizing craftsmanship and aligning it with the demands of Industry 4.0, young professionals can pursue meaningful careers, professional development, and technological innovation within their home country, rather than abroad. To better prepare young people for evolving labour market demands, vocational education should focus on aligning training with emerging sectors, promoting gender balance across professions, and supporting informed decision-making about career and migration opportunities.

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COMMUNICATION CHOICES OF YOUNG ADULTS LIVING IN THE UPPER SILESIAN-ZAGŁĘBIE METROPOLIS RELATED TO COMPETENCE DEVELOPMENT IN THEIR LEISURE TIME

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Purpose: The aim of the article is to identify factors influencing the mobility of young adults living in the Upper Silesian-Zagłębie Metropolis (GZM) in relation to competence development during their free time not related to work and formal education. The study fills a research gap concerning patterns of leisure mobility and educational mobility.

Design/methodology/approach: The article presents the results of a questionnaire survey (CAWI) conducted in 2025 on a group of 500 young adults living in the GZM. The sample was selected using a quota method and reflected the age structure of the general population. The presented analysis focused on a group of 365 respondents who declared that they travelled in order to improve their competences in their leisure time.

Findings: The study identified factors influencing the choice of transport mode among young adults living in the GZM in connection with activities aimed at improving their competences in their free time.

Research limitations/implications: The limitation of the study comes mainly from the research assumptions – the study is based on respondents' declarations rather than observations of actual transport behaviour. The geographical scope, the specific nature of the area under study and the specific nature of the research group may influence the results obtained.

Practical implications: The results provide valuable guidance for public entities involved in planning sustainable urban mobility and transport policies for metropolitan areas.

Social implications: Understanding the factors that influence the transport decisions of metropolitan residents in relation to their leisure activities allows for better identification of areas requiring public intervention related to the implementation of sustainable urban mobility goals.

Originality/value: The article addresses the poorly understood area of transport choices related to competence development during free time unrelated to work and formal education. It provides original empirical data that allows us to identify patterns of leisure mobility related to competence development among young adults living in metropolitan areas.

Keywords: young adults, sustainable mobility, leisure mobility, competence development, Upper Silesian-Zagłębie Metropolis (GZM).

Category of the paper: Research paper.

1. Introduction

The European Union's approach to sustainable development as expressed in the European Green Deal, the requirements associated with the widespread digitisation of the economy, and the urgent need to strengthen the resilience of the European economy draw attention to the possibility of achieving synergistic effects because of implementing the concept of the so-called *twin transformation*. According to this concept, the transformation of the economy towards a digital and sustainable economy is a prerequisite for maintaining Europe's competitiveness (Muech et al., 2022). The implementation of the twin transformation requires a coherent approach to competence development (Tabares et al., 2025). It is necessary to provide training that enables various stakeholder groups to acquire the necessary digital competences to support sustainable development (Hofmann Trevisan, 2024). The scope of the competences required to support the implementation of the twin transformation goals is based on the *DigComp* (Cosgrove, Cachia, 2025) and *GreenComp* (Bianchi et al., 2022) competence frameworks adopted by the European Union. These competences can be acquired or improved through formal education (institutionalised, leading to recognised qualifications), non-formal education (alternative or complementary to formal education) and informal education (based on self-learning) (UNESCO Institute for Lifelong Learning, 2025).

Competence development through informal and non-formal forms of education often takes place during leisure time. Despite the popularity of distance learning, face-to-face and hybrid forms of education continue to play an important role, generating transport needs among people who choose to engage in such leisure activities. The increase in transport needs related to improving competences during free time from work and formal education generates increased external costs (social and environmental) of the functioning of transport systems. The accumulation of competence development services in central urban areas raises questions about the impact of mobility related to skills development during leisure time on the achievement of sustainable development and sustainable urban mobility policy goals.

The aim of this article is to identify the factors influencing the choice of transport by young adults living in the Upper Silesian-Zagłębie Metropolis (GZM) who travel in their leisure time for the purpose of competence development. In the presented study, the authors decided to focus on leisure mobility related to the improvement of skills by young adults. Young adults (aged 18-34) are a particularly active group in terms of competence development in their leisure time. This group is also characterised by the highest level of mobility and willingness to experiment with different means of transport, which makes it an interesting subject for research in the area of sustainable transport behaviour. The dynamically changing needs of the labour market resulting from the double transition may increase the mobility needs of the group under study, affecting the achievement of sustainable urban mobility goals.

2. Literature review

Making educational and career decisions in today's uncertain and complex world requires taking into account many factors, not only economic ones, but also technological changes, the digitalisation of the work environment and sustainable development. According to K. Nosek-Kozłowska (2025, p. 119), factors such as the need for self-fulfilment, career development, increased self-confidence and adaptation to new technologies play a key role.

For years, the European Union has been taking action to link sustainable development goals with digital challenges, and researchers point to digitalisation as one of the key factors for building the competitiveness of European enterprises, which also determines the achievement of climate goals in the EU (Czygżewska-Misztal, Cabańska, 2023, p. 109). It can be observed that there is a synergy effect between digital transformation and green transformation, i.e. the so-called "twin transition" (Rehman et al., 2023). The twin transition should be understood *as an economic and political approach focused on the simultaneous green and digital transformation of the economy as interdependent, interacting and inseparable processes. The combination of these two types of transformation allows for increasing the benefits of combining the implementation of digital technologies and the objectives of the European Green Deal (or, more broadly, sustainable development) and achieving the resilience of economies and societies* (Osiecka-Brzeska, 2025, p. 225).

Therefore, digital competence management is becoming one of the key tools for human resource management in companies operating in a knowledge-based economy. New types of jobs are emerging, requiring competences that we do not yet possess (European Commission, 2020a). Symela and Stępnikowski (2021) emphasise that as a society we face challenges such as personalised universal education, digital illiteracy and technological unemployment.

That is why it is so important to focus on the analysis of digital competences through the active and conscious participation of individuals, which guarantees personal and social development, and also counteracts various forms of digital exclusion and their further consequences (Ogonowska, Walecka-Rynduch, 2023, p. 632).

It can be noted that the European Union is not indifferent to activities related to improving citizens' competences. These activities have been undertaken for many years. However, in 2023, the European Declaration on Digital Rights and Principles for the Digital Decade was adopted, which places people at the centre of the digital transformation and helps to consolidate the framework within a set of common European values and principles. This declaration is reflected in the DigComp 3.0 guidelines, The Digital Competence Framework for Citizens with new examples of knowledge, skills and attitudes. It incorporates recent and emerging digital technological trends and their implications for digital competence, while maintaining the overall framework stability and technology neutrality (European Commission, 2026). In response to the need for change in education related to sustainable development,

the European Commission has introduced The European Sustainability Competence Framework – GreenComp. This programme focuses on improving competences for sustainable development, i.e. accepting the complex nature of sustainable development, visualising a sustainable future and taking action for sustainable development (GreenComp, 2026).

The above programmes are focused on various forms of education, so it is worth noting that, according to a report by the Central Statistical Office (2024, p. 41), formal education in Poland particularly concerns young people, among whom the share of those aged 18-24 (by 5.8 percentage points) and 25-29 (by 4.4 percentage points) has decreased compared to the previous survey conducted once every six years. As regards non-formal education, the level of participation decreased for almost all age groups between 18 and 69. However, there has been a significant increase in educational activity in the case of informal learning. This concerned all age groups, and in particular young people aged 18-24 (by 30.6 percentage points). As K. Nosek-Kozłowska (2025, p. 119), empirical data indicate the importance of non-formal education and self-initiated forms of learning, which is a development and update of classical theories, given the growing role of technology and micro-learning.

Both the DigComp and GreenComp competence frameworks provide a kind of roadmap for actions to support the population in the era of dual transformation. It is interesting to see what factors influence the choice of means of transport for various forms of competence development.

The concept of sustainable mobility was first used in European Community documents in *the Green Paper on the impact of Transport on the Environment - A Community strategy for "sustainable mobility"* (1992). The Green Paper pointed to the need to develop transport systems which, on the one hand, would effectively meet the transport needs of city dwellers and, on the other, would cease to generate excessive external costs in the form of environmental and social burdens. The literature on the subject indicates that achieving sustainable mobility requires a combination of three strategic approaches (Holden et al., 2020):

- efficiency strategies - requiring the implementation of efficient technologies that reduce the environmental impact of mobility, e.g. through the promotion of electromobility,
- change strategy - aiming to change existing travel patterns, e.g. through incentives to change the mode of transport,
- reduction strategy – reducing the number of journeys and shortening the distance travelled, e.g. by promoting remote forms of activity.

It should be noted that these approaches involve different challenges. The *Strategy for sustainable and smart mobility – European transport on the road to the future* (European Commission, 2020) identifies 10 flagship initiatives to increase the sustainability of mobility. Interestingly, all initiatives focus on technical aspects aimed at promoting and developing decarbonised transport technologies. The EU focuses primarily on technological issues in balancing mobility, while issues related to modal shifts or mobility reduction seem to be, at best, an additional effect of technological change. As indicated by the research of Holden

et al. (2019), this approach does not contribute to achieving the expected environmental effects to the desired extent, which makes it even more important to seek answers to questions about the factors influencing travellers' choice of mode of transport, not only in relation to obligatory mobility, but also optional mobility.

The paradigm of sustainable mobility is treated as an alternative to classical transport planning (Banister, 2008). In the classical approach, transport demand is treated as a derivative of other needs, while the concept of sustainable mobility requires considering that mobility itself can be a goal, especially if it is pursued during leisure time. The implementation of EU policy objectives in the area of sustainable mobility requires an understanding of the individual factors influencing transport behaviour decisions, including those relating to leisure mobility in the context of their environmental impact (Malekzadeh et al., 2025). It should be remembered that transport needs met by car (especially private cars), regardless of whether the journey is mandatory or optional, generate significant external costs, e.g. related to space occupancy, harmful emissions or congestion (Adamiak et al., 2016; Ceron, Dubois, 2005).

Mobility patterns may be related to lifestyle and demographic and social characteristics such as age, gender, level of education, family situation or financial status (Næss, 2006; Karpiński, Skrzypczak, 2025). The choice of mode of transport may be influenced by the spatial and temporal availability of mobility services, travel time and distance, the desire to maintain independence, or subjectively perceived convenience (Bina, Biassoni, 2023).

In the literature on the subject, leisure mobility is defined by excluding activities that generate the need to travel. Leisure mobility is therefore mobility that is not generated, for example, by work or formal education. Leisure mobility is a specific type of transport behaviour dependent on individual or group motives for spending free time (Toger et al., 2023). Due to its characteristics, leisure mobility is more difficult to predict and manage than obligatory mobility. This is due, among other things, to its non-routine and individualised nature (Ohnmacht et al., 2009).

Previous studies indicate that young adults are a social group whose needs are relatively poorly considered in transport planning processes, despite their characteristically high level of mobility (Porter, Turner, 2019). The authors of the report *Youth on the move: Young people and transport in the 21st century* (2024) point out that the transport choices of young adults are a combination of subjective factors (e.g. related to individual aspirations) and objective factors (e.g. availability and quality of infrastructure). Previous studies also show that despite the perception of young adults as more sensitive to environmental issues, paradoxically, when it comes to transport choices, they do not necessarily choose more sustainable forms of travel (Suchanek, Szmelter-Jarosz, 2019).

Taking into account the literature review, a research gap can be observed. Until now, authors have dealt with leisure mobility, but not in the context of travel aimed at improving competences. At the same time, it has been pointed out that the importance of non-formal education, also provided in face-to-face and hybrid forms, is growing, and therefore young

people need to use various means of transport to get to training sessions or courses. This article aims to identify the factors influencing the choice of transport by city dwellers, including young adults, related to improving their competences in their free time unrelated to work or formal education.

3. Methods

This article uses the results of a survey conducted in the second quarter of 2025 using the CAWI (Computer-Assisted Web Interview) method. The survey covered 500 people aged 18-34 living in the Upper Silesian-Zagłębie Metropolis. The selection of respondents was quota-based and reflected the age structure of the general population of young adults living in the GZM. The survey questionnaire, prepared as an original, proprietary tool, contained 27 substantive questions and 13 questions with socio-demographic characteristics of the respondents. The most important information about the respondents is presented in Table 1.

Table 1.

Structure of respondents in terms of key socio-demographic characteristics

Variable	Categories	%	Variable	Categories	%
Age	under 19	5.8	Monthly income per person in the household	up to 2,500	12.0
	19-24	26.8		2500-4500	37.8
	25-29	17.6		above 4500	36.6
	30-34	49.8		NA	13.6
Gender	Female	53.4	Place of residence [population]	over 100,000	40.6
	male	46.6		50-100 thousand	19.2
Education	Primary and vocational	15.6		10-50 thousand	19.4
	Secondary	47.2		below 10 thousand	20.8
	higher	37.2			

Source: authors' own work.

The analyses were based on respondents' answers, which can be treated as qualitative variables directly related to the questions asked. Moreover, an additional variable was created, taking into account the declared preferred mode of transport for competences development and the frequency of travel by different means of transport. In this way, each respondent was assigned to one of six groups:

1. most often travels on foot, by bicycle or scooter,
2. most often chooses public transport,
3. most often travels by car – as a driver or passenger,
4. travels by various means of transport, but predominantly by sustainable forms,
5. travels by various means of transport, without any mode being predominant,
6. generally, does not travel, as they mainly choose online training courses.

The main objective of the analysis was to identify the factors that significantly influence the choice of transport used by respondents to travel to various types of training and courses in their leisure time. Due to the scale of measurement of these variables, the chi-square statistic was selected for the analysis. The results were supplemented with the V-Cramer measure, allowing the strength of the examined relationship to be determined (Cramér, 1946). In addition, selected significant relationships were further explored using correspondence analysis (Greenacre, 2021). This analysis indicates the relationships between categories of variables, not just between the variables themselves. Its most important element is a correspondence map, which shows points representing the categories of the two variables under study. A close distance between points is interpreted as a connection between these categories. Unfortunately, a correspondence map can only be obtained when the number of categories for each variable is greater than 2. Otherwise, the results are interpreted using an auxiliary dendrogram (e.g., using Ward's hierarchical method (Ward, 1963)).

This article is of an applied nature. It does not discuss the mechanisms of the statistical methods used in detail, as this is not necessary for the interpretation of the results obtained. All analyses and calculations were performed using SPSS Statistics and R software.

Within the framework of this study, referring to the objectives of the article, the following research hypotheses were formulated:

- H1:** the choice of means of transport used by respondents to improve their competences in their free time unrelated work and formal education depends significantly on their age, income, household size, and the frequency and distance of their journeys.
- H2:** the choice of public transport as a means of travel for the purpose of improving competences in one's leisure time depends primarily on the availability and quality of transport services, including, among other things, the availability of a direct connection to the destination, the distance and travel time, and the costs incurred.
- H3:** the choice of a car as a means of transport for improving competences in leisure time unrelated to work and formal education depends primarily on the respondent's belief that public transport takes too long, runs too infrequently, and does not guarantee a comfortable journey.

The results of the analyses carried out to verify the above hypotheses. The interpretation of the results obtained, and the discussion are presented later in the article.

4. Results

Out of 500 participants in the study, i.e. young adults from the GZM, as many as 425 people have improved their competences over the last 3 years. Of this group, 365 people travelled to participate in courses, training and to supplement their competences, of which (Fig. 1):

- the largest subgroup (35.6%) consists of respondents who travel using various means of transport (without indicating a preferred form),
- 25.2% of young adults most often travel by car,
- a total of 39.2% of people travel using various forms of sustainable transport.

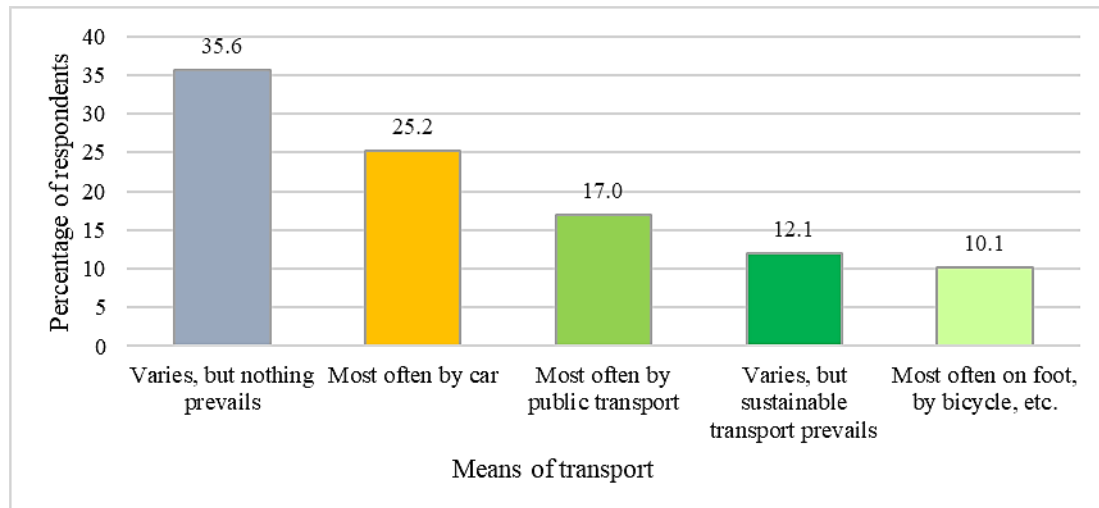


Figure 1. Distribution of respondents in terms of the most frequently used means of transport for travelling to improve their competences.

Source: authors' own work.

Due to the objective of the study, only the group of 365 people who improve their competences and do so at least partially in a stationary form were subjected to further analysis. We examined which socio-demographic characteristics of respondents and factors related to their travel have a significant impact on the choice of means of transport used by young adults from the GZM to travel to training courses. For this purpose, a chi-square test was performed, and Cramer's V measure was calculated (Table 2). Test probability values (p-values) lower than the accepted significance level of 0.05 indicate that five characteristics are significant: (1) possession of a monthly ticket and (2) discounts on public transport, (3) frequency of travel, (4) age, and (5) the respondent's primary occupation. The strength of this relationship is rather weak, as evidenced by the low V-Cramer's measure values (Table 2). Surprisingly, neither income, education, place of residence, nor the number of people living in the respondent's household have a significant impact on the preferred means of transport.

Table 2.

Chi-square test results and V-Cramer's measure values indicating factors that significantly and insignificantly influence the choice of means of transport

Factor	Results of the correlation analysis		
	χ^2	p	V
Possession of a monthly ticket	49.23	< 0.001	0.367
Having discounts on public transport	23.37	< 0.001	0.253
Frequency of travel	23.44	0.003	0.200
Age	38.03	< 0.001	0.186
Primary occupation	39.79	0.005	0.166
Place of departure	15.50	0.050	–

Cont. table 2.

Education	15.00	0.059	–
Monthly income	14.45	0.807	–
Number of persons in GD	14.30	0.282	–
Place of residence	13.82	0.312	–
Distance travelled	10.02	0.614	–
Gender	4.41	0.353	–

Source: authors' own work.

To further explore the results obtained, correspondence analysis was performed for the indicated significant relationships, and the relationships between the points representing the categories of the examined characteristics were interpreted. As already mentioned, when the number of categories is no greater than 2 (which is the case for the variables *Possession of a monthly ticket* and *Possession of public transport discounts*), the interpretation of the results can only be based on an auxiliary dendrogram.

It is not surprising that respondents who use public transport most often and, in general, sustainable transport, usually have a monthly ticket and discounts on public transport. Other people generally choose cars or various means of transport that are not predominantly sustainable (Figs. 2a and 2b).

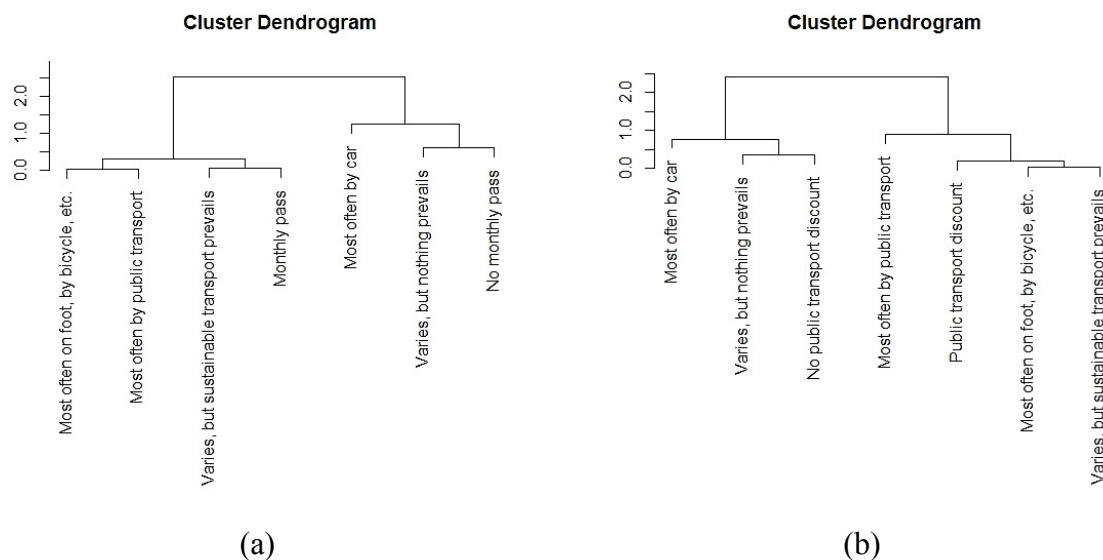


Figure 2. Auxiliary dendrograms showing the links between the most frequently chosen means of transport and the possession of (a) a monthly ticket and (b) discounts on public transport.

Source: authors' own work.

Furthermore, it can be observed that (Fig. 3a):

- people who travel frequently and very frequently to improve their competences most often do so on foot or by bicycle or scooter, although some respondents also choose various forms of transport, with sustainable transport predominating,
- young adults who travel sporadically to improve their competences generally use cars, but also other means of transport, with no clear preference for any particular form,
- respondents who travel rarely for training and courses most often use public transport.

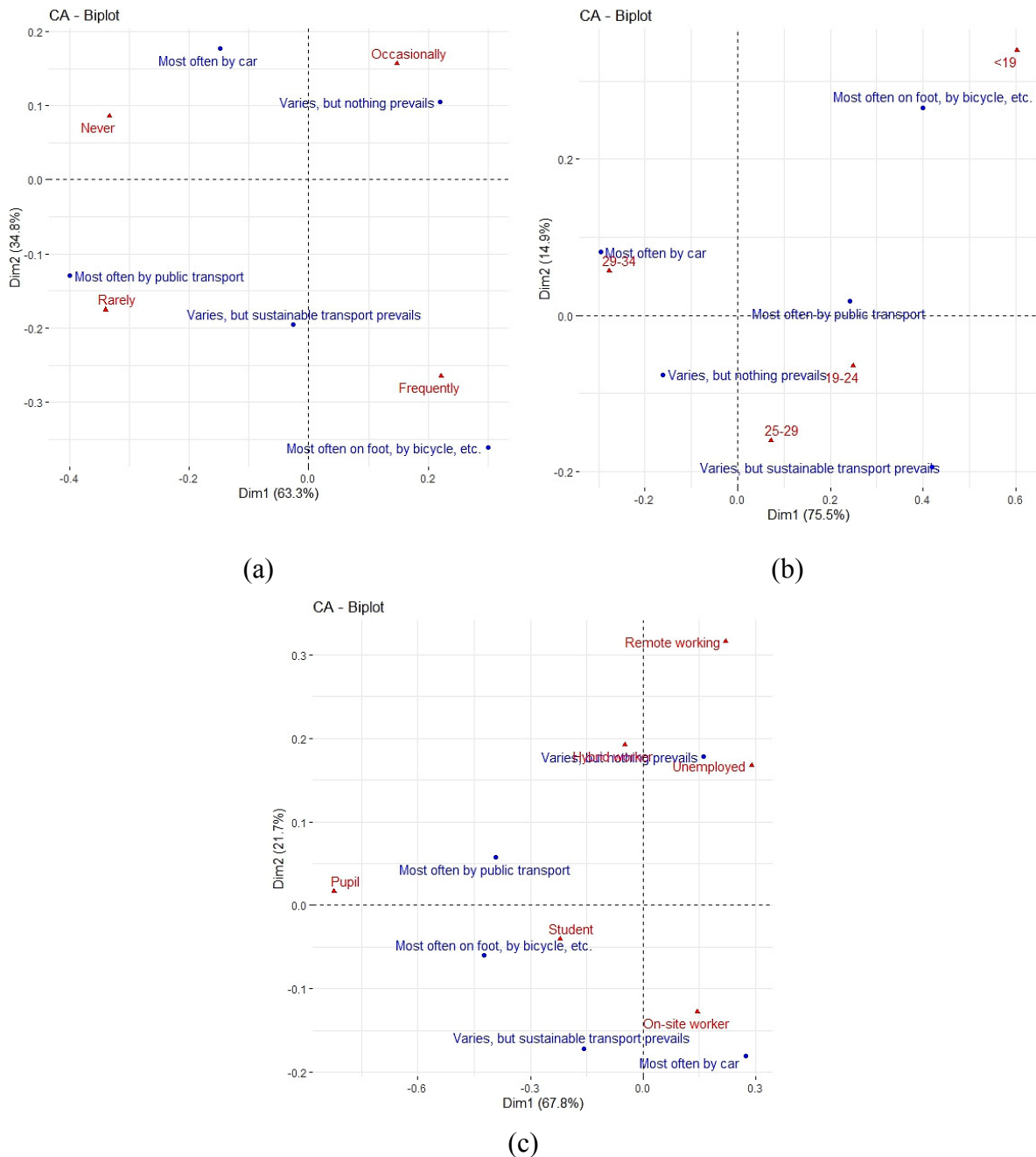


Figure 3. Correspondence maps showing the relationships between the most frequently chosen mode of transport and (a) travel frequency, (b) age, and (c) the respondent's primary occupation¹.

Source: authors' own work.

The relationships visible in the other correspondence maps (Figs. 3b and 3c) indicate that:

- the youngest respondents, under the age of 19, most often travel on foot, by bicycle or by scooter to improve their competences,
- people aged 19-24 generally choose public transport,

¹ Dim1 and Dim2 create a new coordinate system that was created during the execution of the correspondence analysis algorithm.

- this is also confirmed by the observation that travelling by public transport, on foot, by bicycle or by scooter is characteristic of students and pupils,
- people aged 25-29 use various means of transport to get around,
- the oldest people in this group (aged 30-34) most often travel to courses and training sessions by car,
- young adults working in an office also prefer to travel by car, although some people in this group sometimes choose other means of transport, predominantly sustainable forms of transport,
- respondents who work remotely, in a hybrid mode, and the unemployed use various means of transport, with no clear preference for any particular form.

The final stage of the study was to examine the factors that have a significant impact on the choice of public transport and cars as a means of transport for the purpose of improving competences. Once again, chi-square tests were performed and V-Cramer's measures were calculated. The results are presented in Tables 3 and 4.

Table 3.

Chi-square test results and V-Cramer's measure values indicating factors that significantly and insignificantly influence the choice of public transport for the purpose of travelling to improve competences

Factor	Results of the correlation analysis		
	χ^2	p	V
No car	37.06	< 0.001	0.247
Ability to reach the designated location by public transport	19.15	0.014	0.177
Problem with parking space	15.95	0.043	0.162
Travelling to improve competences, only short distances	10.84	0.211	–
Convenience of travelling by public transport	9.91	0.272	–
Ability to arrive on time using public transport	9.41	0.309	–
Public transport is more environmentally friendly	8.30	0.405	–
The public transport offer is adequate for the respondent's needs	7.91	0.443	–
Travelling by car is too expensive	7.49	0.485	–
Another member of the household uses the car	5.48	0.705	–
Public transport services are attractive	5.03	0.754	–
The problem of congested streets	3.07	0.930	–

Source: authors' own work.

In summary, the choice of public transport as a means of travelling to training courses and classes depends significantly on three factors: (1) whether the respondent owns a car, (2) the possibility of reaching the destination by public transport, and (3) the availability of parking spaces.

Table 4.

Chi-square test results and V-Cramer's measure values indicating factors that significantly and insignificantly influence the choice of a car for travelling to improve competences

Factor	Results of the correlation analysis		
	χ^2	p	V
Car ownership	30.20	<0.001	0.300
Travelling by public transport takes too long	28.13	< 0.001	0.205
Public transport runs too infrequently	24.46	0.002	0.191
Public transport does not guarantee comfortable travel.	19.95	0.011	0.172
Travelling by car is cheaper	19.05	0.015	0.168
Public transport vehicles are in poor technical condition	12.70	0.123	–
No direct public transport connections	11.94	0.154	–
Travelling too far	10.40	0.238	–
Lack of safety on public transport	8.71	0.367	–
Lack of public transport connections	7.89	0.445	–
Uncertainty about reaching the destination	5.84	0.665	–
Uncertainty about arriving on time	5.76	0.674	–

Source: authors' own work.

In turn, the choice of a car as a means of transport for the purpose of improving competences is significantly influenced by (1) car ownership and the belief that (2) travelling by public transport takes too long, and moreover, that public transport (3) runs too infrequently, (4) does not guarantee comfortable travel and (5) is more expensive than travelling by car.

5. Discussion

The study provides unique empirical data on the transport choices of young adults living in the GZM in relation to improving their competences in their leisure time. The results, set in the context of previous research on the subject, allow for a deeper understanding of the mechanisms shaping this type of mobility in metropolitan areas. The results confirm that young adults are not a homogeneous group (Rek-Woźniak, 2016, p. 89).

The declarations of respondents who use various means of transport without a clear preference (35.6%) may indicate a pragmatic approach to mobility, described by the International Transport Forum (2024) as characteristic of contemporary young people.

The clear differentiation of mobility patterns according to age confirms Næss's (2006) findings on the impact of this characteristic on transport choices. The transition observed in the study from active mobility (under 19 years of age) to the dominance of public transport (19-24 years of age) to a preference for cars (30-34 years of age) can be interpreted in the context of changing economic opportunities and life situations. This is consistent with the concept of Karpiński & Skrzypczak (2025), who point to the impact of the stage of life on leisure mobility patterns. Surprisingly, our study did not confirm a significant impact on the choice of transport mode of factors such as income, education, place of residence and travel distances. The reason

for this may be the relatively high homogeneity of the group in terms of the above-mentioned characteristics, as:

- respondents declared a relatively high level of income (73.2% of respondents indicated that the income per person in their household exceeded PLN 3,500, with approximately 70% indicating that their household consisted of no more than 3 people);
- the researched group is dominated by people with secondary and higher education (almost 85% in total);
- the characteristics of the spatial and temporal availability of public transport services in the GZM area are relatively uniform (InfoGZM, 2026).

The results for people aged 19-24 are particularly interesting, as they predominantly declare that they use public transport. This result corresponds with the observations of Bin & Biassoni (2023), indicating that people under the age of 26 are more likely to use public transport than other age groups. The dominance of car preference in the oldest age group (30-34 years) can be interpreted through the prism of the concept of life-course mobility - professional stability, living with a partner or parenthood may be a pre-condition for a greater tendency to use a car (Janke et al., 2021). The impact of the concept of life-course mobility on transport decisions is also confirmed by the results of the presented research, which indicate that the respondent's primary occupation is an important factor influencing the choice of transport mode.

The significant impact of having a monthly ticket and access to discounts on the choice of public transport may indicate that tariff policy can influence the timing of public transport passengers' transition to car use, but does not necessarily shape permanent transport attitudes, which again is consistent with research on the concept of life-course mobility.

An analysis of the factors influencing the choice of car reveals an interesting way in which respondents perceive public transport. Those who declare that they use public transport for leisure travel related to improving their competences indicate that the main barriers to choosing public transport are excessive travel time, infrequent services, and lack of comfort, which may indicate that public transport services in the studied metropolis are perceived as not meeting the quality criteria of potential travellers. This result corresponds with the concept of three strategies for achieving sustainable mobility presented by Holden et al. (2020) – it shows that the strategy of technological efficiency alone, manifested in rolling stock and ICT investments, is insufficient, and that the authorities responsible for shaping sustainable urban mobility policy should implement change or reduction strategy tools to a greater extent.

Also interesting is the statement by some respondents that travelling by car is cheaper than travelling by public transport. This result may reflect the difficulty of estimating the total costs of car use.

The significant correlation between travel frequency and choice of transport mode provides interesting insights in the context of the theory of transport habit formation.

6. Summary

The study allowed for the verification of the research hypotheses. The first hypothesis was partially confirmed – age and travel frequency significantly influence the choice of transport mode, but income, number of people in the household and travel distances are not significant factors influencing the choice of transport mode among young adults living in the GZM in connection with improving their competences. The second hypothesis, concerning factors influencing the choice of public transport, was also partially confirmed – the lack of a car, the possibility of reaching the destination and the availability of parking spaces proved to be key factors. However, contrary to expectations, the importance of direct accessibility of connections or travel time was not confirmed. The third hypothesis was fully confirmed – the choice of a car significantly depends on the perception of public transport as consuming too much time, running too infrequently and not providing adequate travel comfort.

From a theoretical perspective, the study contributes to the development of knowledge about leisure mobility. Mobility related to improving competences occupies an interesting position between strictly recreational mobility and mobility related to formal education, combining elements of both types. In the context of the sustainable mobility paradigm, the results indicate the limited effectiveness of a purely technological approach and confirm the need to take behavioural and qualitative factors into account in transport system planning.

The practical implications of the study mainly concern the planning of transport and education policies at the metropolitan level. The results suggest the need to:

- differentiating mobility balancing tools according to the age group of young adults, with particular emphasis on the specific needs of people aged 25-34 who are in a transitional phase between education and professional stability,
- improving public perception of public transport, not only through technological investments, but also by better tailoring the offer to the requirements of potential passengers.

The methodology of the study, based on a survey of respondents, has limitations related to the possible discrepancy between declared and actual behaviour. The nature of the study, which covers only one period, does not allow for the capture of changes in transport behaviour over time. It would be particularly interesting to examine how transitions between stages of life entail changes in leisure mobility patterns. Extending the study to other metropolitan areas would allow for an assessment of the specificity of the GZM in comparison with other agglomerations and the identification of universal and contextual factors influencing transport choices. It would be particularly interesting to compare the results from areas with different spatial structures (monocentric vs. polycentric) and different levels of public transport system development.

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THE IMPACT OF CHANGES IN THE EMPLOYMENT STRUCTURE ON MACROECONOMICS INDICATORS IN POLAND IN 2009-2024

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Purpose: The aim of this article is to assess the impact of changes in the employment structure on key macroeconomic indicators in Poland over the period 2009-2024.

Design/methodology/approach: The study is based on econometric models estimated using the classical ordinary least squares method, employing annual data from Statistics Poland (GUS), Eurostat and the National Bank of Poland (NBP) for the years 2009-2024. The analysis examines the influence of sectoral employment shares on major macroeconomic variables such as GDP, CPI inflation, average monthly wages, the unemployment rate, the NBP reference rate, and the trade balance.

Findings: The results indicate that an increase in employment shares in high-productivity sectors (including sectors 1, 3, 9, and 10) supported GDP growth and higher average wages. In contrast, sectors characterised by low cost elasticity or limited productivity had a dampening effect on economic growth or contributed to inflationary pressures. The CPI inflation models showed that employment in sectors 1, 7, and 15 increased inflationary pressure, whereas sector 13 had a disinflationary effect. Changes in employment shares in sectors 8, 9, and 16 contributed to a decline in the unemployment rate, while the impact on the trade balance varied depending on cost structures and the trade characteristics of each sector.

Research limitations/implications: The analysis is limited to data for Poland, which restricts the generalisability of the findings to other countries.

Practical implications: The conclusions may be useful for public institutions in designing employment strategies, education policies, and policies supporting digitalisation and innovation. The sectoral structure of employment emerges as a crucial factor determining macroeconomic stability.

Social implications: Sectoral shifts affect living standards, wages, employment stability, and price levels. The results may support public debate on labour market transformation, regional disparities, and the need for skill adaptation in the context of digitalisation and automation.

Originality/value: The article provides a comprehensive analysis of sectoral shifts in employment and their simultaneous impact on multiple key macroeconomic indicators. It identifies the sectors most important for Poland's economic stability and highlights directions for economic policy based on econometric modelling results.

Keywords: employment structure; macroeconomic indicators; developmental tendency models; inflation; GDP g.

Category of the paper: Research paper.

1. Introduction

Employment structure is a main element of the functioning of the economy, and its changes reflect the transformation, modernization, and cyclical processes occurring both in the labor market and across the real economy (Niewiadomska, 2010). In Poland, the years 2009-2024 were a period of exceptionally dynamic transformation, encompassing the consequences of the global financial crisis, the gradual recovery of economic potential, the rapid growth of service sectors, and the disruptions resulting from the COVID-19 pandemic and strong inflationary pressures in 2021-2023. These changes had a direct impact on basic macroeconomic indicators, such as CPI inflation, unemployment rate and the level of economic activity of the population.

Analyzing the relationship between changes in employment structure and macroeconomic indicators allows for a better understanding of the mechanisms underlying the contemporary Polish economy. An increase in employment in certain sectors can reinforce inflationary pressures through demand and cost effects, while the development of other sectors can contribute to lower unemployment or stabilize prices. These relationships are particularly important in the context of technological change, digitalization, and the growing role of knowledge-intensive sectors in the economic structure.

Monitoring macroeconomic indicators is crucial both for the government in planning fiscal and monetary policy and for investors in making financial decisions. The study's results can be a valuable source of knowledge for economic policymakers, labor market institutions, and macroeconomic forecasters. They allow for an understanding of how structural changes in employment impact economic development and what labor market policies can foster macroeconomic balance in Poland.

Many researchers also emphasize the benefits of structural changes not only for economic growth, but also for society and the natural environment (Cyrek, 2024; Bondarev, Greiner, 2022; Kong et al., 2024).

The aim of this article is to examine the impact of changes in the employment structure on key macroeconomic indicators in Poland in the years 2009-2024, with particular emphasis on economic growth, labor market conditions, as well as identifying changes in the strength and direction of these relationships during periods of economic shocks. The study focuses on identifying causal relationships between the progressing tertiarization of the economy and such measures as the growth rate of Gross Domestic Product (GDP), the unemployment rate, the level of labor productivity, and wage dispersion.

The study employs econometric methods, including linear models (development trend models) based on parameter estimation using the classical ordinary least squares (OLS) method, allowing for the identification of both the direction and the strength of relationships between the analyzed variables. The analysis seeks to address the following research questions:

- how did the employment structure in Poland change in the years 2009–2024?
- did changes in the employment structure have a significant impact on selected macroeconomic indicators in Poland?
- which segments of the labor market contributed most strongly to increasing inflationary pressure, and which had a stabilizing potential or supported improvements in labor market conditions?

The achievement of the research objective and answers to the above questions led to the formulation of the following research hypotheses:

H1: Changes in the employment structure in Poland in the years 2009-2024 had a significant impact on economic growth measured by GDP.

H2: An increase in the share of employment in sectors with higher productivity was associated with a decline in unemployment and an increase in labor productivity.

The study covered selected macroeconomic indicators for Poland and employment shares in 17 sectors in Poland between 2009 and 2024. Data came from the Central Statistical Office's BDL (Local Data Banking Data) and EuroStat. The study considered the following macroeconomic indicators: GDP per capita, average monthly gross wages, CPI inflation, registered unemployment rate, reference rate, trade balance, industrial production, and retail sales.

Employment shares came from the following sectors: Legal and accounting activities (S1), Services to buildings and landscape activities (S2), Public administration and defence; compulsory social security (S3), Education (S4), Human health activities (S5), Residential care activities (S6), Crop and animal production, hunting and related service activities (S7), Manufacture of fabricated metal products, except machinery and equipment (S8), Construction of buildings (S9), Specialised construction activities (S10), Wholesale and retail trade and repair of motor vehicles and motorcycles (S11), Wholesale trade, except of motor vehicles and motorcycles (S12), Retail trade, except of motor vehicles and motorcycles (S13), Land transport and transport via pipelines (S14), Food and beverage service activities (S15), Computer programming, consultancy and related activities (S16), Financial service activities, except insurance and pension funding (S17).

The GRETL program and an Excel spreadsheet were used to perform the necessary calculations.

2. Employment structure and economic processes

The relationship between employment structure and macroeconomic processes is widely analyzed in the economic literature, both theoretically and empirically. Classical approaches to structural change in the economy were pioneered by Fisher (1939), Clark (1940), and Kuznets (1966), who argued that employment shifts from agricultural to industrial and service sectors are a natural element of long-term economic development. These studies emphasize that these changes affect not only productivity levels but also macroeconomic stability, price dynamics, and labor market equilibrium.

Mortensen and Pissarides (1994) emphasize the role of structural matching between labor supply and demand from economic sectors. Their empirical research shows that changes in employment structure can lead to structural unemployment or, conversely - to its reduction if employment in expanding sectors increases. The main result of this article is that the unemployment rate depends on the balance between the rate of job creation and the rate of job destruction. Both processes are influenced by factors such as productivity, unemployment benefit levels, employment costs, production technologies, and demand and supply shocks. Their models help explain why unemployment increases during recessions (increased job destruction) and why it does not immediately decline after an economic recovery (lags in matching processes).

Baumol (1967) introduced the concept of unbalanced growth, showing that different sectors of the economy grow at different rates. "Dynamic" sectors (e.g., industry) have high productivity, while "stagnant" sectors (e.g., low-capital-intensity services) grow more slowly. This imbalance leads to employment shifts, rising costs in services, and potential inflationary pressures. Baumol argues that structural changes are a natural part of economic development and must be taken into account in economic policy planning.

Ngai and Pissarides (2007) present a formal multisectoral model that describes how economic development leads to employment shifts between sectors. In the model, the share of agriculture declines, the share of industry increases, and later the share of services increases. These shifts result from differences in sectoral productivity and consumer preferences. The study shows that structural changes can influence economic growth, wage dynamics, and inflationary pressures.

Cost-determination models of inflation indicate that sectoral changes in employment can influence wage pressures, especially in industries with high labor intensity or limited supply elasticity (Layard, Nickell, Jackman, 2005). Research by the OECD (2020) and the International Monetary Fund (IMF, 2021) shows that shifts in employment toward service sectors are often associated with higher price dynamics due to the greater role of cost factors and imperfect competition. In turn, sectoral shifts toward more productive industries can have a disinflationary effect through technological effects and efficiency improvements (Bils, Chang, 2000).

In the Polish labor market, researchers point to the increasing employment in the service sector of the economy, the growing importance of knowledge-intensive sectors, and the changing structure of labor demand influenced by automation and digitization. Empirical studies indicate that sectoral changes in Poland between 2010 and 2020 had a significant impact on the decline in unemployment and stabilization of the labor market, although they could also have contributed to increased inflationary pressure in sectors with low cost elasticity (Balcerowicz-Szkutnik, 2016; Kotlorz, Skórska, 2013; NBP, 2020).

3. Employment structure in Poland in 2009-2024

Changes in the employment structure in Poland in the years 2009-2024 were characterized by a progressive increase in employment in the service sector and a decrease in employment in agriculture (Balcerowicz-Szkutnik, 2016), which had a significant positive impact on key macroeconomic indicators such as GDP, labor productivity and unemployment rate.

Between 2009 and 2024, employment rates in Poland showed a significant, steady upward trend (Fig. 1). Despite global economic fluctuations (pandemic, war in Ukraine), the Polish labor market demonstrated considerable resilience: employment rates increased, while the unemployment rate decreased. According to data from the Central Statistical Office (GUS), the female employment rate increased from approximately 51% in 2009 to approximately 67% in 2024, indicating not only the country's improving economic situation but also the growing professional activity of Polish women. The male employment rate also increased, remaining significantly higher than the female employment rate. This is a consistent trend in the Polish labor market – men constitute the majority of employed people in Poland. During the analyzed period, the gap between the male and female employment rates decreased from 11.9 percentage points in 2009 to 10.6 percentage points in 2024, with the largest differences of 13.6 percentage points and 13.8 percentage points recorded in 2019 and 2020, respectively.



Figure 1. Employment rates in Poland in 2009-2024.

Detailed employment shares in Poland in individual sectors according to the EuroStat classification in the years 2009-2024 are presented in Figure 2.

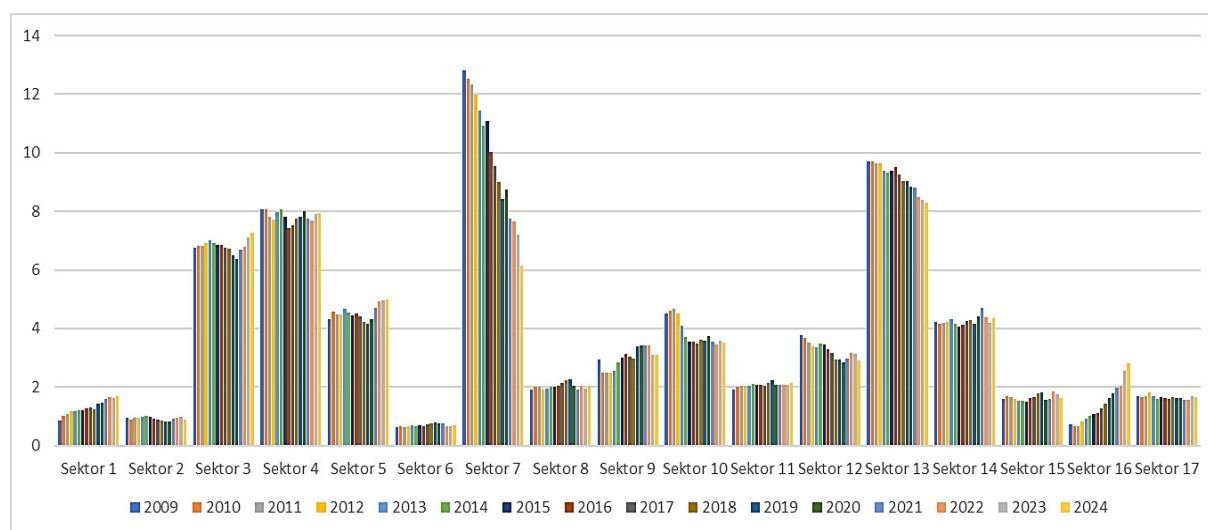


Figure 2. Employment shares in sectors in Poland in 2009-2024.

Despite a persistent downward trend during the period under review, the largest employment shares were recorded in sector 7 (Crop and animal production, hunting, and related service activities) between 2009 and 2017, followed by sector 13 (Retail trade, except for motor vehicles and motorcycles) between 2018 and 2024. The dominance of sector 7 in the initial period of the study shows that agriculture was and still is (ranked 4th in 2024) a significant employer. The shift in leadership in 2018 to the retail sector is the result of ongoing mechanization and increased productivity in agriculture, which is shifting the workforce to other sectors of the economy. The dominant position of sector 13 confirms that Poland has become a consumer- and service-oriented economy. The largest employment shares were

recorded in sectors 4 (Education), 3 (Public administration and defense; compulsory social security), 5 (Human health activities), 14 (Land transport and transport via pipelines), and 10 (Specialized construction activities). The consistently high employment levels in sectors 3, 4, and 5 indicate extensive public and social services. A significant increase in employment was recorded in sector 16 (Computer programming, consultancy, and related activities), from 0.71% in 2009 to 2.81% in 2024. The dynamic development of the IT industry in Poland demonstrates that this sector has become a driving force for the economy and service exports. Sector 1 (Legal and accounting activities) also saw a steady increase in employment, indicating the growing bureaucracy associated with legal regulations and reporting requirements.

4. Macroeconomic indicators of Poland in 2009-2024

The main macroeconomic indicators describe the state and dynamics of the national economy, and their analysis allows for the assessment of its condition and development potential. Between 2009 and 2024, Poland experienced significant economic growth, characterized by steady GDP growth (with the exception of the pandemic year of 2020), a decline in unemployment to record lows, and periods of elevated inflation, particularly in 2022-2024. Figure 3 presents the dynamics of GDP and selected macroeconomic indicators. Due to the scale of the values, a secondary axis (right-hand side of the chart) was used for the indicators unemployment rate, reference rate, and average monthly earnings.

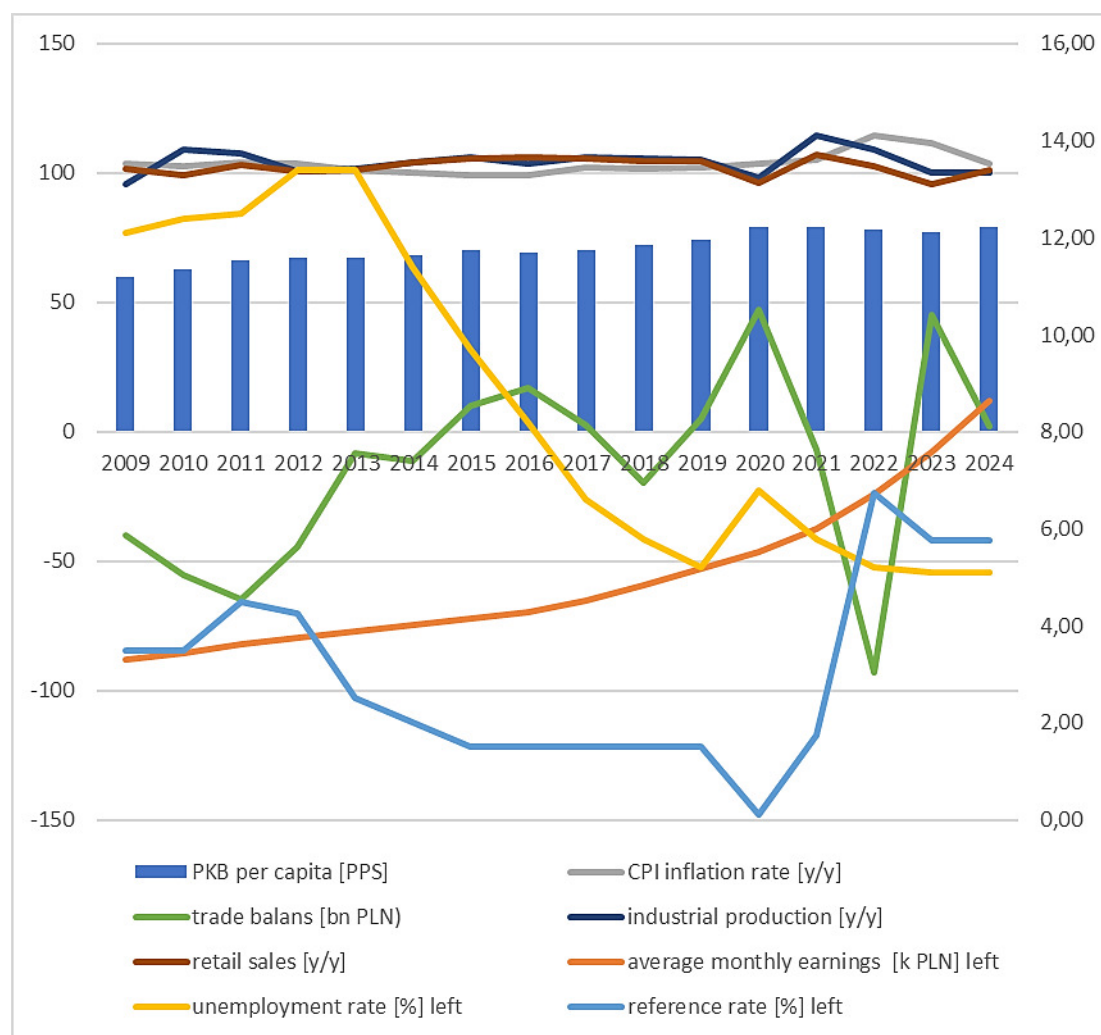


Figure 3. Macroeconomic indicators of Poland in 2009-2024.

Based on the data presented in Figure 1, it can be seen that GDP per capita in PPS (Polish Public Procurement Standards) steadily increased during the period under review. The impressive GDP growth, from 60% of the EU average in 2009 to nearly 80% of the EU average, indicates a real increase in the affluence of Polish society and its catching up with the EU average. The average annual CPI in Poland between 2009 and 2024 was characterized by significant fluctuations. Deflation was recorded in 2015 and 2016, leading to a decline in the overall price level. In subsequent years, inflation gradually increased, reaching a peak of 14.4% in 2022, driven by global factors such as the Covid-19 pandemic, the war in Ukraine, and the energy crisis. In 2024, the price growth rate slowed, reaching an average annual CPI of 3.6%. Between 2009 and 2024, the largest increase (260.31%) was recorded in the average monthly salary. This value increased from PLN 3,315.38 in 2009 to PLN 8,630.27. The highest wage growth, driven by high inflation and the labor market situation, was recorded between 2022 and 2024, reaching a year-on-year growth rate of 11.7%-13.6%. The unemployment rate experienced the largest downward trend during the period under review. This indicator dropped from 11.5% in 2009, peaking at 13.8% in 2013, to 5.1% in 2024. According to Eurostat data, in 2024, Poland had the lowest unemployment rate in the EU. In the first years of the period

under review, Poland recorded a negative trade balance. Since 2015, it has periodically recorded a trade surplus, which has been crucial for economic development. However, in 2022, the trade balance sharply deteriorated, mainly due to high prices of imported energy resources. In 2023-2024, a positive balance was restored, confirming the resilience of Polish exports. From 2009 to 2024, both industrial production and retail sales in Poland showed an upward trend. After declines in both in 2009, a period of stable and strong growth was observed (2010-2019), with retail sales often growing faster than GDP. In 2020, there was a slowdown due to the Covid-19 pandemic. In 2021, industrial production recorded record growth (14.7%). 2023 saw a slight decline in production, while retail sales slowed significantly due to high inflation affecting consumer purchasing power. However, data from 2024 indicate a return to moderate growth in both macroeconomic indicators. The National Bank of Poland (NBP) reference rate changed significantly between 2009 and 2024, reflecting the country's economic situation and the decisions of the Monetary Policy Council (MPC). After the global financial crisis, interest rates remained relatively low at 3.5%, gradually rising to 4.5% in 2010-2011. A series of interest rate cuts occurred between 2012 and 2015. In 2015, the reference rate reached a historic low of 1.5% and remained at that level until March 2020. In response to the pandemic-induced crisis, the Monetary Policy Council (MPC) cut interest rates three times, bringing the reference rate to a record low of 0.1% in May 2020. In 2021-2022, amid rising inflation, a cycle of interest rate increases occurred. The reference rate rose to 6.75% and remained at that level until September 2023, when the National Bank of Poland (NBP) lowered it by 0.75 percentage points and then by 0.25 percentage points.

5. Models of Developmental Tendency

Models of developmental tendency are one of the main classes of econometric models used to describe changes in a dependent variable using an explanatory variable, which is time. These models are also used for forecasting economic phenomena described by time series. Generally, a trend model can be written as (Cieślak, 2011):

$$y_t = f(t) + \varepsilon_t, \text{ (additive model)} \quad (1)$$

$$y_t = f(t) \cdot \varepsilon_t, \text{ (multiplicative model)} \quad (2)$$

where:

y_t is the forecasted variable at time t ,

$f(t)$ is a time function that analytically describes the given phenomenon,

ε_t is a random variable for which the expected value is 0 (additive model) or 1 (multiplicative model), and its variance is finite,

$t = 1, 2, \dots, n$.

The analytical form of the trend function can be chosen in various ways and can take different forms depending on the nature of the forecasted variable. For this purpose, a graphical analysis of the time series is performed, and based on it, the nature of the regularities of changes in the phenomenon under study is determined. The choice of the appropriate analytical form of the trend function is a matter of intuition and the researcher's economic knowledge (Stanisz, 1993).

In the next stage, the model is verified. The selection of an appropriate model consistent with empirical data is made based on: the coefficient of determination, the assessment of the significance of the model's structural parameters (t-Student test), the autocorrelation of model residuals (Lagrange multiplier test), the heteroscedasticity of model residuals (White's test), and the normality of the distribution of residuals (Jarque-Bera test). In the final stage, the verified model of developmental tendency is used for prediction, which involves extrapolating the trend function (Cieślak, 2011).

6. The impact of employment on macroeconomic indicators

For selected macroeconomic indicators, development trend models were constructed in the form of:

$$Y_t = \alpha_0 + \sum_{i=1}^{17} \alpha_i X_{i_t}$$

where:

Y_t - macroeconomic indicator,

X_{i_t} - share of employment in the i-th sector,

α_i - structural parameters of the model.

Based on time series of selected macroeconomic indicators and employment shares in selected sectors for the 2009-2024 period, the following development trend models were derived. The models were positively verified in terms of the significance of structural parameters, assessment of the model fit, normality of the random component distribution, homoscedasticity of residuals, and first-order autocorrelation.

The econometric model describing the impact of changes in the employment structure on the value of GDP in the years 2009-2024 is as follow:

$$Y_{PKB} = 71,82 + 19,97X_1 + 3,48X_7 - 13,14X_{12} \mp 6,81X_{16} - 16,98X_{17}, R^2 = 0,9822$$

Changes in the employment share in sector 1 had the greatest impact on GDP growth. A 1 percentage point increase in the employment share in sector 1 resulted in a 19.97 PPS increase in GDP, *ceteris paribus*. An increase in the employment share in sector 16 (GDP increase by 6.81 PPS) and in sector 7 (GDP increase by 3.48 PPS) also had a positive impact on GDP, however, the impact of sector 1 was much stronger than that of sectors 16 and 7. The employment shares in sectors 12 and 17 had a negative impact on GDP during the analyzed period, with a 1 percentage point increase in the employment share in sector 17 resulting in a 16.98 PPS decrease in GDP, while in sector 12 it resulted in a 13.14 PPS decrease in GDP. The above model explains 98.22% of the variability in GDP, which indicates a very good fit.

The model describing the impact of changes in employment shares on the CPI inflation rate is expressed by the formula:

$$Y_{CPI} = 127,30 + 18,13X_1 + 4,78X_7 - 14,57X_{13} + 23,62X_{15}, R^2 = 0,8357$$

The above model indicates that changes in the employment shares in sectors 1, 7, 13, and 15 have a significant impact on the CPI inflation rate. Changes in the employment shares in sectors 1, 7, and 15 have a pro-inflationary effect, with employment in sector 15 having the strongest impact. A 1 percentage point increase in the employment share in sector 15 increases the CPI by 23.62 points. Conversely, changes in employment in sector 13 by 1 percentage point have a counterinflationary effect, lowering the CPI while the employment share increases by 14.57 points.

Average monthly earnings model for characters:

$$Y_{earnings} = 1517,97 + 2023,96X_3 - 424,06X_7 + 1018,48X_9 + 1054,36X_{10} - 1451,51X_{13}, R^2 = 0,9893$$

The model was characterized by the largest number of sectors in which the employment share had a statistically significant impact on the value of the dependent variable. Based on the above model, it can be concluded that during the analyzed period, average monthly wages increased with the increase in the employment share in sectors 3, 10, and 9, and decreased with the increase in employment in sectors 13 and 7. Sector 3 had the largest positive impact on average wages: an increase in the employment share in this sector resulted in a PLN 2,023.96 increase in wages, followed by an increase in employment in sector 10 by PLN 1,054.36, and in sector 9 by PLN 1,018.48. The increase in the employment share in sectors 7 and 13 had a negative impact on the value of the average monthly wage.

The reference rate model of the form

$$Y_{reference\ rate} = 0,3344 - 0,3136X_6 - 0,0212X_{13} + 0,0678X_{15}, R^2 = 0,8155$$

indicates that changes in employment in sector 6 had the greatest impact on the change in the reference rate. A 1 percentage point increase in employment in this sector contributed to a 0.3136 percentage point decrease in reference rates. Similarly, an increase in employment in sector 13 resulted in a 0.0212 percentage point decrease in reference rates. Changes in sector 15 were positively correlated with the reference rate. A 1 percentage point increase in employment in sector 15 contributed to a 0.0678 percentage point increase in reference rates.

The model describing changes in the unemployment rate is of the form:

$$Y_{unemployment\ rate} = 1,44 - 0,10X_8 - 0,04X_9 - 0,03X_{16}, R^2 = 0,9455$$

Based on the above model, it can be seen that a 1% increase in the employment shares in sectors 8, 9, and 16, respectively, leads to a reduction in the unemployment rate by 0.10 percentage points, 0.04 percentage points, and 0.03 percentage points, respectively, which is a positive phenomenon in the labor market. This unemployment model is consistent with economic intuition: increased employment in productive sectors of the economy, especially professional services and IT, contributes to an improvement in the overall labor market situation and a reduction in unemployment. Of the variables included in this model, sector X8 has the greatest potential for labor absorption and unemployment reduction.

The model below describes the impact of employment shares in selected sectors on the trade balance in the period under consideration

$$\begin{aligned} Y_{balance} &= 80114X_7 - 109955X_{10} - 179694X_{12} + 166543X_{13} + 268410X_{16}, R^2 \\ &= 0,7465 \end{aligned}$$

In this model, the constant is close to 0, meaning that the trade balance is modeled entirely by the percentage shares of employment in individual sectors. Employment growth in sectors 7, 13, and 16 improved the trade balance by PLN 80,114,000, PLN 166,543,000, and PLN 268,410,000, respectively. Employment growth in sectors 10 and 12, on the other hand, has a negative impact on the trade balance—they support imports and reduce exports. The balance model clearly indicates a dichotomy in the Polish economy: knowledge-based and export-oriented services (IT) and traditional sectors (agriculture, trade) generate surpluses, while sectors X10 and X12 are likely highly dependent on imports (e.g., energy-intensive industries or those requiring imported machinery). The IT sector is a key driver of the positive trade balance in the period under review,

7. Summary and Discussion

This article presents an empirical assessment of the impact of changes in the employment structure across sectors on Poland's macroeconomic indicators in the years 2009-2024. The conducted study complements the classical approach based solely on macroeconomic aggregates. The results obtained are significant both from a cognitive and an applied perspective. For the most part, they confirm the proposed research hypotheses, particularly that changes in the employment structure have a significant impact on macroeconomic processes in Poland, including economic growth and the labor market. The study demonstrates that not only the level of employment, but also the sectoral employment structure, affects economic growth and labor market conditions.

In Poland, between 2009 and 2024, the employment share in agriculture (sector 7) systematically declined and significantly affected most macroeconomic indicators. Another clear trend was the steady increase in employment in the IT sector (sector 16) as well as consistently high employment shares in service sectors such as trade, finance, education, and healthcare (sectors 3, 4, 5, 7, 10, 13, 14). During the analysed period, the Polish economy became more diversified, less dependent on agriculture, with a strong trade and services sector and a rapidly growing segment of modern technologies and professional services.

The econometric analysis for Poland in 2009–2024 shows that changes in the employment structure had a significant impact on key macroeconomic indicators. An increase in employment shares in highly productive sectors (e.g., sector 1 for GDP, sectors 3 and 10 for wages) supported economic growth and higher earnings, while rising employment in less productive or cost-intensive sectors had a dampening or pro-inflationary effect.

The CPI inflation models indicated that employment in sectors 1, 7, and 15 exerted upward pressure on prices, whereas sector 13 had a disinflationary effect. Sectoral shifts in sectors 8, 9, and 16 contributed to reducing the unemployment rate, while the impact on the trade balance depended on sector-specific characteristics—employment growth in some industries improved the balance, while in others it deteriorated it.

The results obtained are consistent with the findings of other studies, which confirm the development of the service sector and knowledge-intensive sectors and their role in generating economic growth (Balcerowicz-Szkutnik, 2016; Klimczyk, 2008). Similar results, although not directly related to the Polish economy, were obtained by Sahadevan (2020), who found a unidirectional relationship running from structural changes to economic growth, and by Soni and Subrahmanya, whose studies confirmed unidirectional causality from industrial growth to GDP growth and from the growth of services to GDP growth. In contrast, Dietrich (2009) concluded that there are varied patterns of interaction—both from economic growth to structural changes and in the opposite direction—for seven OECD countries.

The results highlight the importance of monitoring the employment structure as a factor determining economic development, price dynamics, and labor market conditions, while also indicating the need for a balanced sectoral policy. The study could be extended to other EU countries to verify whether the observed relationships are universal or specific to the Polish economy. Furthermore, an international comparative analysis could be conducted to evaluate Poland in the context of other European countries.

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INFLATION AND CURRENCY FLUCTUATIONS: COMPARATIVE STUDY WITH THE POLISH ZLOTY

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Purpose: The study investigates the impact of inflation on exchange rate dynamics between 2000-2023, with special attention to PLN-based currency pairs.

Design/methodology/approach: Panel data econometric modeling was applied for 120 currency pairs (including 15 pairs with the Polish złoty).

Findings: The research confirms significant influence of current and lagged inflation on exchange rates. For current inflation, the direction of the relationship was positive, suggesting appreciation, while for lagged inflation the direction of the relationship was negative. The PLN pairs showed stronger effects.

Research limitations/implications: R^2 values below 0.25 suggest existence of other unexplained macroeconomic determinants.

Practical implications: The results provide important guidance for both institutional and individual market participants. Accurate forecasts of inflation and understanding how central banks react to inflation surprises can help firms and investors better manage exchange rate exposure and hedge currency risks.

Originality/value: The article provides a comprehensive assessment of the directional effects of both current and lagged inflation over the period 2000–2023 and offers an additional perspective on the impact of consumption on exchange rate dynamics. Furthermore, it enables a comparative analysis of the specific characteristics of PLN-denominated currency pairs relative to other currencies under study.

Keywords: currency market, inflation, exchange rate determinants, Polish złoty, panel data analysis.

Category of the paper: Research paper.

1. Introduction

This study analyzes the impact of inflation on exchange rate dynamics between 2000 and 2023, with a particular focus on currency pairs involving the Polish złoty. The primary objective of the research was to examine the effect of current and lagged inflation on exchange rates and

to compare the strength of this impact in the case of PLN-based currency pairs relative to other currency pairs. Based on this, the following research questions were formulated:

- a) What is the impact of current inflation on exchange rate dynamics?
- b) What is the impact of lagged inflation from the previous period on exchange rate dynamics?
- c) Are there significant differences in this impact between currency pairs with PLN and other currency pairs?
- d) What other factors significantly affect the prepared models?

The research methodology was based on panel data analysis for 120 currency pairs, of which 15 comprised PLN-based pairs. Econometric modeling was employed using Driscoll-Kraay standard error estimators, which are robust to autocorrelation and cross-sectional dependence. The dependent variables collected were the absolute differences of annual changes in exchange rates. The independent variables are the dynamics of inflation (current and lagged), interest rates, and, as control, other selected macroeconomic variables.

The results confirmed a significant impact of inflation on exchange rates. Current inflation demonstrates an expected relationship—an increase in inflation leads to currency depreciation (coefficient close to 1). Unexpectedly, lagged inflation exhibits a stronger, opposite effect leading to currency appreciation. For PLN-based pairs, the impact of inflation was stronger, and the significance of the VIX index indicates capital outflow from the zloty during periods of uncertainty. The findings have practical implications—accurate inflation forecasts support investment and operational decisions of enterprises and individuals.

2. Inflation as a factor influencing the exchange rate

Exchange rate quotations depend on a multitude of factors. One classification divides these factors into three categories: economic, institutional, and psychological (Świder, 2018).

The first category appears relatively straightforward to measure using various economic indicators such as gross domestic product and inflation. The remaining two categories—institutional and psychological factors—are more challenging to quantify. Institutional factors include aspects such as political stability and central bank interventions. Psychological factors pertain to expectations regarding future economic changes and may also result from various behavioral influences. Investors might also seek to hedge portfolio value by relying on characteristics of safe haven assets (Mrowiec, 2024). Table 1 presents a summary of these factors.

Table 1.*Types of Assets Considered as Safe Havens*

Economic factors	Non-economic factors
GDP growth Inflation rate Interest rate changes Unemployment rate Development level Structure of the economy and its level of competitiveness Level of technical support	Political Factors Degree of Political Stability Political Shocks Systemic Solutions Monetary and Fiscal Policy
	Psychological factors (market participants' expectations)

Source: Matuszewska-Janica, Witkowska, 2008, pp. 55-75.

Inflation itself is thus categorized within the group of economic factors, and its influence on exchange rates has been extensively studied. Numerous studies confirm the expected effect of inflation leading to the depreciation of a given currency. Dornbusch (1976) described a relationship in which monetary expansion causes an immediate currency depreciation that overshoots its long-term equilibrium value, followed by a gradual return to equilibrium. Frenkel (1976) and Mussa (1976) referenced the rational expectations hypothesis, according to which monetary expansion not only induces depreciation but may also sustain it due to changes in expectations of future monetary growth. The study by Lothian and Taylor (1996) demonstrated that despite short-term deviations from purchasing power parity, in the long term (several years), differences in inflation rates between countries correspond proportionally to exchange rate changes.

Among Polish researchers, Wojciech Świder (2018) examined the relationships between nominal interest rates, real interest rates, and inflation with the exchange rates of three currency pairs: USD/JPY (1971-2013), GBP/USD (1959-2013), and GBP/JPY (1971-2012). Inflation was found to be a strong factor contributing to currency depreciation in the long run, consistent with theoretical assumptions. A similar verification was conducted by Wdowiński (2010), whose analysis confirmed the presence of relative purchasing power parity for the EUR/PLN currency pair in the period 1995-2008, taking into account changes in PPI indices. Rubaszek and Serwa (2009), analyzing the behavior of the Polish złoty during the period 1989-2005, also devoted considerable attention to inflationary changes, which were particularly significant in the early years of Poland's economic transformation.

3. Methodology

In the first part of the analysis, the selection of currencies to be analyzed was performed. The selection criteria included the availability of economic data for the economies using the respective currencies, the size of these economies, and the availability of exchange rate quotations against the USD. Based on these criteria, 16 currencies were selected in Table 2.

Table 2.
Currencies analyzed

Country symbol (OECD database)	Currency code	Currency
CZE	CZK	Czech koruna
AUS	AUD	Australian dollar
BRA	BRL	Brazilian real
CAN	CAD	Canadian dollar
CHE	CHF	Swiss franc
SWE	SEK	Swedish krona
GBR	GBP	British pound
HUN	HUF	Hungarian forint
ISR	ILS	Israeli shekel
JPN	JPY	Japanese yen
MEX	MXN	Mexican peso
NOR	NOK	Norwegian krona
NZL	NZD	New Zealand dollar
POL	PLN	Polish zloty
USA	USD	US dollar
EA19	EUR	Euro

Source: own study.

The selection allowed for the construction of 120 different currency pairs, including 15 pairs containing PLN.

The next stage involved selecting the variables for the model. In addition to inflation data, six additional control variables were chosen. The purpose of their selection was to isolate the effect of inflation by controlling for other significant economic factors that could distort the relationship. The selected control variables are visible in Table 3.

Table 3.
Selected variables for the model

Variable	Purpose
Inflation rate (CPI)	Measuring changes in price levels
Inflation rate for the previous period (CPI n-1)	
Long-term interest rate	Measuring the price of credit and deposits
Short-term interest rate	
Expenditures on consumer goods and services	Consumption level
Balance of payments current account	The volume of foreign exchange
Net exports in relation to GDP	
VIX Index	Global measurement of uncertainty in financial markets

Source: own study.

The data were collected using databases from the OECD, stooq.pl, and the Federal Reserve Bank of St. Louis.

Following the variable selection, the next step involved computing the relevant variables and their relationships among the analyzed economies. This process yielded the endogenous variable in the form of absolute differences of annual changes in exchange rates between two currencies against the USD.

The dependent variables included:

- Absolute differences in annual changes of inflation dynamics in period N (CPI).
- Absolute differences in annual changes of inflation dynamics in period N-1 (CPI_lag1).
- Absolute differences in annual changes of long-term interest rates (L_interest).
- Absolute differences in annual changes of short-term interest rates (S_interest).
- Absolute differences in annual dynamics of expenditures on goods and services consumption (Consumption).
- Absolute differences in the ratio of current account balance to GDP (Current_account).
- Absolute differences in the ratio of net exports to GDP (Netexport).
- Average annual level of the CBOE Volatility Index: VIX (VIXCLS).

Subsequently, panel data econometric modeling was conducted (Baltagi, 2008) using Driscoll-Kraay standard error estimators (Driscoll, Kraay, 1998), which are robust to autocorrelation and cross-sectional dependence in panel data. Based on Hausman tests and tests for the intercept, a fixed effects model was applied. This modeling was performed separately for 15 currency pairs containing PLN and for the remaining 105 pairs excluding this currency.

4. Panel model without PLN

The results of the panel model without PLN are presented in the Table 4.

Table 4.

Panel model estimation results without PLN

Variable	Estimator	Standard error	t-statistic	p-value
CPI	0.92539	0.27636	3.3484	0.0008264***
CPI lag1	-1.4369	0.41538	-3.4593	0.000552***
L_interest	-0.0006579	0.0031726	-0.2074	0.83574
S_interest	-0.0010755	0.002259	-0.4761	0.6340377
Consumption	-0.49974	0.11875	-4.2082	2.678e-05***
Current_account	-0.097027	0.11049	-0.8781	0.3799592
VIX	6.5409e-05	0.00045495	0.1438	0.885695
Netexport	-0.10172	0.13904	-0.7316	0.4644663

Source: own study.

The model fit statistics are as follows:

R^2 (within): 0.1735

Adjusted R^2 : 0.1313

AIC: -4943.06

BIC: -4885.61

According to the p-values, the statistically significant parameters at the 0.05 significance level were the Consumer Price Index (CPI), the one-period lagged CPI, and expenditures on goods and services consumption. For the CPI, the estimated coefficient was positive as

expected, with a value of 0.92. In contrast, the lagged inflation parameter took on a negative sign, amounting to -1.44.

5. Panel model with PLN

In the panel model for currency pairs involving PLN, besides CPI, lagged CPI, and expenditures on consumer services, the VIX index also emerged as a significant model component. The estimator for CPI was 1.06, while for lagged CPI it was -1.54. Detailed parameters are shown in Table 5.

Table 5.
Panel model estimation results with PLN

Variable	Estimator	Standard error	t-statistic	p-value
CPI	1.0580719	0.3202097	3.3043	0.001065 **
CPI_lag1	-1.5436796	0.3510851	-4.3969	1.516e-05 ***
L_interest	-0.0024563	0.0023350	-1.0519	0.293665
S_interest	0.0016800	0.0022681	0.7407	0.459417
Consumption	-0.3900103	0.1385123	-2.8157	0.005182 **
Current_account	-0.2072831	0.2214035	-0.9362	0.349894
VIX	-0.0039980	0.0014636	-2.7316	0.006668 **
Netexport	0.4690990	0.6423056	0.7303	0.465742

Source: own study.

The model fit statistics are as follows:

R^2 (within): 0.2343

Adjusted R^2 : 0.1794

AIC: -728.32

BIC: -690.32

6. Discussion

In both models for currency pairs with and without PLN, the current period CPI is statistically significant and positively signed, consistent with prior research (e.g., Monadjemi, Lodewijks, 2021; Coakley, Fuertes, Taylor, 2005). A coefficient close to 1 would even indicate a model effect aligned with purchasing power parity. Inflation and depreciation occur simultaneously and on a similar scale, suggesting that investors rapidly incorporate inflationary conditions into their investment decisions.

Lagged inflation was also statistically significant. However, in both models it exhibited a negative sign. This result is less intuitive. A potential explanation for this phenomenon may lie in the fact that when central banks conduct credible inflation-targeting policies, they respond to higher-than-expected inflation releases from the previous period by raising real interest rates (Clarida, Waldman, 2008). Consequently, the market anticipates monetary policy tightening, which favors domestic currency appreciation following the data announcement, even though it pertains to an already concluded period (Engel, Wu, 2024). This effect arises from a mechanism whereby higher inflation leads investors to anticipate interest rate increases by the central bank, resulting in an appreciation of the domestic currency in the short term. The expectation of restrictive measures and the signaling of monetary policy credibility can reverse the classical negative relationship between inflation and exchange rates. These findings may also find support in Dornbusch's overshooting model (Dornbusch, 1976). In the context of inflation's impact and central bank response, Dornbusch's model explains that following unexpected inflation information (particularly lagged inflation), the foreign exchange market may initially overreact (with substantial exchange rate changes), followed by gradual stabilization and return to equilibrium as monetary policy actions unfold and prices adjust. Davis and Sagnaner (2024) note that responses to inflation shocks vary depending on the perceived level of monetary policy transparency. In their analysis, Poland, like other developed economies, exhibits a positive correlation between inflation shocks and exchange rate changes.

Beyond inflation variables, a significant variable in both models proved to be the difference in the dynamics of changes in the value of goods and services consumed by households and by non-profit institutions serving households. In the model without PLN, the estimator for this variable was -0.5, while in the model with PLN it was -0.39. The direction of changes was consistent, indicating that increased consumption translated into domestic currency appreciation. In this aspect, studies present divergent perspectives on the relationship between consumption's impact and exchange rates. Contrasting with these results are studies suggesting that the effect of elevated demand should result in currency depreciation due to, among other factors, increased expenditures on imported goods (Iyke, Ho, 2020). On the other hand, there are studies focusing on the relationship between productivity growth and accompanying consumption, which translates into rising prices of non-tradable goods and, consequently, domestic currency appreciation (Harding, Stefański, Toews, 2020; Corsetti, Dedola, Leduc, 2004).

The final variable that proved significant in one of the models was VIX dynamics. It exhibited a negative significant coefficient for the model with PLN, indicating that this currency tends to weaken during periods of increased stock market volatility. This tendency is consistent with research on carry trade unwinding. Higher-yielding currencies, often associated with greater risk, tend to weaken during times of mounting uncertainty (Brunnermeier, Nagel, 2008).

7. Conclusions

The conducted analysis confirmed a significant impact of inflation on exchange rate dynamics during the period 2000-2023. The research findings both corroborate previous studies by other researchers and provide new insights into ambiguous issues.

7.1. Impact of current inflation on exchange rates

Current inflation demonstrates a strong and statistically significant impact on exchange rate dynamics, consistent with theoretical predictions. A coefficient close to 1 (0.93 for pairs without PLN and 1.06 for pairs with PLN) indicates an almost proportional translation of inflation differentials into exchange rate changes, which confirms the operation of the purchasing power parity mechanism in the short term. This result suggests that foreign exchange market participants quickly and efficiently incorporate current inflation data into their investment decisions, leading to concurrent depreciation of the currency of the country with higher inflation.

7.2. Impact of lagged inflation on exchange rates

A surprising finding of the study was the strong, opposite effect of inflation lagged by one period (coefficient -1.44 for pairs without PLN and -1.54 for pairs with PLN). This phenomenon, though seemingly contrary to economic intuition, finds explanation in the mechanism of credible monetary policy. The publication of data indicating higher-than-expected inflation from the previous period may trigger anticipation of monetary policy tightening by the central bank, leading to domestic currency appreciation in the subsequent period. This effect illustrates how expectations regarding future monetary policy actions can reverse the classical relationship between inflation and exchange rates.

7.3. Differentiation of impact for pairs with PLN

The analysis revealed significant differences in the strength of inflation's impact between currency pairs containing the Polish zloty and other pairs. The coefficients for pairs with PLN are higher for both current inflation (1.06 vs 0.93) and lagged inflation (-1.54 vs -1.44), indicating greater sensitivity of the zloty to inflation changes. Additionally, for pairs with PLN, the VIX index proved to be a significant factor (coefficient -0.004), with its negative sign confirming the tendency for the zloty to weaken during periods of increased uncertainty in financial markets. The higher coefficient of determination for the model with PLN (R^2 within: 0.23 vs 0.17) further confirms that for this currency, the selected macroeconomic variables better explain exchange rate variability.

7.4. Role of other macroeconomic factors

Beyond inflation, consumption dynamics proved to be a significant factor in both models (coefficient -0.50 for pairs without PLN and -0.39 for pairs with PLN). The negative sign of this parameter suggests that consumption growth is accompanied by domestic currency appreciation, which may result from productivity growth and the associated increase in non-tradable goods prices. The remaining control variables, including interest rates and current account balance, did not demonstrate statistical significance, which may stem from the fact that their impact is already partially absorbed by other variables in the model or that their influence is more complex and nonlinear.

7.5. Practical implications

The research findings have significant practical implications for various groups of market participants. For enterprises conducting international operations, accurate inflation forecasts and anticipation of central bank reactions can provide a foundation for effective foreign exchange risk hedging. Foreign exchange market entities — such as investors and businesses — should consider not only current inflation data, but above all the manner in which the market interprets these data in the context of future monetary policy. For Polish market participants, awareness of the zloty's heightened sensitivity to inflation changes and its tendency to weaken during periods of global uncertainty is particularly important.

7.6. Limitations and directions for future research

Despite the application of advanced econometric methods robust to autocorrelation and cross-sectional dependence, the study has certain limitations. Relatively low coefficients of determination (R^2 within below 0.25) suggest that other significant factors affecting exchange rates exist that were not included in the models. Future research would benefit from including explicit measures of market expectations, such as forward-looking indicators derived from interest rate futures, central bank communication indices, or survey-based inflation expectations. This would allow for a more direct test of the proposed mechanism linking past inflation to currency appreciation through expected policy responses. This may be more feasible with a more detailed analysis, narrowed to a smaller number of currencies, which will facilitate the collection of relevant data on future monetary actions. An additional limitation of the study is the lack of comprehensive statistical tests that would allow for a more precise assessment of how significantly the impact of inflation differs between currency pairs including PLN and those without it.

In summary, the study provides empirical evidence of the complexity of the relationship between inflation and exchange rates. Investors and entrepreneurs should take into account both current and past inflation trends. However, they should be aware that their significance may have opposite implications. Additionally, the sensitivity of the Polish zloty to inflation factors

and global uncertainty confirms its status as an developing market currency, requiring particular attention in foreign exchange risk management.

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ANALYSIS AND EVALUATION OF THE DESCRIPTION OF BUSINESS MODELS IN THE ANNUAL REPORTS OF SAMPLE COMPANIES

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Purpose: The primary goal of this study is to analyze the scope and form of business model descriptions presented in the reports of six companies. An attempt was made to compare the readability and clarity of the business model descriptions in the reports studied.

Design/Methodology/Approach: The analysis was based on literature studies and data obtained from the analysis of the annual reports of the selected companies.

Findings Analysis of business model disclosures in 2024 reports indicates that surveyed companies are committed to compliance and are disclosing information about their business models. However, there are differences in the presentation and format of data, length, and scope of disclosures regarding business model elements. Business model reports include a common section presented by all surveyed companies, such as company description, stakeholder orientation, and value proposition. This is generally a lengthy chapter, divided into subsections with different names depending on the report, making it difficult to find and compare business model descriptions. Information regarding business models in the analyzed reports is difficult to compare between entities. Some companies described business models in great detail but did not include drawings or charts, which hinders their quick readability. It is also more difficult to assess the completeness of the information descriptions with complex tables. Disclosures about business models scattered across various chapters of very comprehensive reports, coupled with the lack of appropriate graphical presentation, make it difficult for the reader to find essential information describing the organization's business model.

Practical implications: Analysis and monitoring of information contained in annual reports/reports on companies' business models will enable better management of specific areas within companies.

Originality/value: ESG reporting according to the standards applicable for 2024 was a significant challenge for companies. Describing business models in integrated reporting according to CSRD standards is a new phenomenon, which justifies conducting research.

Keywords: business models, companies, annual reports.

Category of the paper: Case study.

Introduction

Well-thought-out, developed business models bring a number of benefits to companies, such as increased efficiency, better adaptation to market changes, ease of scaling, and easier investment acquisition. The concept of a business model is not clearly defined in the literature (Snihur, Markman, 2023; Szopinski et al., 2022; Snihur et al., 2025). This is because a company's business model must be closely linked to the specific nature of the company's operations. It is linked to the company's strategy and defines how to effectively manage the company to achieve market success. Business models are analyzed and presented in various ways in scientific publications. Many researchers have conducted research on business models, primarily in the fields of design and management (Baden-Fuller, Mangematin, 2013; Battistella, 2012; Vedovato, 2016). The need to describe the business model in reports is required by the Corporate Sustainability Reporting Directive (CSRD) on corporate sustainability reporting (Directive 2022/24646). Information about business models in reports has been deemed relevant and important for potential investors and stakeholders to analyze a company's operations. Sharing experiences in integrating social and environmental factors into daily business activities fosters credibility and market transparency.

The CSRD introduced new reporting standards that require companies to adopt greater transparency and a comprehensive approach to ESG (E-environmental, S-social responsibility, G-corporate governance). Large financial and insurance companies, as well as public entities already required to prepare non-financial reports under Directive (EU) 2014/95 of the European Parliament and of the Council of 22 October 2014, were required to submit CSRD reports for 2024.

ESG reporting according to the 2024 standards posed a significant new challenge for companies. Presenting comprehensive information on the environment, social well-being, and corporate governance, as well as describing business models in accordance with the new procedure, was often a difficult task for companies. This creates room for reflection and analysis, and therefore research in this area is advisable and justified.

This article presents information on the description of business models in reports based on legal regulations and analyzes the presentation and transparency of business model information in the ESG reports of six companies for 2024.

Guidelines developed on the basis of EU directives and Polish regulations on ESG reporting require, among other things, the preparation of a description of the company's business model and strategy of the company in relation to material sustainability issues (ESG Reporting Guidelines, 2024).

Legal regulations and guidelines indicate the need to include a description of the model and value chain in reporting, but they do not clearly outline the scope and form of the description. This is primarily due to the ambiguous definition of a business model and the varying

specificities of companies. The research presented in this article is a pilot study due to the fact that companies submitted reports according to CSRD standards for the first time for 2024. The primary goal of the research is to analyze the scope and form of the description of business models presented in the reports of the six companies studied. An attempt was also made to compare the readability and clarity of the description of business models in the reports examined. A hypothesis was put forward: There are difficulties in the comparability of business model descriptions in the annual reports of companies from 2024. The analysis was based on literature studies on the discussed topic and on data obtained from analyses of the annual reports of selected companies. Based on the literature, the regulations regarding reporting according to CSRD were analyzed, with particular emphasis on the requirements for describing business models. Six companies were selected for the study. Business model description in integrated reporting is a new phenomenon, which justifies conducting the research.

Defining the scope and form of business model description in reporting is crucial for entities to reliably comply with their reporting obligations. Analyzing and monitoring information contained in annual reports on enterprises' business models allows for better management of specific areas within companies. The information, analyses, and comparisons presented in this article fill a research gap related to the implementation of new regulations. It should be emphasized that continued and expanded research will be necessary in the coming years. The need for continued research stems primarily from planned and already developed changes in reporting. On February 26, 2025, the European Commission presented the first package of simplifications in the area of sustainable development, the so-called Omnibus I. The changes introduced by the EU Council and the European Parliament will still require implementation into national law. The issue of disclosing information regarding business models in reports is also constantly debated and ambiguous.

Literature review

The concept of a business model, as interpreted in the literature, is very broad. According to Gajda, "the lack of consensus regarding the interpretation of the term 'business model' stems, among other things, from the varying contexts in which the term is used" (Gajda, 2014). Osterwalder et al. (2005) point out that there are three frameworks within which the concept of a business model can be understood:

- an abstract concept capable of describing the entire real-world business,
- a scheme classifying various types of businesses with similar characteristics,
- a conceptualization of a specific, real-world business model.

The following definitions, understood by various authors, can be found in the literature: (Gajdzik et al., Brzóska, 2009; Afuah, 20024; Grabowska, 2019; Kardas, 2016):

- Architecture for the flow of products, services, and information, including a description of various business activities and their roles.
- A unique configuration of strategy, processes, technology, and corporate governance over an organization.
- A description of the roles and relationships between consumers, customers, allies, and suppliers, identifying the flows of products, information, and cash, as well as the main benefits for participants in the structure.
- A multi-component object that simplifies business operations by describing the logic of creating value for customers and capturing some of that value by the enterprise.

The attempt to define and standardize the concept of a business model was undertaken at a time of growing interest in non – financial information in organizational reporting.

The International Federation of Accountants (IFAC) defined a business model as the way an organization accepts inputs and generates value for stakeholders. It encompasses an organization's goals, revenue streams, strategy, business operations, and other functions. It also defines how the value expected by its owners, value for customers, or other key stakeholders is created.

Despite the varying definitions formulated by many authors over the years, common elements can be identified, such as the concept of value proposition (Lanzolla, Markides, 2021; Shepherd et al., 2023; Doligarski, 2013) (Table 1).

Table 1.
Various definitions of the concept of a business model

Various definitions of the concept of a business model	Source
A business model is the essence of managing transactions in such a way as to create value by exploiting business opportunities.	Amit, R., Zott, C. (2010). Business model design. An Activity System Perspective. <i>Long Range Planning</i> , vol. 22, p. 217.
A business model is a description of how resources are combined and transformed to generate value for stakeholders and how the enterprise will be rewarded by stakeholders in return for the value delivered to them.	Margretta, J. (2002). Why Business Models Matter? <i>Harvard Business Review</i> , vol. 80, p. 87.
A business model is the logic of how a business creates and delivers value to customers.	Teece, D.J. (2010). Business Models, Business Strategy and Innovation. <i>Long Range Planning</i> , vol. 43, p. 173.
A business model is a company's value proposition for specific customer groups and a company architecture that demonstrates the generation of profitable and sustainable revenue streams.	Osterwalder, A., Pigneur, Y. (2012). <i>Tworzenie modeli biznesowych. Podręcznik wizjonera</i> . Gliwice: Helion (Onepress), p. 2.
A business model is an indication of how a company identifies and creates value for customers and captures some of that value in the form of revenue.	Casadesus-Masanell, R., Ricart, J.E. (2010). From Strategy to Business Models and onto Tactics. <i>Long Range Planning</i> , vol. 22, p. 196.

Source: own study based on: Amit, Zott, 2010; Margretta, 2002; Teece, 2010; Osterwalder, Pigneur, 2012; Casadesus-Masanell, Ricart, 2010.

By carefully designing and continuously refining their business model, organizations can adapt to changing market conditions, capitalize on new opportunities, and ultimately achieve long-term success (Schulte, 2013; Seethavaman, 2020; Ritter et al., 2020; Manninen et al., 2018).

It is also worth emphasizing that business model and corporate strategy are two different concepts, often incorrectly used interchangeably. A business model describes and explains how a company operates and how it generates revenue. A business strategy, on the other hand, describes and explains how, where, and for what purpose the business model will be used (Jabłoński, 2019; Oblój, 2002; Zott et al., 2008; Czainska et al., 2021).

Therefore, a lack of clarity in defining a business model can impact, among other things, the description of business models in companies' annual reports.

The CSRD on Corporate Sustainability Reporting (Directive 2022/24646) entered into force in January 2023. The CSRD was transposed into Polish law on 1 January 2025 by the provisions of the Act of 17 December 2024 amending the Accounting Act, the Act on Statutory Auditors, Audit Firms and Public Oversight and certain other acts (Journal of Laws of 2024, item 1863).

It amends the reporting requirements set out in the previously applicable NFRD. It introduces new reporting standards that require companies to take greater transparency and a comprehensive approach to ESG.

The new Corporate Sustainability Reporting Directive introduces new guidelines for companies to report on their activities. On December 16, 2022, the Corporate Sustainability Reporting Directive (CSRD) was published in the Official Journal of the EU. The CSRD replaced Directive 2014/95/EU on the disclosure of non-financial information (Non-Financial Reporting Directive, NFRD).

The CSRD is part of a comprehensive package of legislative changes for the sustainable financing of economic growth, which are intended to help the EU achieve climate neutrality by 2050. The directive introduces mandatory ESG reporting (data on environmental (E), social (S), and corporate governance (G)) for all large companies and large capital groups (including large listed companies), significantly expanding the number of entities required to report. The reporting obligation for 2024 applies to entities meeting the following criteria:

- employing 500 employees,
- net revenues of EUR 40 million or a balance sheet total of EUR 20 million.

One of the key intentions and changes in reporting under the above directive was the introduction of uniform European Sustainability Reporting Standards (ESRS), which specify the data subject to disclosure (Table 2, Table 3).

Table 2.
European Sustainability Reporting Standards-ESRS

EUROPEAN SUSTAINABILITY REPORTING STANDARDS		
ESRS CROSS-SECTIONAL STANDARDS		
ESRS 1 GENERAL REQUIREMENTS		
ESRS 2 GENERAL DISCLOSURES		
ESRS ENVIRONMENT	ESRS SOCIETY	ESRS CORPORATE GOVERNANCE
ESRS E1 Climate Change ESRS E2 Pollution ESRS E3 Water and Marine Resources ESRS E4 Biodiversity and Ecosystems ESRS E5 Resource Use and the Circular Economy	ESRS S1 Own Employees ESRS S2 Employees in the Value Chain ESRS S3 Affected Communities ESRS S4 Consumers and End User	ESRS G1 Running a business

Table 3.
Cross - sectional standards ESRS1 i ESRS 2

ESRS CROSS-SECTIONAL STANDARDS	
ESRS1 GENERAL REQUIREMENTS	ESRS 2 GENERAL DISCLOSURES
General recommendations and principles for creating reports Using rules Structure of standards Basic concepts Significance testing	Mandatory indicators for: General (GR) Strategy (SBM) Governance (GOV) Impact, Risk, and Opportunity Management (IRO)

Source: own work based on <https://www.gov.pl/web/finanse/europejskie-standardy-sprawozdawczosci-zrownowazonego-rozwoju-przyjete2>, 2.10.2025.

The new reporting requirements will be implemented at different times for different groups of enterprises. Reports under the new rules will be published by entities already reporting in 2025 for the 2024 financial year, by other large entities for the 2025 financial year, and listed SMEs will submit their first reports for the 2026 financial year according to separate, simplified standards, which EFRAG will develop in 2023.

The descriptions of business models under the CSRD are intended to ensure the comparability and reliability of disclosed data. This information will be subject to mandatory verification.

According to the standards introduced by the CSRD Directive, information about the business model has been structured and recorded in the section "Strategies and Business Model":

- 2-SBM 1 Strategy, Business Model, and Value Chain.
- 2-SBM 2 Interests and Opinions of Stakeholders.
- 2-SBM 3 Significant Impacts, Risks, and Opportunities, and Their Interrelationships with the Strategy and Business Model.

The implementation of the Act into national law necessitated the introduction of an amendment to the Accounting Act in 2024. The previous version of the Accounting Act only mentions "The statement on non-financial information shall include at least:" "a concise description of the entity's business model.

The amended Accounting Act introduces a new Chapter 6c, "Sustainability Reporting", which is a key part of the implementation of Directive 2022/2464 (CSRD) regarding the provisions on preparing sustainability reporting.

According to the Accounting Act, companies should include the following information related to their business model in their reports:

- Information on the entity's key intangible resources.
- An explanation of how the entity's business model depends substantially on such key intangible resources.
- An explanation of how intangible resources constitute a source of value creation for the entity. Key intangible resources are understood as resources without physical substance on which the entity's business model depends and which constitute a source of value creation for the entity.

In addition, information about the business model should appear in a separate section of the activity report containing information necessary to understand the entity's impact on sustainability issues and to understand how sustainability issues affect the entity's development, performance, and situation, hereinafter referred to as "sustainability reporting". This section should include, among other things, information on a concise description of the entity's business model and business strategy, including a description of:

- a. the resilience of the entity's business model and business strategy to risks related to sustainability issues,
- b. opportunities for the entity related to sustainability issues,
- c. the entity's plans, including implementation actions and related financial and investment plans, to ensure that the entity's business model and business strategy take into account:
 - the transition to a sustainable economy,
 - limiting global warming to 1.5°C,
- d. how the entity's business model and business strategy consider the needs of the entity's stakeholders and the entity's impact on sustainable development issues.

It is essential that the business model is presented in an accurate and transparent manner in annual reports. This influences the perception of the company by various stakeholders in the following aspects (Abdelkafi, 2013; Pedersen, 2018; Massa, 2024):

- enables understanding of how the company's operations impact the environment, society, and corporate governance,
- enables identification of risks and opportunities related to the company's impact on sustainable development,
- increases transparency and allows stakeholders to assess the company's commitment to sustainable development,
- builds trust and gains a competitive advantage,
- helps companies define goals and measure progress in environmental, social, and governance areas.

According to the guidelines, the scope of information that should be included in a business model report is limited to presenting:

- business model and value chain,
- business sector(s),
- key products and services offered,
- operating markets,
- key value creation factors.

According to the guidelines, companies should also disclose how sustainability issues are integrated into their strategy, business model, and financial planning. Companies can demonstrate their priorities and the direction they are heading. Implementing proper ESG reporting according to the above regulations and guidelines has become a significant challenge for companies. On the one hand, companies see a number of benefits, but on the other, reporting creates bureaucratic difficulties. Complex regulations and a lack of consistency and clear reporting guidelines have necessitated investment in consultations and training. Specialized firms have been established to support companies in reporting.

Recognizing the challenges of reporting under the current CSRD Directive, on February 26, 2025, the European Commission presented the first simplification package in the area of sustainable development, the so-called Omnibus I. Its goal is to reduce the administrative burden on businesses in the European Union. The package includes two draft directives. One, the so-called "stop-the-clock" directive, postpones deadlines. The second draft contains substantive changes aimed at simplifying the requirements for businesses.

Implementing ESG reporting not only fulfills legal obligations, but also offers a range of benefits for businesses. Companies that adhere to non-financial reporting principles gain a competitive advantage, improved access to financing, and greater stakeholder trust. The investors increasingly analyze various indicators before making business decisions, so transparency in this area can positively impact a company's market perception. A responsible approach to the environment and society helps minimize legal and operational risks.

Methods

The Corporate Sustainability Reporting Directive (CSRD) (Directive 2022/24646) introduced new reporting standards for the description of business models in annual reports. For the first time, large financial and insurance companies, as well as public entities already required to prepare non-financial reports in accordance with the NFRD, were required to submit reports for 2024. The study examined six annual reports for 2024. The study involved analyzing the content of these companies' annual reports and examining the scope and form of information disclosed regarding the business model. The study employed comparative analysis and

deductive reasoning methods. The article draws on literature studies, analyzes legal regulations, and cites research findings from Polish and international authors on topics related to business models.

Results

This article primarily analyzed and assessed the readability and clarity of the business model descriptions in the reports of six companies. Table 4 summarizes the chapters/subchapters containing information about business models, based on the reports' tables of contents. The paper addresses the clarity of the model data presentation in the analyzed reports.

Table 4.
Information about the business model in the annual reports of selected companies

Unit	Names of the report chapters/subchapters containing information on business models	Notes on presenting business models in reports
Dino Polska	DINO Polska and Capital Group Operations (Development Strategy). ESRS 2 (SBM-1) – Strategy, Business Model, and Value Chain. ESRS 2 (SBM-2) – Stakeholder Interests and Opinions. ESRS 2 (SBM-3) – Significant Impacts, Risks, and Opportunities and Their Interrelationships with Strategy and Business Model. KPIs – Operating Expenditures. ESRS G1 (G1-1) Business Conduct Policies and Organizational Culture.	The report's table of contents lacks a dedicated chapter or subchapter titled "business model". Information regarding the model appears primarily in one of the last chapters, "Sustainability Reporting", primarily in the subsection "General Information". Although the term "business model" is cited 10 times in the report, one must search for information scattered throughout the report to find its description.
GK LPP SA	Management Board Report on the Activities of the LPP SA Capital Group. Financial Resource Management. Risk Management. General Disclosures (Business Model). Information on Social Issues. Revenues and Expenses. Management of Impacts, Risks, and Opportunities. E1 Climate Change. E4 Biodiversity and Ecosystems.	In the report's table of contents, information about the business model is presented in the "business model" subsection at the beginning of the report, but a description of the model is also included later in the report. The model description is continued in the middle of the report, in the sustainability chapter, primarily in the general disclosures subsection. This can be confusing for stakeholders, as they may overlook some of the business model information based solely on the chapter title where the term "business model" appears.

Cont. table 4.

Grupa Orlen	General Information. ORLEN Group Business Model. Management: Identification and Assessment of Significant Risks and Opportunities, and Internal Controls for Sustainable Development. Biodiversity and Ecosystems. Resource Use and the Circular Economy. ORLEN Group Employees. People Working in the Value Chain. Affected Communities. Key Intangible Resources. Climate Change. Consumers and End Users.	In the report's table of contents, information about the business model is presented in the first section of the report, "Business Model and Organization of the Orlen Group". Further information regarding the model description is included in the middle section of the report, in the chapter on sustainable development, primarily in the subsection "general information". This can be confusing for stakeholders, as they may overlook the business model information based solely on the chapter title where the term "business model" appears.
PGE Polska Grupa Energetyczna S.A.	PGE Group's Business Development Prospects. [SBM-1] Strategy, Business Model, and Value Chain. [SBM-2] Stakeholder Interests and Opinions. [SBM-3] Significant Impacts, Risks, and Opportunities, and Their Interrelationships with the Strategy and Business Model. People Performing Work in the Value Chain. Business Characteristics. Climate Change. Biodiversity and Ecosystems. Information on Social Issues.	In the report's table of contents, information about the business model is presented in the first section of the report. The information regarding the model description is continued in the middle of the report in the chapter on sustainability, where a distinct subsection appears: "Strategy, business model, and value chain". Information regarding the business model description is contained in two different sections of the table of contents, but the subsections concerning the model are clearly titled, allowing for quick access to basic information regarding the model description. The term "business model" is cited in the text 33 times.
Cyfrowy Polsat S.A.	Our Business. Strategy, Model, and Value Chain. Significant Risk Impacts and Opportunities and Their Interrelationships with the Strategy and Business Model. Description of Processes for Identifying and Assessing Climate-Related Significant Risk Impacts and Opportunities. Employees in the Value Chain. Application of Accounting Principles. Professional Judgment, Accounting Estimates, and Assumptions. Significant Risk Factors and Threats. Climate Change.	The report's table of contents lacks a distinct chapter/subchapter titled "business model". Information regarding the model appears in one of the last chapters, primarily in the "General Information" subsection. It includes information on the business model strategy and value chain. To find a description of the business model, one must search for information scattered throughout the report. Although the term "business model" is cited 33 times in the report.

Cont. table 4.

Tauron Polska Energia	Implementation of Strategic Investments. TAURON Capital Group Management Principles. Corporate Governance Statement. Remuneration Policy for Management Board and Supervisory Board Members. Other Important Information and Events. General Information (Sustainability Reporting). Tauron Group Business Model. Climate Change. Water. Biodiversity and Ecosystems. Affected Communities. Consumers and End Users. Significant Risk Impacts and Opportunities. Tauron Group Value Chain. Recent Stakeholders of the Tauron Group. Analysis of the Financial and Asset Situation of Tauron Polska Energia S.A. Remuneration Policy for Management Board and Supervisory Board Members. Pollution. Social Responsibility.	The main information regarding the description of the model is included in the chapter on sustainable development, where the subsection "TAURON Group business model" appears.

Analysis of the reports indicates that two companies, DINO and Polsat, did not include a chapter title in their table of contents that clearly suggested a description of the business model. Information regarding the business model description was presented primarily in the Sustainable Development (General Information) chapter. Although the term "business model" is cited repeatedly in these reports, finding a description of the business model requires searching for information scattered throughout the report. The scope of information regarding business models is broad but scattered throughout the reports, making analysis and comparison between companies difficult. Certain similarities in format and layout can be observed in the cases of LPP and Orlen, where basic information about the business model appears in two different sections of the report.

Both reports begin with a "Business Model" chapter, but business model information is also included in the sustainability chapter, primarily under the "General Information" subsection. The scope of information on models is broad, and the term "business model" is cited repeatedly throughout the report.

The clarity and readability of comprehensive reports are influenced by the graphical presentation of information. The use of figures and charts in the text facilitates readability and facilitates comparisons. Clarity of communication in comprehensive reporting should be a priority. With this in mind, Table 5 presents the format in which information about the business model was presented in the reports reviewed.

Table 5.

The form of disclosure of information about the business model in the annual reports of companies

Name of the entity preparing the report for 2024.	Form of disclosure of information about the business model				
	Narration	Table	Drawing/diagram	Chart	Infographic
Dino Polska	X				
GK LPP SA	X		X		X
ORLEN	X	X	X	X	
PGE Polskie Grupy Energetycznej S.A.	X	X		X	
Cyfrowy Polsat S.A.	X	X			
Tauron Polska Energia	X	X	X		X

Analyzing the information regarding the business model description in reports (Table 5), it can be seen that when describing their business model, companies most often choose a descriptive/narrative format and present data in the form of single tables. Companies are less likely to use charts, drawings, or infographics to present their business model. If they do appear in reports, they do so sporadically and individually. In many cases, a format such as an infographic would certainly be more readable. Reports present a wealth of information, so diagrams and graphics would certainly be attractive to potential stakeholders.

Discussion

The concept of a business model is not a unified concept in the literature. Researchers analyze and present business models from various perspectives, emphasizing its various elements (Afuah, 2024; Grabowska, 2019; Kardas, 2016). A well-developed and properly described business model is the foundation of a company's success. Therefore, it is crucial that it be presented clearly and legibly in companies' annual reports. Analyzing business models in annual reports can help new companies build a stable business model that will prove effective in challenging situations (Lanzolla, Markides, 2021; Shepherd et al., 2023; Kawacki, 2020). The most structured and clearly presented business model descriptions were found in the Tauron report, where the main information regarding the model description is contained in the chapter on sustainability, under the subsection "TAURON Group Business Model". In all reports, some information about the business model is included in the chapter on sustainability, in accordance with regulations. However, this is generally a lengthy chapter, divided into subsections with different names depending on the report, making finding and comparing business model descriptions difficult.

Companies refer to the guidelines from the SBM 1, SBM 2, and SBM 3 standards when presenting information about business models, complying with the provisions of the European Sustainability Reporting Standards. However, a lack of uniformity in the naming of the sections

or subsections in which business model information is presented has been identified. This complicates finding model descriptions in comprehensive reports and hinders the comparison of business model information in annual reports. The concept of a business model rarely appears directly in the tables of contents of the company reports we reviewed. In some reports, the term is not included in the table of contents, making it difficult to locate information regarding the business model. Although the concept of a business model is frequently cited in various sections of the reports, it should be emphasized that understanding a business model requires detailed knowledge of the elements and concepts related to the business model and familiarization with the entire comprehensive reports. In the reports we analyzed, we found rather poor visualization of business model descriptions. One company included a model description in its report without using any graphical representations. Analyses also indicate that most of the large organizations are reluctant to disclose too much information about their business models. This may be due to, among other reasons, fear of competition or lack of understanding of what a business model should consist of. They also presented such conclusions in their research (Inakshi et al., 2023). The presented research may initiate further research that will allow for a broader analysis of the manner and form of presenting information on business models in companies' annual reports.

Summary

Describing business models in companies' annual reports is currently a legal requirement. Reports prepared according to the CSRD were intended to ensure, among other things, comparability, readability, and credibility of disclosed data. It should be emphasized that a business model affects many areas of an entity's operations, often hindering a clear compilation of information in reports. This article primarily analyzed and assessed the readability and clarity of the business model descriptions in the reports of six companies. An analysis of the business model provisions in the 2024 reports indicates that the audited companies strive to comply with regulations and disclose information about their own business models. However, there are differences in the presentation and format of data, the length, and the scope of disclosures regarding the elements that make up the business model. The business model reports include a common section presented by all audited companies, such as a company description, stakeholder information, and value proposition. In all the reports of the audited companies, some information about the business model is included in the chapter on sustainable development, in accordance with the provisions of the Accounting Act. This is generally a lengthy chapter, divided into subsections with different names depending on the report, making it difficult to find and compare business model descriptions. It is also noted that business model data is also presented in other sections of the report concerning

environmental and social issues. This demonstrates an increasing understanding among entrepreneurs that a business model connects with many areas within a company, and that creating a successful business model requires analysis of multiple areas. However, due to the dispersion of information about business models in the analyzed reports of the companies for 2024, they are difficult to compare across entities. Some companies described their business models in great detail but did not include drawings or charts, which hindered their quick readability. It is also more difficult to assess the completeness of the information in the case of extensive descriptions or descriptions with complex tables. Graphical reports are generally more readable and understandable, and drawings and charts support the message. Visualizing disclosures allows for a quicker assessment of the validity of the described content and allows for easy comparisons with other entities. Model disclosures scattered across various chapters of very extensive reports, lacking appropriate graphical formats, make it difficult for the reader to find important information describing the organization's business model.

The author believes that the reasons for the diversity, difficulty in readability and comparability of reports, and the dispersion of business model descriptions, stem primarily from:

- the lack of a unified, well-established, and transparent definition of the business model itself,
- the broad concept of a business model, which affects many areas of an entity's operations, making it difficult to organize and clearly summarize information,
- complex regulations and a lack of clear, simple reporting guidelines,
- entrepreneurs' lack of comprehensive knowledge of the form, quality, need, and scope of business model disclosure in reports.

Based on the presented research and literature review, the author believes there is a need to:

- define the concept, scope, and form of presenting a business model in reporting,
- streamline and simplify reporting requirements,
- analyze the possibility of creating a standard reporting template that would present the scope and form of describing business models in annual reports,
- further train entrepreneurs on the importance of accurate and clear business model disclosure in periodic reports.
- disclose business models in reports.

Given the challenges of reporting under the principles, on February 26, 2025, the European Commission presented a simplification package in the area of sustainable development, the so-called Omnibus I, and the changes introduced will require implementation into national legal systems. It is crucial that the regulations on presenting models in reports are transparent and standardized for companies, to the extent possible. It is crucial that companies present their business models reliably and accurately in their reports. On the one hand, efforts should be made to reduce certain reporting burdens on companies, while maintaining due diligence in presenting business models.

Presenting a business model is a crucial issue, posing a new and difficult challenge for reporting. The research presented in this article indicates the need for further work to determine the best form, method, scope, and quality of business model disclosures and their usefulness for stakeholders. Work is ongoing to improve the reporting of business model data, and this topic will be the subject of future research. The presented research may initiate further research that will allow for a broader analysis of the manner and form of presenting information on business models in companies' annual reports.

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