POLITECHNIKA ŚLĄSKA **ZESZYTY NAUKOWE**

SILESIAN UNIVERSITY OF TECHNOLOGY SCIENTIFIC PAPERS

ORGANIZACJA I ZARZĄDZANIE
Zeszyt Naukowy nr 231

ORGANIZATION AND MANAGEMENT
Scientific Paper no. 231

Współczesne zarządzanie

Contemporary management

Pod redakcją
Radosława WOLNIAKA

Edited by
Radosław WOLNIAK

GLIWICE 2025

Kolegium redakcyjne

REDAKTOR NACZELNY – Dr hab. inż. Barbara KULESZ, prof. PŚ
REDAKTOR DZIAŁU – Prof. dr hab. inż. Radosław WOLNIAK

Wydano za zgodą
Rektora Politechniki Śląskiej

ISSN 1641-3466
ISSN 2720-751X

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Wydawnictwo Politechniki Śląskiej
Gliwice 2025

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Nakł. 30 Ark. wyd. 51 Ark. druk. 43,5 Papier offset 70x100, 80 g
Zam. 87/25

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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 37 papers.

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Radosław Wolniak

SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

THE CO-CREATION OF HIGH-RISE PLANNING REGULATIONS: CASE GDANSK

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Purpose: The local regulations for high-rise planning in Gdańsk were established through the "Smart High-Rise Development Study" in 2008 and provide guidelines for managing the design process for high-rise developments. It aimed to ensure social commitment to build a dense urban environment while maintaining livability. The Gdansk high-rise plan can be seen as a high-rise strategy, covering comprehensive urban analysis, with a particular focus on co-creation in the planning of high-rise buildings.
Aim: The research aims to improve the public involvement in setting city policies, drawing on the Gdansk experience with establishing specific regulations on high-rise planning.
Methodology: The background for this study included a literature review, explicitly focusing on Appert and Montes, Morato, and Glauser, who are most relevant because they address the challenges of regulating high-rise buildings. Key insights from articles about planning regulations and co-creation were applied to analyse the content of the High Rise Study in Gdansk and the co-creation process. This examined the institutional changes and the identification of risks with scheduling contingency planning beyond the city planning procedure.
Findings: In the research, a critical analysis was conducted on the opportunities and challenges of co-creating regulations, along with identifying limitations within the presented high-rise study. As a top-down approach was used in the Gdansk case, urban planners initiated stakeholder involvement. They limited the stakeholders' insights to the agreed-upon focus, and the results were incorporated into the document through the addition of a local planning procedure.
Social implications: The trade-offs involved in high-rise development in European cities can be addressed using a collaborative approach, such as in Gdansk. The findings emphasize how Gdansk stakeholders co-created this strategy, examining only a selected few key aspects of high-rise development. The main contribution of this case study shows how high-rise regulations can gain social support with input from the general public within a shared focus.
Originality/value: The research on the Gdansk case adds to existing literature on co-creating procedures for high-rise planning regulations and other city policies. They present new insight into the co-creation process tested as a key part of developing high-rise planning rules. The approach enhances our understanding of how to establish top-down rules for involving stakeholders in co-developing city policies on essential issues like high-rise regulations.
Keywords: co-creation in planning; high-rise strategy; community involvement in city policy.
Category of the paper: Research paper/case study.

1. Introduction

While Shakespeare's phrase "What is the city but the people?" is accurate, buildings are essential for urban life. Cities grow by building upward or outward, and when they resist construction, people miss out on urban experiences (Glaeser, 2011). Successful high-rise development requires careful, comprehensive planning, including architectural analyses and designing public spaces that integrate well within urban structures. Gdańsk, the capital of the Pomeranian Province and centre of the Gdańsk Metropolitan Area, is a significant business hub with a rich history. Unfortunately, in Gdansk, the existing high-rise developments from the 70ties stand in architectural opposition to Stare Miasto (the Old Town) and the nearby historic area of Główne Miasto (the Main City). This situation has raised awareness of the need for the co-creation of a specific high-rise planning procedure in Gdańsk. As a result, the additional local regulations for high-rise planning in Gdańsk, namely "Smart High-Rise Development Study"[1], formulated additional guidelines for the city planning procedure in case of high-rise development, which covered various topics related to comprehensive urban analysis, specifically, the public participation framework in the planning procedure of High-Rise Buildings. However, what was initially meant to be the co-creation process in defining new regulations was limited to social commitment for the additional procedure addressing identified scheduling contingency risks.

1.1. Thriving City Rules

Cities thrive on minimal physical space between people and businesses, fostering proximity, density, and connection that enable collaboration and enjoyment. Their success hinges on the demand for these interactions. Historically, cities have flourished with small firms and skilled individuals, as seen in their past as a hub of inventors. Economic vitality drives property prices upward, but limited new constructions make the cities less affordable. Paris's famous landmarks remain visible due to preservation efforts, transforming the city into one that is primarily accessible to the wealthy. Cities are defined by their people, not just their buildings. Athens

[1] *High-rise planning regulations* refer to the planning of High-rise buildings that must adhere to the legal standards outlined in the technical rules for high-rise constructions in Poland, as specified in the Regulation of the Minister of Infrastructure on the technical conditions to be met by buildings and their location (Journal of Laws 2022, item 1225). The national regulations cover various aspects, including fire safety, requirements for building entrances, window security, balustrade specifications, and specific technical solutions for roofs, balconies, and loggias on upper floors. There is also an obligation to maintain a biologically active area on the plot and to incorporate plant insulation. Technical solutions must ensure efficient management of information, energy, water, and waste, while also making sure that the building's height and location match the surrounding terrain. According to these regulations, high-rise buildings are defined as those exceeding 55 meters in height.
In addition to the national high-rise building regulations that must be met, the local regulations in Gdansk described in the *Smart high-rise development study* on high-rise planning apply to buildings with a minimum height of 40 meters and a facade width between 5 and 50 meters. The purpose of the Smart High Rise study is to identify suitable locations for these high-rise buildings within the urban landscape and to ensure their placement is publicly acceptable.

prospered through trade and intellectual exchange, leading influential figures like Socrates and Aristotle to emerge. The synergy of ideas in urban environments spurred innovation over time (Glaeser, 2011, p. 30).

Urban centers, regardless of their humble beginnings, can lead to remarkable outcomes. Artistic movements thrive in concentrated spaces, as illustrated by connections formed in cities (Glaeser, 2011, p. 254). Successful cities share a vital characteristic: they attract intelligent individuals and foster teamwork. Human capital is essential for a thriving city, and while skilled individuals often gain formal education, much knowledge is acquired afterward. In less affluent regions, human capital can come from entrepreneurial spirits with little formal education. Height restrictions in cities like Paris or New York may seem obscure, but they shaped the future. If a city's history becomes a constraint, it loses one of its greatest strengths: the ability to build upward. The best cities blend skills and *create opportunities for those who start with less to end with more* (Glaeser, 2011, p. 230). The proposed approach is to develop under the following three simple rules:

First, cities should streamline the permitting process by replacing it with a simple fee system. If tall buildings block light or views, cities should estimate those costs and charge builders accordingly. Disruptive activities also incur social costs, which should be levied against builders, similar to how drivers are taxed for congestion. The fees collected can then benefit those adversely affected, such as neighbors losing light because of new projects.

Second, historic preservation must be limited and clearly defined. While landmarking significant structures, such as the Flatiron Building, is reasonable, preserving numerous postwar buildings is excessive. In cities like New York, the landmarks commission could protect a fixed number, around five thousand buildings. Changes to this list should occur gradually, avoiding abrupt halts to construction in previously unprotected areas. In globally beloved cities like Paris, finding space for dense development close to the city center is essential.

Ultimately, neighborhoods should have the authority to preserve their unique character. Residents in certain areas may wish to exclude bars, while others might want to support them. Instead of top-down regulations, neighborhoods should be allowed to establish limited building rules, requiring broad community approval. However, they should not entirely prevent construction to avoid becoming NIMBY enclaves (Glaeser, 2011).

1.2. High-Rise Planning Implications

Polish cities tend to favour lower-rise development compared to urban areas elsewhere, with most city centres featuring dense, 19th-century structures protected by cultural heritage laws. Cities like Kraków, Poznań, Wrocław, or Gdansk are experiencing urban sprawl and declining downtown populations. City planning is focused on increasing density, as it can enhance efficiency in infrastructure, transportation, and energy use, and revitalising large housing estates through initiatives that improve living conditions, including constructing new high-rise buildings in areas without historical significance. Gdansk serves nearly 1.4 million

residents and aspires to be a modern metropolis, with a seaside location that attracts investment and opportunities. The urban form identity is shaped by three key components: the Sea and Tricity Landscape Park (nature), the Ports (harbour and airport), and Gdansk - Sopot - Gdynia (cities along the transport route axis), ensuring its genius loci.

Gdańsk, with its coastal location and proximity to the capital, has experienced significant growth over the past two decades. The increase in population and job opportunities has led to a higher demand for efficient residential and commercial spaces. Gdańsk is poised to grow over the next few decades. However, achieving sustainable development within its existing boundaries to keep pace with regional competitors is challenging. Thus, high-rise buildings can serve as powerful symbols and contribute to a strong sense of identity for the landscape. Institutions are crucial in ensuring that high-rise development fosters social cohesion, utilizing participatory governance models to engage communities in planning (Cucca, Ranci, 2021).

High-rise developments can exacerbate or mitigate energy consumption, making institutional responses to climate adaptation crucial in guiding sustainable city growth. In urban planning, this translates into governmental capacity at multiple levels—local, regional, and national—to implement development strategies that accommodate growing urban populations. These institutional frameworks have significant implications; they directly influence the adoption of innovative urban policies, determining how cities can sustainably manage high-density living while enhancing citizen welfare (Kazepov et al., 2023). The literature highlights a complex interrelationship between institutional frameworks, planning, and execution of high-rise developments. Urbanization presents multifaceted challenges that require strategic governance, where policies must promote collaboration among various stakeholders to ensure that high-rise projects are equitable and sustainable. The negative perception of high-rise developments from the 1970s underscored the urgent need for introducing contingency planning for any high-rise development plans in Gdansk.

2. Method Examining Institutional Change in Gdansk

In response to the challenge of creating suitable new developments, policymakers in Gdansk have started to regard tall buildings as a potential solution to the need for expansion. The evolution of high-rises, like those in London, illustrates a shift in urban governance, followed in Gdansk. Developers' interests began aligning more closely with local authorities, facilitating many high-rise projects despite previous restrictions (Appert, Montès, 2015; Morato, 2022). This creates a paradox in which developers are empowered yet must navigate a regulatory landscape that can stifle the innovation necessary for contemporary high-rise development. Economic reliance on private developers adds another layer of complexity to high-rise planning.

Local governments are increasingly dependent on private capital due to austerity measures that impact public funding, resulting in a symbiotic relationship where urban planning is closely linked to market dynamics. This connection can prioritize developer interests over comprehensive urban needs, complicating the planning process and potentially undermining long-term urban sustainability (Karampour, 2020). Economic incentives often conflict with urgent environmental and social concerns, underscoring the necessity for integrated approaches that include diverse stakeholder perspectives. Considering the city planning procedure in Poland, the presented Gdansk case in project management outlines strategies to address potential delays or setbacks that may occur during the project timeline.

This foundation focused on the implications of high-rise planning in addressing challenges, with a special emphasis on executing high-rise development planning procedures that prioritize local communities and establish a public consultation process while obtaining any building permission. The above involves the proactive identification of risks and the development of alternative approaches to ensure that project goals are met. This may include allocating extra time (contingency time) to accommodate unforeseen issues or making adjustments, such as accelerating delivery or modifying the project scope. Specific criteria were established to determine which areas in Gdańsk are suitable for tall buildings and to identify measures that ensure the sustainability and livability of new high-rise developments.

The Gdansk initiative, in the form of a co-creation process, was undertaken in 2008 and led to the study titled "Smart High-Rise Development Study". Feedback from residents and stakeholders played a crucial role in shaping the final high-rise policy. Therefore, the procedures, criteria, and methods for specific areas are established in the High-rise Development Study. In locations suitable for tall buildings, specific guidelines for public participation are implemented for new high-rise developments, following the defined timeline. The high-rise policy differentiated the procedure in designated areas for developing well-designed (iconic) high-rise buildings, which should be located in strategic clusters and well-served by public transport in Gdansk and other regions that allow for high-rise developments under several conditions, with the primary focus on establishing rules and procedures for public participation and community involvement (see also table 1).

Table 1.
Key aspects of the scheduling contingency plan for High Rise Development in Gdansk

KEY ASPECT	Scheduling contingency for High rise planning	Gdansk - Beyond the city planning procedure
Risk Identification	Identify potential risks that could impact the project timeline, such as resource unavailability, supply chain issues, or unforeseen delays.	Recognised in the case of High Rise Development.
Contingency Time	Allocate additional time in the project timeline to absorb potential delays or uncertainties.	Structured the possible delays in the procedure.
Alternative Strategies	Develop alternative approaches to address schedule slippage.	Scheduling the contingency planning.

Cont. table 1.

Communication	Establish clear communication channels to inform stakeholders about potential delays and contingency measures being implemented.	Structuring the possible process into procedure.
Implementation	When a risk materializes, activate the pre-planned contingency measures to minimize the impact on the project timeline.	Pre-planned methodology.

Source: own study.

Nonetheless, a standard way to deal with any unexpected emergent events in any high-rise developments involves anticipating and preparing for various emergencies, such as fires, evacuations, and other disruptions, to minimize their impact on both residents and building operations. It includes developing emergency action plans, training building occupants, and ensuring adequate communication and evacuation procedures.

Nevertheless, in Poland, the planning permission for high-rise buildings is strictly governed by legal regulations. Therefore, any additional requirements regarding the scope and content in the urban scale of the application, the decision, and the considerations involved cannot be addressed at the architectural project level. Therefore, the specific design solutions should be implemented according to the additional procedures set out in the "Smart High-Rise Buildings" to adequately address the challenges surrounding high-rise developments at the scale of Gdansk. One of many strategies to increase urban density and vibrancy is constructing high-rise buildings not alone but surrounded by public green spaces. The effective tall buildings policy for Gdańsk considers the impact of high-rise developments on people and places, not just how they affect the skyline, but also how changes in urban development affect them. In response to urban pressures, high-rise developments require a policy framework that considers not only architectural and financial feasibility but also the potential socio-economic inequities that may arise from them. This echoes Gent's analysis of housing strategies in neighborhood regeneration, which emphasizes the interplay between policy frameworks and market characteristics (Gent, 2010).

2.1. Comprehensive High-rise Planning

High-rise buildings in urban areas demand a multidimensional impact approach considering environmental, social, and safety factors. The literature indicates a need for comprehensive strategies to tackle the unique challenges of high-rise developments, emphasizing sustainability, safety, and community integration. High-rise buildings can significantly influence urban morphology and environmental sustainability. Baiz et al. argue that, despite their potential benefits regarding land efficiency, high-rise structures often generate negative social impacts, such as impersonal relationships among residents (Baiz et al., 2017). The environmental implications of high-rise buildings are substantial, particularly concerning wind dynamics and their interactions with urban fabric. Yu et al. discuss how high-rise structures can alter pedestrian-level wind environments, necessitating integrated planning to mitigate any adverse effects on urban life (Yu et al., 2024). Zhang et al. examine how wind

impacts and the outdoor environments surrounding high-rise buildings during extreme weather events can threaten structural integrity and occupant safety (Zhang et al., 2022). They highlight the necessity for dynamic contingency planning that considers various environmental factors, such as potential disasters, to enhance the safety of high-rise developments. These findings underscore the importance of considering ecological impacts and advocating for sustainable practices in high-rise development projects.

Research on the future resilience of urban infrastructure indicates that high-rise buildings may not adapt efficiently to climate-related hazards, such as heat waves and floods. Guerreiro et al. highlight the necessity for detailed climate risk assessments in urban areas, which should inform the adaptation measures required for high-rise buildings (Guerreiro et al., 2018). As urban environments face increasing climatic threats, integrating contingency plans that outline mitigation and adaptation strategies becomes critical.

The guidance states that tall buildings must exhibit the highest architectural quality, ensure user safety, maintain a positive relationship with their historical context, guarantee good accessibility, utilize renewable energy sources, and enjoy social acceptance. Project evaluation criteria should also include their relationship to cultural heritage, transport infrastructure, and environmental sustainability; consider appropriate locations and excellent design quality; include advanced technology; and enhance the attributes of the immediate area and the broader setting. Ultimately, the resulting high-rise buildings should provide more benefits than costs.

Environmental sustainability is vital, especially regarding climate change. Urban planners must evaluate the role of high-rise buildings in mitigating or exacerbating urban heat island effects and resource consumption. Incorporating low-carbon building initiatives is essential, emphasizing developments that aim to minimize carbon emissions and adhere to sustainable architectural practices (Madhusanka et al., 2022). As Glauser discussed, the relationship between high-rises and environmental sustainability is not merely about eco-friendly designs but ensuring these buildings contribute positively to urban ecosystems and community health (Glauser, 2022). Comprehensive environmental assessments should precede any high-rise project to establish strategies for mitigating potential adverse impacts on urban climates.

2.2. Demand for additional regulations

Local communities in various European cities express their views on high-rise buildings and their long-term economic impacts on neighbourhoods. Current legislative trends in Europe and Poland are shifting away from merely approving planning acts with the scope of public participation towards co-creating policies with the public. The proposed public participation framework and procedure can ensure access for the local community. Furthermore, the proposed high-rise buildings' planning must be integrated into their surroundings, and visibility must be evaluated accordingly, from City Landscape Control Points. The proposed procedure should actively promote engagement with local communities

throughout the high-rise building development process. (See also: Local and City Landscape Control Points for Impact Assessment)

The "Smart High-Rise Buildings" outlines the designated areas for high-rise structures. It specifies that the local spatial development plan is the key document determining whether the construction of such structures is permissible or prohibited. The document identifies areas suitable for high-rise buildings and establishes fundamental guidelines for their development. The Gdansk policy reflects a desire to develop a modern city while embracing change and taking risks, but respecting and protecting the city's historical values and skyline.

The significance of contextual characteristics emphasizes that successful high-rise strategies embrace local identities and civic engagement from the outset (Amhoff, 2019). Scheduling in contingency planning mechanisms must, therefore, consider the individual narratives of urban locales, allowing for tailored approaches that respect historical contexts and current city dynamics. The general decision was based on studying the two main approaches identified in high-rise zoning within European Cities.

In Paris (as in Rome, Venice, Vienna, Prague, and St. Petersburg), the policy regarding tall buildings is very restrictive to protect the historical value of the city skyline and prevent it from being distorted. A complete ban on high-rise development is imposed on the historic downtown, whilst clusters of high-rise buildings are situated in peripheral areas. The exceptions are such icons as the Notre Dame and the Eiffel Tower, where the tower is acceptable in the city skyline. Paris has relocated modern offices and exceptionally tall buildings to peripheral areas like La Défense to protect its historic skyline. Only iconic structures like Notre Dame and the Eiffel Tower are allowed in the central skyline. However, these heritage-focused policies come at an economic cost. While Paris may excel in the "city as museum" aspect, it does not compete effectively in international financial, insurance, trading, banking, and legal markets.

In contrast, London is characterised by its constant evolution. The city embraces change, takes risks, and is open to mixing different functions, materials, styles, dimensions, and heights. It does not adhere to any singular historical style, whether Georgian, Victorian, or Edwardian. New buildings are expected to contribute to this ongoing tradition of variety and cosmopolitan change, ultimately creating heritage for the future. This philosophy is outlined in London's interim strategic planning guidance. The "Guidance on Tall Buildings", first issued in March 2003, outlines how the CABE (Commission for Architecture and the Built Environment) and English Heritage strongly advocate defining basic requirements for high-rise buildings within local planning documents and establishing evaluation criteria for urban design in the UK. Local authorities were encouraged to use this guidance to evaluate such projects and develop local policies.

Smart High-Rise Development Study focuses on a comprehensive attempt to maximize the benefits of high-rise buildings while minimizing their negative impacts according to:

- Position the building at a suitable distance from existing urban areas, using roads, railway tracks, or green spaces as buffers.
- Ensure access to the main public areas with a clear entrance.
- Serve as a landmark and vantage point for the surrounding area.
- Provide beautiful and accessible public spaces, including a viewing area or dining space on the top floor.
- Include semi-public spaces for recreation and social interaction among residents to foster a sense of community.
- Utilize durable, high-quality materials for long-lasting aesthetic appeal.
- Prioritize underground parking, limit above-ground options, and integrate green spaces.
- Incorporate retail functions into any above-ground parking to enhance street appeal.
- Use renewable technologies for energy and water recovery.
- Manage the building for flexible use, diverse functions, security, and user privacy.
- Complete site development and system installations concurrent with user occupancy.

However, a fundamental aspect in high-rise structures involves ensuring emergency preparedness, particularly concerning fire incidents, which includes establishing effective communication and training protocols to facilitate timely evacuation during a fire emergency. Fire safety is a paramount concern in high-rise buildings, requiring extensive contingency planning due to the challenges of evacuation and rescue in emergencies.

3. Result: Upgraded planning: Smart High-Rise Development Study”

According to the Building Height Regulations outlined in Article 8 of the Ordinance of the Minister of Infrastructure (Dz.U.2022.1225 t.j. z dnia 14.08.2024), a high-rise building is defined as one that exceeds 25 meters but is no taller than 55 meters. Buildings taller than 55 meters are classified as "Tall". However in Gdansk, based on the impact on the cityscape from neighboring streets and courtyards, a high-rise building is defined specifically as a building of a minimum height of 40 meters and an elevation length between 5 and 50 meters, excluding structures such as aerials, masts, electricity pylons, and industrial buildings. As the potential visibility of high-rise buildings is significantly impactful when viewed from nearby streets or distant locations, various architectural designs of such high-rise buildings should be additionally assessed based on visibility analyses from designated vantage points, as well as Local and City Landscape Control Points. Vantage points were established at street level, 12 and 20 meters from the development. These distances were chosen to represent the

typical street width in downtown Gdańsk. The narrower streets are access roads of lesser importance or situated within areas of historic development. In contrast, the broader streets that divide the downtown quarter, such as Grunwaldzka Alley, have an average width of approximately 55 meters at the center of Wrzeszcz.

The document of "Smart High-Rise Development Study" visually identifies areas within a city's planning framework, indicating which locations are: designated[2], recommended[3], appropriate[4] (including restricted), inappropriate[5], or excluded[6] from high-rise development.

The "Smart High-Rise Development Study" aims to develop a remedy procedure for addressing scheduling contingencies in instances where potential conflicts arise around sensitive locations for high-rise developments (See also: table 2).

[2] *Designated areas* selected to develop key landmarks to emphasis or enrich the city's composition, particularly in exceptional locations along the main arteries leading to the city centre (City Gates) but also for Developing Prestige Zones within the Central part of the city along the main communication axis:

[3] *Recommended areas* selected to the exceptional importance of the locations due to the concentration of metropolitan services mostly in the Central part of the city along the main communication axis.
- It complements the values of the integration hub of metropolitan significance.
- It holds special importance in the urban landscape, for example, with the creation of water features.
- It focuses on the revitalisation of the area and its neighbourhoods.
- It closes the compositional axis of the main avenues.

[4] *Areas appropriate (including Restricted Areas)* for High Rise development are located according to their potential i.e. in Central part of the city along the main communication axis, around the transfer and integration hubs, in the Mixed-use districts of the Lower Terrace and Post-shipyard areas. The indicated areas specific for Gdansk context are also Letnica Młyniska industrial district (near the stadium) and Port and logistics distribution centre near the Sucharskiego route.

[5] *Areas inappropriate* designated for natural values protected by any regulations or due to exposure zones
a) Conservation protection zones due to exposure zones of historic complexes.
b) Areas with natural values protected by the Environmental Protection Law, including: Protected landscape areas; NATURA 2000 areas; Tricity Landscape Park buffer zones; Seaside belt (buffer zone); Natural and landscape complexes/Protected corridors in scenic views studies in city scale.
c) Areas with developed urban structures: Compact, low-rise developments; Post-war housing estates and Peripheral areas in relation to the city centre.

[6] *Excluded areas* are those where prohibitions exist due to applicable regulations, such as strict protection of existing uses. Exclusions may arise from cultural, environmental and technical reasons, including:
a) Cultural Reasons: Cemeteries and parks; Manor and palace complexes; Areas listed in the register of monuments, including the vicinity of historic monuments.
b) Environmental Protection Reasons: Forests; Nature reserves; Tricity Landscape Park; Ecological sites; Water bodies.
c) Infrastructure/Technical areas, such as: Airports with height limit zones; Groundwater intakes and protection zones; Waste disposal sites; Agricultural land.

Table 2.
Overall and synthetic presentation of the procedures for the Study of High Rise Development

Designated Places In the northern part of Śródmieście, a problematic area has been identified near Stare Miasto (the Old Town), adjacent to the historic development of Główne Miasto (the Main City), where existing high-rise buildings are located (such as Zieleniak, Prorem, and the Heweliusz Hotel). The construction of these buildings within the buffer zone of Śródmieście and the potential for their reconstruction or expansion has sparked significant controversy and differing opinions between the Heritage Officer for the province and local architects. The area designated for high-rise development is broadly defined as the central part of the city, known as Dolny Taras. However, not every location within this area suits high-rise buildings due to existing regulations or other legitimate concerns.	**Recommended Areas** The recommended areas for high-rise development are specific public spaces of significant importance. These areas are designated as locations where high-rise buildings are encouraged, in prestigious locations, according to either a notable concentration of metropolitan Services or considerable significance in the urban landscape. The local spatial development plans impose no height limits on these recommended areas. Additionally, the procedures and requirements for locating high-rise buildings have been simplified. Most of the recommended areas for high-rise development are located along Grunwaldzka Alley. Within the linear-nodal structure, specific locations have been identified as critical for enhancing functionality and visual appeal at the end of the Hallera axis in the Seaside Belt, due to their significant relevance in the landscape context.	**Appropriate Areas (including Restricted Areas)** Gdańsk aims to complement its urban fabric in the predominantly developed, primarily residential Lower Terrace. Therefore, the document delimits the specific area, which allows for locating high-rise buildings in the Lower Terrace and a few locations in the Upper Terrace to highlight the city's "gateways". From a landscape perspective, the Lower Terrace is preferable for high-rises, as it allows the city skyline to remain framed by the moraine height, preventing buildings from exceeding the height of the hills.
Inappropriate Areas The areas located on the outskirts of the central metropolitan zone have been deemed unsuitable for high-rise buildings and are therefore subject to restrictions. The Upper Terrace is identified as a key area for urban development in terms of housing, services, and transportation, with low-density development and high-quality living standards. The existing and proposed development in these areas and their importance to the urban landscape should highlight the natural and environmental qualities of the Area. This focus necessitates limitations on the size of new buildings, effectively ruling out high-rise construction.	**Excluded Areas** Certain areas, which together occupy 42% of Gdańsk, prohibit high-rise developments. These exclusions are based on established regulations that restrict the construction of high-rise buildings, aiming to protect Gdańsk's cultural heritage and natural environment from high-rise development. There are 12 areas in Gdańsk where high-rise development is forbidden, ensuring strict protection of existing land use and development. The areas excluded from high-rise development due to cultural values (cemeteries, manor park complexes, historic monuments and sites), environmental protection reasons (ecological, nature reserves, water bodies, woods).	**Restricted areas** Areas that protect historic monuments require consent and adherence to the procedures. In other appropriate places, development can proceed based on the local plans, provided that all necessary processes are completed. Therefore, each high-rise proposal will be analyzed individually for its architectural impact and contribution to the cityscape. The aim is to create clusters of high-rise buildings that enhance the city’s dynamics and highlight significant locations such as gateways and district centers. Concentrating high-rise buildings in the Grunwaldzka Alley along the main transport axis is advisable to improve the urban environment for economic and transportation reasons.

Source: own study based on Gdansk Development Agency, "Smart High-Rise Development Study”.

The resulting "Smart High-Rise Development Study" identified potential courses and timelines of action for high-rise development while drawing from national regulations, planning studies, and insights gathered from local interviews. The other cities' experiences, supported by comprehensive planning, provided valuable background information on factors relevant to Gdańsk, which helped identify action lines and risks in the overall urban strategic framework. The consensus reached was limited to locations that received positive feedback from stakeholders and residents, and other areas where high-rise developments are inappropriate but still possible (see also: table 3).

Table 3.
Overall and synthesis of the additional procedure in case of High Rise Development

Area of High Rise	Appropriateness	Method	Special Procedure within the local plan making stage of the Development	Additional recommended elements at the plan making stage of the development	Special requirements related to high rise Development to be considered in local plan and at the plan making stage of the development
Excluded	No	-	-	-	Special requirements accordance with Heritage Office
Inappropriate	no	-	-	-	
Appropriate	Yes/or no	Local plan	Plan draft (1) Presentation of the plan (2) Visualization from control points (3) Environmental impact points (4) Positive opinion of the Commission (5) Laying on for public viewing (6)	Presentation of the concept of the building (1) Visualization from control points (2) Environmental impact assessment (3)	Height limit to 55 m „Flat Foot" on the first floors, Recreational green Area (in residential high rise buildings)
Recommended	Yes	Local plan	Laying out for public viewing (6)	Presentation of the concept of the building	Setting the maximum height of high rise building. Accessible public space Limited parking spaces
		Development Brief Procedure			
Designated places	Yes	Local plan	Laying out for public viewing (6)	Presentation of the concept of the building	Setting the maximum height of high rise building ,
		Development Brief Procedure			

Source: own study based on Gdansk Development Agency, "Smart High-Rise Development Study".

This high-rise policy excluded discussions about Gdańsk's central location, which designates areas for developing well-designed (iconic) high-rise buildings that should be strategically clustered and well-served by public transport. It also identified locations unsuitable for raising high-rise investments. In "appropriate" areas (including restricted areas), the local plan will dictate whether high-rise development is acceptable or banned at any location within its scope. According to the local plan, high-rise buildings are only permitted in these areas.

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Since 2008, the "Smart High-Rise Development Study" policy has designated specific areas in the city for well-designed tall buildings, which should be strategically clustered and accessible by public transport. Some areas have been marked as conditional sites for high-rise developments, while others have been deemed inappropriate for such projects. Areas particularly suited for well-designed tall buildings have been identified, especially around the central location in Gdansk.

3.1. Procedures in the "Smart High-Rise Development Study"

A more lenient procedure is proposed for "recommended" areas and designated places. Here, a high-rise building can be situated according to the local plan. A development brief procedure (a building conditions decision) may be used if no local plan is available. For designated places, the local plan is crucial for specifying the minimum height of a high-rise building, which landscape and aesthetic considerations may influence.

In the recommended areas outlined in the local plan, it is also possible to establish a maximum height for high-rise buildings that considers landscape and aesthetic factors. However, there are no explicit limits on such buildings' height.

The additional procedure builds on the local plan for the recommended area or designated place, which may include additional elements related to the project and public participation. Therefore, the local plan for high-rise development in designated areas prioritizes public participation beyond basic legal requirements and includes the following obligations:

1. Presenting the draft in an accessible graphic format that details the high-rise buildings' locations and specifications.
2. Making the draft available on the website for public comments and local input.
3. Preparing visualizations of high-rise buildings from designated landscape control points.
4. Assessing the potential impact of high-rise buildings on the sustainable environment.
5. Gaining approval from the City's Commission for Architecture and the Built Environment regarding the cityscapes.

6. Providing public access to visualizations, plan drafts, and statutory forecasts. The plan draft outlines the initial phase of planning, addressing critical issues related to functional and spatial structure. While area charts and environmental forecasts will follow, the draft should be easy to understand and encourage public discussion, especially regarding high-rise proposals. Previously presented to the City's Commission for Architecture and the Built Environment, the drafts for high-rise projects will also be posted online, inviting written and online feedback.
7. Community members will select local landscape control points for visualization. Visualizations will integrate the proposed high-rise into panoramas from specified control points, supplemented by panoramic photos. A simplified cuboid representation will be used at this stage, where the investor and architectural designs are not yet available. As plans progress, more detailed visualizations can be developed.
8. The City Development Board will assess the visualizations for approved high-rise projects, serving as an advisory board for the president of Gdańsk.
9. A positive assessment is necessary to advance the planning process and facilitate the development of high-rise buildings in Gdańsk. Assessing the impact on the sustainable environment is an essential aspect of the planning process related to the local plan. However, additional studies, including visualizations and evaluations of the impact on sustainability, will be part of the statutory process for publicly presenting the draft plan. This allows participants to understand better the draft, its justification, and its potential effects, which enables them to make more informed decisions regarding comments and arguments.

The appropriateness of high-rise development is defined in the regions marked as recommended or designated. The local plan may, in justified cases, specify maximum or minimum heights for high-rise buildings based on landscape and aesthetic considerations. When high-rise buildings are proposed through the development brief procedure, the legal regulations determine the application's scope, the decision's contents, and the considerations for granting or refusing the decision.

There is no legal basis for imposing additional requirements on the applicant, and the decision-making body cannot justify its opinions based on criteria outside the law. However, the investor may engage in additional procedures or requirements if they benefit the overall aims. The extra elements of the planning process mentioned above may lead to an expanded application or, in cases of negative assessment or significant social conflict, to a withdrawal of the application (see also: Table 4).

Table 4.
The delimitation areas and the rules of their delimitation for the location of high-rise development

Location	Area [ha](% Gdansk area)	Delimitation Area/ Rules of delimitation	Location of high-Rise Development	Planning permission under
Excluded	11.150 (around 42%)	Excluded Location of High Rise Under regulations	Excluded (with exemptions)	—
Inappropriate	12.200 (around 46%)	Excluded Location of High Rise Under Landscape Reasons	Prohibited	—
Appropriate (including restricted)	3.200 (around 12%)	Possible Location of High Rise not excluded not indicated areas	Allowed	local Area plan
Recommended	186 (around 0,7%)	Appointed Location for High Rise in prestige fragments and indicated areas	Recommended	local Area plan
Designated places	-	Peculiar locations of High Rise according to City Composition	Mandatory	local Area plan

Source: Gdansk Development Agency, "Smart High-Rise Development Study".

The issues addressed in the "Smart High-Rise Development Study" are extensive and cover various aspects of urban life. They lack legal regulations and involve decisions that impact the city for decades. The discussed findings, including urban analyses, are documented in the associated "Smart High-Rise Development Study".

The High-Rise Policy reiterates that the local spatial development plan is the crucial document that dictates the possibility or prohibition of high-rise construction. Additionally, anyone can upload "Smart High-Rise Development Study", an annex to the resolution of the Gdańsk City Council No. XXVIII/764/08 dated September 25, 2008.

Benefits are clear, as the scheduling helps in preventing project delays and ensures adherence to deadlines (reduced risk of deadlines). It has improved project management through a well-defined plan, which allows for a proactive and quicker response to unexpected issues. Crucially, it impacts enhanced stakeholder relationships, as clear communication and proactive mitigation efforts help maintain stakeholder trust and confidence. Last but not least, by preventing cost delays and rework, the co-created additional procedures can contribute to overall project cost savings in the case of high-rise Development.

3.2. Local and City Landscape Control Points for Impact Assessment

Landscape control points are designated sites suitable for high-rise development, which should be naturally located, open, accessible to the public, and integrated with urban spaces. When choosing landscape control points, consider the significant large-scale cultural landscape elements described in the Local Development Policy. Essential features include scenic viewpoints and trails that provide a comprehensive city view.

The four main criteria for selecting Control Points are assessing the recommended and appropriate location from the relevant place (context). The goal is to obtain the fullest possible view over areas deemed suitable for high-rise development (broad scope). Popularity of the viewpoint can be measured by the high number of visitors arriving at the location with a view on areas identified for high-rise development (reception frequency). Due to access limitations, existing high-rise buildings were excluded from consideration as control points. The observation point's tourist appeal was crucial while selecting, as well as easy accessibility, scenic views, available facilities, and additional functions (Promotion).

The Main City Landscape Control Points were divided into the strategic (five) and the Intra-City Points category (four). Local Landscape control points, including street axes, flyovers, natural terrain elevations, and scenic openings, also serve as control points within areas identified for high-rise development.

The characteristic locations of the local landscape control points are supposed to be selected by local inhabitants during a public participation process organized by the investor. A maximum of three points will be chosen each time. For each high-rise building located in the designated areas, the investor must conduct a landscape study covering all specified control points: strategic and intra-city points, and a maximum of three local points determined through a social participation process. This totals ten control points.

Public oversight will necessitate that the investor include the planned high-rise building in view from all control points featured in the Study of High-Rise Development. These visuals must be presented during the Commission for Architecture and the Built Environment sessions or any other group appointed in the participation process.

4. Discussion: Co-creating or consulting the High Rise Planning amendments?

Contrary to Rousseau's belief that "Cities are the abyss of the human species", cities facilitate collaboration and allow humanity to flourish. Urban density enhances knowledge exchange, enabling individuals to learn from one another. As seen with renowned artists and thinkers throughout history, cities foster connections that strengthen our ability to observe, listen, and learn. In Gdansk, facilitating collaboration and allowing residents' participation in building upwards were crucial. While local communities may be apprehensive about constructing a high-rise building nearby, this does not necessarily mean they would oppose such projects in more distant locations.

In Bristol, a social consultation program related to high-rise buildings was conducted under the "Height Matters?" umbrella and carried out in two stages. The first stage focused on gathering comments. A comprehensive and interactive website dedicated to the issue of high-

rise buildings was created and hosted on the Council's official site. All were invited to download copies of the draft Supplementary Planning Document, participate in online discussion groups, and consider the arguments for and against tall buildings. Two seminars on high-rise buildings were held at the Architecture Centre, specifically targeting professionals in the local built environment.

4.1. Social communication, including public consultation

Social communication is essential for exchanging information and interacting within the community. Effective communication requires public authorities to view local communities as equal partners. This interaction should be two-way; public authorities provide information while citizens have channels to express their opinions. When allowed to share their views, citizens can feel like co-managers of local affairs, which increases their willingness to engage in public initiatives.

Consequently, the undertaken framework involved residents and stakeholders in consulting the "Smart High-Rise Development Study" document. Their feedback was instrumental in shaping the final high-rise policy in Gdańsk, which established the following:

1. The definition of critical height for tall buildings in Gdańsk.
2. Specific criteria for determining areas in Gdańsk appropriate (and inappropriate) for tall buildings.
3. Local control points are used to assess the designs of high-rise buildings.
4. Measures to assess and ensure the sustainability and livability of new high-rise developments.
5. The procedure for ensuring public participation in high-rise planning.

In Gdańsk, Public Consultations for the "Smart High-Rise Development Study" focused primarily on raising awareness about creating the draft document related to high-rise buildings and collecting community feedback. The following methods to gather public opinions and encourage creative discussion on this controversial topic include:

- An online survey on high-rise buildings.
- A student competition for high-rise concept ideas.
- Workshops for non-governmental organizations.
- A brainstorming session with the City Development Board.

Despite their potential impact on the surrounding area, residential high-rise buildings can help foster a sense of community among their residents. Therefore, small local communities can be developed, particularly when residents share common traits such as ethnic backgrounds, similar socio-economic statuses, emotional investments in the environment, satisfaction with their living conditions, and a high level of psychological well-being. High-rise buildings may facilitate the creation of these communities by bringing together individuals with similar characteristics.

Key elements contributing to a sense of community include cooperation, care, and concern for shared resources. Therefore, when designing new high-rise buildings, it is advisable to incorporate small communal spaces where residents can meet and engage in informal interactions. An in-depth exploration of the issues related to the perception of high-rise buildings and environmental psychology can be found elsewhere.

4.2. Differences between Public Consultation and Co-creation process

Local plans in Gdansk that allow for high-rise development must first identify the values and limitations of the specific location for such buildings concerning the functional and spatial structure of the urban unit, the existing neighboring developments, and access to public transport. A key reason for placing high-rise buildings is their location; if only essential service buildings of considerable metropolitan significance existed nearby, and efficient transport systems were accessible. Locating high-rise buildings, particularly those with service functions, in the Grunwaldzka Alley and areas designated as suitable will enhance the importance of this spatial structure, activate the city, and contribute to its attractiveness, potentially sparking qualitative changes.

Designated Placesare specific locations identified for the development of notable high-rise buildings. Most of these designated areas, as outlined in the "Smart High-Rise Development Study", are located along Grunwaldzka Alley. They enhance the unique character of specific sites and contribute to the urban structure by incorporating new elements identifiable with the city. These designated places are also strategically selected near major transportation routes leading to the downtown area.

Public consultation and co-creation are both forms of involving stakeholders, but they differ in their level of engagement and influence. Public consultation primarily involves gathering feedback on a pre-defined proposal, while co-creation actively involves stakeholders in defining problems, developing solutions, and making decisions (Open Government Declaration, 2021). The detailed breakdown of issues addressing the co-creation standards is presented in table 5.

Table 5
The detailed breakdown High high-rise study process addressing the standards of cocreation and public consultation (Open government, 2021)

	Public Consultation (PC)	**Co-creation (CC)**	**Framework of the standard (OPD, 2021)**	**High rise study**
Focus:	Gathering feedback on a pre-defined idea, policy, or project	Collaborative development of solutions, often involving diverse stakeholders in the problem definition, solution design, and decision-making processes.	**Transparency: Information regarding** processes, activities, decisions and outcomes should be easily accessible by any interested stakeholder. Proactively publish and disseminate information in the most relevant format and through the most appropriate means throughout the action plan cycle and provide regular progress updates on commitment development and implementation.	CC
Stakeholder Role:	Stakeholders provide input, but the ultimate decision-making power typically rests with the initiating party	Active, collaborative ad co-owners of the process and outcomes.	Inclusive participation: Allow for a diversity of voices to participate in the meaningful process. The process involves identifying priorities and proposing solutions. Conduct outreach to minority or traditionally underrepresented groups and ensure access to information regarding the opportunities for participation and input.	CC
Level of Engagement	More passive, focused on information gathering	More Active participatory and empowering.	Innovation and ambition: Strive to go beyond the minimum requirements outlined here and innovate on ways to develop, co-create and implement ever more ambitious and transformative open government reforms via highly transparent, participatory and collaborative processes. Minimum requirements should be seen as the starting point, not the goal.	CC
Outcome focus:	Consultation aims to refine existing ideas, Public comment on proposed regulations, and surveys on citizen satisfaction with them	Co-creation aims to refine ideas and generate new approaches—joint workshops with stakeholders working together to design a new solution collaboratively developed.	Accountability: Provide clear information about the results of consultation processes and the outcomes of commitment implementation. They should explain, for example, why certain stakeholder priorities were not included as well as the reasons for any changes or delays during commitment implementation.	CC

Source: own study based on Open Government Declaration materials.

The High Rise Study was co-created in 2008, representing an advanced and collaborative approach that went beyond public consultation. It fostered greater commitment among stakeholders and residents and had the potential to lead to more innovative and effective outcomes.

However, the complete application of Participation and Co-Creation Standards published in 2021 took place in 2022. The co-creation process (as an action plan) was guided by four overarching principles derived from the Open Government Declaration:

- Inclusivity in Co-creation: Co-creation ensured that everyone has a voice and a stake in the process. Building psychological safety and leveling the playing field were essential for fostering innovation.
- Decision-Making Power: While the initiating party retains decision-making power in traditional consultations, this time, stakeholders played a more significant role in shaping decisions during co-creation.
- Level of Engagement: The co-creation process emphasized active collaboration and shared ownership (OPD, 2021).

In 2022, the Steering Committee, composed of key decision-makers, facilitated stakeholder engagement in the design process. A series of open meetings and workshops utilized the "World Café" and "Three Horizons" concepts to gather stakeholder preferences and assess urban challenges over time.

The process was organized according to the Open Government standards, specifically providing spaces and mechanisms for ongoing dialogue throughout the action plan cycle.

- Promote shared responsibility for the development and implementation of action plans between the government and civil society.
- Encourage ambition and innovation.
- Ensure that there is a clear understanding of the minimum requirements and facilitate assessments for greater accountability and learning.

Reaching a consensus on spatial solutions in the Gdansk central location has taken over a decade since the initiation of the high-rise study. It has highlighted the need for formal cooperation between public administration entities, social partners, and the local community to address a growing awareness of the economic value of space, particularly in densely built areas with established technical and transport infrastructure (such as roads and public transport), and social infrastructure (including health services, schools, and kindergartens). The socio-economic and spatial conditions make the Lower Terrace a prime location for high-rise buildings. With its historic architecture, the 19th-century Wrzeszcz, the post-Cistercian Oliwa, and the areas along the Seaside attract investors due to their distinct character or *genius loci*, and a sea view adds exceptional value, given that Gdańsk is a seaside metropolis.

5. Summary

The "Smart High-Rise Development Study" in Gdańsk focused on a scheduling contingency while it was co-created. This concept of detailing the additional procedure involved allocating extra time in the project planning to accommodate unexpected delays or issues that may arise during the development process. In Gdańsk, it is especially crucial to include this additional time, as high-rise developers must engage with the public participatory process and comply with the city's specific requirements. Proper high-rise planning procedure is vital; failing to do so could jeopardize planning deadlines and lead to dissatisfaction among stakeholders and community members. A contingency approach requires strategies that balance economic interests with community preservation efforts. Asseraf et al. highlighted the marketing and organizational aspects of contingency planning, emphasizing the importance of effectively communicating potential benefits to stakeholders and securing community support for new development projects (Tamošaitienė et al., 2013). This underscores the need for strategic outreach and engagement efforts as part of broader contingency measures, aiming to minimize community pushback while promoting acceptance of high-rise developments.

Planned high-rise developments often provoke protests from residents, typically stemming from NIMBY (Not In My Back Yard) attitudes, where residents have negative feelings toward developments in their immediate area, despite overall support for similar projects elsewhere. Thus, incorporating scheduling contingency into high-rise planning through the "Smart High-Rise Development Study" helps to structure the public involvement process. On the other hand, although scheduling contingency planning could revive the meaning of planning as a rational and deterministic (thus fair) approach, the presented attempts limit public involvement to only a scope that can be controlled, and therefore, the one that all stakeholders in the high-rise development process can accept.

The local development plan, commonly known as the local plan, is a crucial document determining whether high-rise buildings can be located in the specified areas (locations are designated, recommended, appropriate (including restricted), inappropriate, or excluded from high-rise development). In areas classified as "excluded" and "inappropriate", the plan will prohibit high-rise development, except for specific instances involving high-rise buildings in excluded areas that are recorded as historic monuments and have received consent from the Heritage Officer.

The standard comprehensive planning procedure effectively addresses the complex environmental, aesthetic, and height-related concerns associated with high-rise buildings. However, it tends to overlook potential social conflicts that may arise during the planning process. To mitigate this issue, the presented approach involves implementing specific procedures that allocate sufficient time to address anticipated conflicts. This proactive strategy aims to prevent delays and the escalation of more serious conflicts by addressing them directly.

The "Smart High-Rise Development Study" within city planning requires a multifaceted approach considering economic viability, social equity, environmental sustainability, and aesthetic coherence. This framework focuses on scheduling and managing conflicts, promoting a holistic approach that integrates economic viability with community welfare and environmental sustainability. It emphasises stakeholder engagement planning and interdisciplinary collaboration, bridging the gap between urban growth and community values, ultimately facilitating a more harmonious coexistence of high-rise structures within the urban environment.

Acknowledgements

This project received funding from the European Union's Horizon 2020 Research and Innovation program (GA No 730254) under the JPI Urban Europe's call „SUGI - FWE NEXUS". This project has received funding from the National Science Centre, Poland (2017/25/Z/HS6/03050).

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SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

CHATGPT GAINS IMPACT IN EDUCATION AND RESEARCH: POTENTIAL, BENEFITS, AND CHALLENGES

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Purpose: The aim of this paper is to provide a comprehensive analysis of ChatGPT's role in education and research, highlighting its capabilities, benefits, limitations, and ethical implications. The study investigates how AI-assisted tools like ChatGPT are transforming academic practices and contributing to the evolution of digital education.
Design/methodology/approach: A qualitative analytical approach is employed, using ChatGPT as a case study to explore its applications in academic writing, research support, and knowledge dissemination, integrating insights from recent literature and theoretical frameworks on AI in education.
Findings: The study reveals that ChatGPT enhances academic effectiveness by facilitating writing processes, supporting research methodologies, and providing instant access to information. However, it also identifies limitations such as potential biases, overreliance on AI, and challenges in ensuring academic integrity. The paper outlines possible future developments in AI-assisted learning and research.
Research limitations/implications: The paper is limited by its focus on ChatGPT as a single AI model and does not include empirical data from user surveys or experiments. Future research should explore comparative analyses of different AI tools and assess long-term impacts on learning outcomes and research quality. In addition, the conceptual model introduced here requires empirical validation through pilot studies in higher education settings, examining its practical feasibility, ethical compliance, and institutional applicability. Such studies would enable refinement of the framework and its adaptation to diverse academic contexts.
Practical implications: A model for the effective integration of AI tools in academic environments is proposed, including advice on responsible use, training for educators and students, and strategies to enhance digital literacy.
Social implications: The paper discusses ethical considerations such as data privacy, authorship, and the risk of misinformation. It emphasizes the need for responsible AI integration and the development of policies to ensure equitable access and ethical use in education.
Originality/value: This paper offers a timely and in-depth examination of ChatGPT's educational and research potential, providing valuable insights for educators, researchers, policymakers, and developers of educational technologies. It contributes to the ongoing discourse on AI's role in shaping the future of academia.
Keywords: ChatGPT, artificial intelligence, digital education, academic research, AI-assisted learning, ethical considerations, future developments.
Category of the paper: Viewpoint.

1. Introduction

The integration of artificial intelligence (AI) into education and research is transforming traditional paradigms of knowledge acquisition, processing, and dissemination. AI-powered tools, such as ChatGPT, offer unprecedented opportunities for students, educators, and researchers to access large amounts of information, automate writing processes, and enhance academic effectiveness. As AI technology continues to evolve, understanding its implications for education and research becomes increasingly important (Wang, Fan, 2025).

ChatGPT, developed by OpenAI, is a conversational AI model based on deep learning and natural language processing (NLP) algorithms. Trained on extensive textual data, it generates human-like responses to a wide range of queries, making it a valuable resource for educational and research purposes. However, as with any technological advancement, the adoption of ChatGPT presents both opportunities and challenges that require critical evaluation.

This paper aims to provide a comprehensive analysis of ChatGPT's role in education and research, addressing its benefits, challenges, and the ethical considerations associated with AI-assisted learning. Despite a growing number of studies on AI in education, few have proposed or tested comprehensive governance frameworks for responsible ChatGPT integration. Additionally, recommendations for enhancing the potential of AI-driven tools in academic environments will be proposed.

While many researchers acknowledge the benefits of AI in optimizing learning processes, concerns related to reliability, ethical considerations, and the potential for misinformation remain (Smith et al., 2023; Johnson, Lee, 2024). Recent studies have explored the impact of AI-driven educational tools, particularly in the wake of the COVID-19 pandemic, when online learning and digital education resources became a necessity (Bozkurt et al., 2022; Camilleri, 2021). Although AI-assisted education offers advantages such as instant feedback, personalized tutoring, and automated research assistance, its effectiveness in diverse academic environments remains under scrutiny (Bettayeb et al., 2024; Kosmyna et al., 2025).

This study aims to identify the primary factors influencing the effectiveness and acceptance of ChatGPT in higher education and research.

2. Patterns of user interaction with ChatGPT

Users interact with ChatGPT for a diverse range of academic and research-related inquiries (fig. 1).

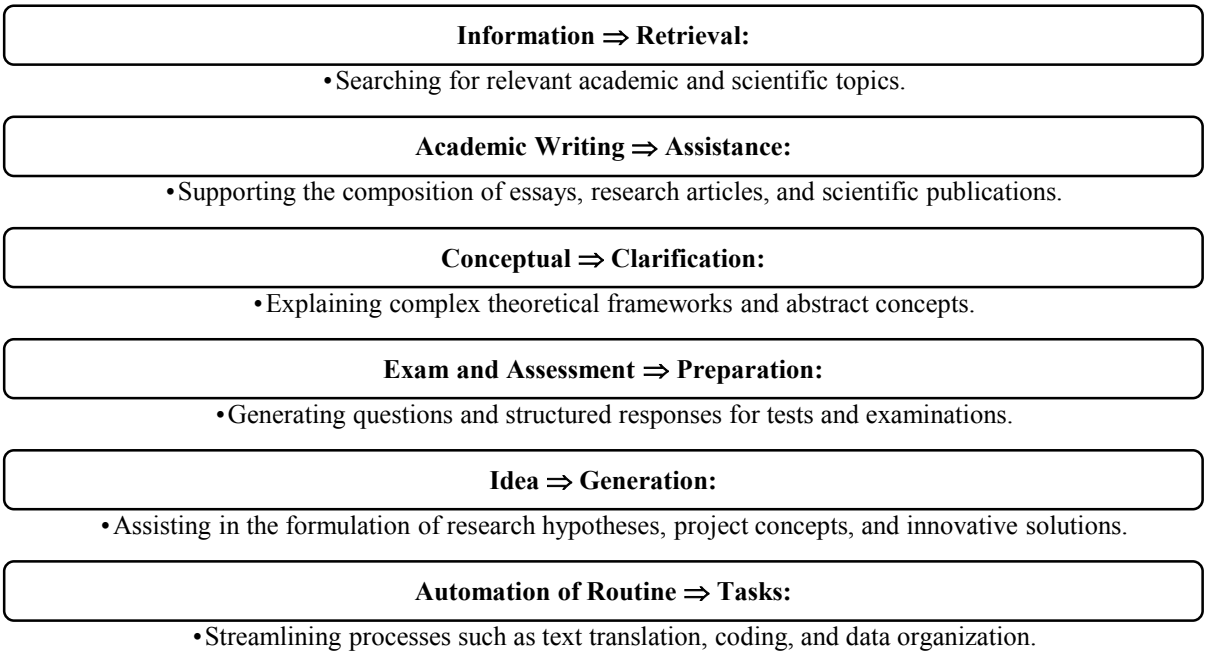

Figure 1. Typical academic and research-related queries to ChatGPT.

These functionalities highlight ChatGPT's potential as a versatile tool in higher education, enhancing efficiency in both learning and academic research. Its integration, however, requires careful consideration of accuracy, ethical implications, and potential effects on cognitive development. The use of ChatGPT in the learning process provides several key benefits. First, accessibility: it is available 24/7, allowing students to receive support at any time, regardless of location (Rajabi et al., 2024; Yu et al., 2024). Second, efficiency: it delivers instant responses, accelerating information retrieval and enabling learners to focus on higher-order cognitive tasks (Baig, Yadegaridehkordi, 2024). Third, personalization: ChatGPT adapts its outputs to the user's knowledge level, facilitating individualized learning experiences (Bettayeb et al., 2024). Fourth, versatility: it supports a broad spectrum of academic activities, including text composition, programming, and data analysis (Gill et al., 2024). Fifth, interactivity: functioning as a virtual tutor or discussion partner, ChatGPT promotes engagement and deeper understanding of complex topics. By combining these advantages, ChatGPT can substantially improve accessibility and efficiency in education, empowering both students and educators with an innovative digital learning tool. Nonetheless, its effectiveness depends on responsible usage, critical evaluation of outputs, and integration within structured educational frameworks. Despite these benefits, several limitations (fig. 2) – such as variable accuracy, potential ethical concerns, and risks to the development of critical thinking – must be carefully considered (Kosmyna et al., 2025).

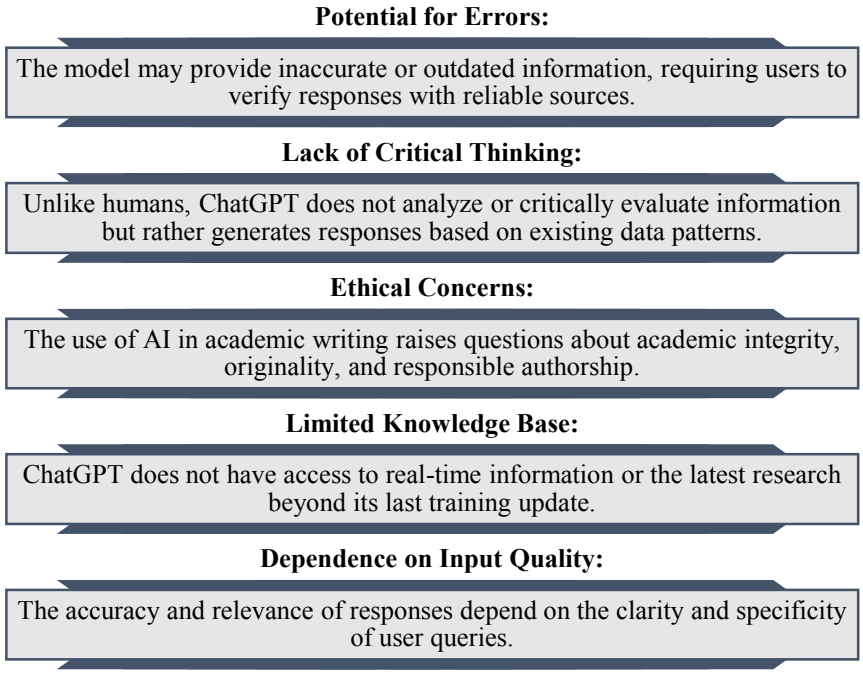

Figure 2. Major limitations and challenges of ChatGPT use in education.

While ChatGPT serves as a valuable educational tool, it should be used thoughtfully, complementing – rather than replacing – human reasoning, research skills, and ethical academic practices.

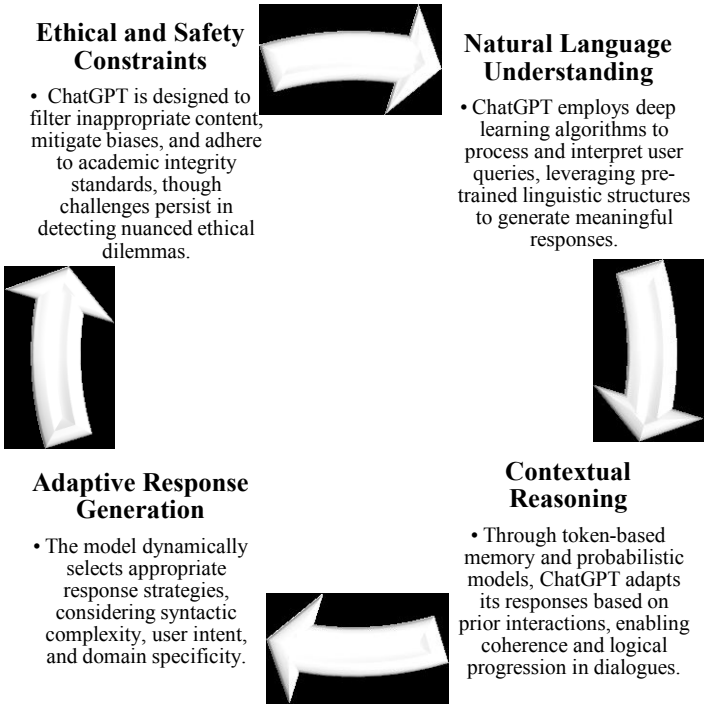

Figure 3. A model for effective integration of ChatGPT into the academic environment.

The proposed model (fig. 3) consists of four core components that structure ChatGPT's interaction with users in educational settings. These components operate within an iterative feedback loop, in which user inputs continuously refine AI-generated responses, enhancing

both accuracy and contextual relevance. The model serves as a conceptual foundation that can be further validated through institutional pilot implementations and comparative studies.

3. Applications and advantages of ChatGPT in education and research

ChatGPT's impact on education and research can be observed across multiple dimensions. It facilitates knowledge expansion by supporting students in understanding complex concepts and supplementing traditional learning materials. It also provides substantial assistance in academic writing, helping users draft research papers, organize arguments, and refine language, while necessitating careful validation of sources. In terms of research methodology, ChatGPT streamlines literature reviews, data interpretation, and hypothesis formulation, improving efficiency during the early stages of research. At the same time, it presents challenges to critical thinking, as AI-generated responses cannot replace human analytical reasoning and require ongoing oversight.

Ethical considerations are equally important, as AI-generated content must align with academic integrity standards, ensuring transparency in AI-assisted research. Additionally, ChatGPT does not have access to real-time data, potentially limiting the relevance of the information.

AI responses may reflect biases present in the training data, requiring ongoing refinement. Furthermore, while ChatGPT provides general knowledge, highly specialized academic discourse may still require human expertise, and AI-generated content should be supplemented with plagiarism detection tools to ensure its originality.

That is why future improvements will focus on integrating real-time data retrieval, enhancing AI model transparency, and refining context-awareness algorithms to maximize its effectiveness as an educational and research tool.

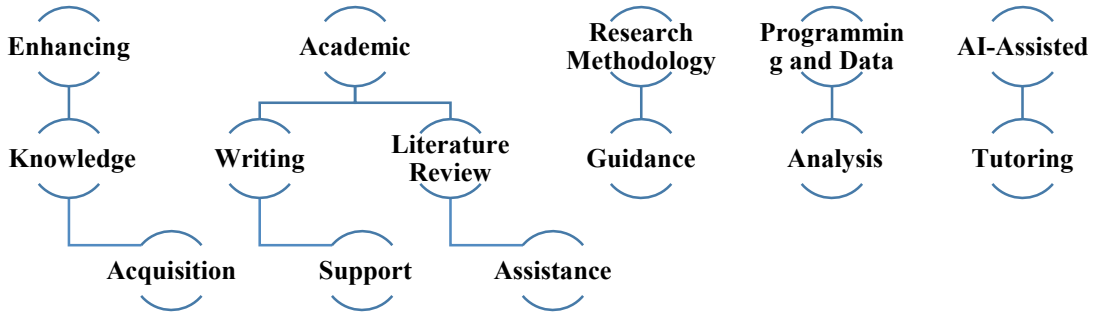

Figure 4. ChatGPT's capabilities and applications in academia.

ChatGPT's functionality extends across multiple domains, making it a versatile and valuable tool for academic use. Its integration into education and research has reshaped how students learn, how educators teach, and how researchers conduct studies. The following applications illustrate ChatGPT's most significant contributions to academia (fig. 4).

Knowledge Acquisition and Learning Support

ChatGPT serves as an intelligent learning assistant, helping students and educators clarify complex concepts, summarize academic materials, and explain theoretical ideas in easy-to-understand terms. By offering adaptive responses tailored to user input, it supports self-paced learning and accommodates diverse learning styles.

Academic Writing and Research Assistance

Researchers and students increasingly use ChatGPT for writing-related tasks such as drafting manuscripts, structuring essays, generating research questions, and refining arguments. It assists in paraphrasing, improving grammar, and formatting citations, which enhances the clarity and coherence of academic writing. It also helps organize literature reviews, synthesize findings, and design research methodologies.

Programming, Data Analysis, and Technical Support

In scientific and technical disciplines, ChatGPT provides guidance in coding, debugging, and data visualization. It assists with interpreting results, explaining algorithms, and supporting the application of statistical and computational methods across various research contexts.

Administrative and Tutoring Applications

AI-assisted tools based on ChatGPT are increasingly used for routine academic tasks, including grading, scheduling, and document generation. Educators integrate ChatGPT into e-learning platforms to create virtual tutors that deliver real-time feedback, generate practice questions, and encourage interactive learning.

Collectively, these applications demonstrate ChatGPT's potential to enhance accessibility, streamline academic workflows, and foster innovation in both teaching and research.

4. Facets of ChatGPT integration into higher education and academia

4.1. Challenges and Limitations

Despite its growing usefulness, ChatGPT also presents several challenges that must be addressed to ensure responsible integration into academia:

- Accuracy and Reliability: AI-generated responses may contain factual inaccuracies or outdated information and should always be verified against credible sources.
- Contextual Limitations: ChatGPT may oversimplify complex academic discourse or lack depth in specialized fields.
- Ethical and Integrity Concerns: Unregulated use of AI may lead to issues of plagiarism, authorship and intellectual transparency.
- AI Dependency: Overuse or misuse can reduce students' critical thinking and problem-solving abilities.
- Bias and Data Constraints: Since ChatGPT is trained on large datasets, inherent biases can affect its objectivity, and it lacks real-time access to the latest research.

Recognizing these limitations is crucial to maintaining balance between technological innovation and human judgment.

4.2. Ethical Considerations and Responsible AI Use

Ethical integration of ChatGPT in education and research requires institutional guidelines and individual responsibility. The following principles are essential:

- Transparency and Disclosure: Users should acknowledge AI assistance in academic work to maintain intellectual honesty.
- Plagiarism Prevention: Clear standards must define acceptable AI use to ensure originality and proper attribution.
- Data Privacy and Security: Institutions must protect user information and comply with data protection regulations.
- Bias Awareness: Continuous monitoring and model improvement are necessary to minimize bias in AI-generated content.
- AI Literacy and Ethics Education: Students and educators should be trained to critically evaluate AI outputs and use them responsibly.

These measures ensure that AI enhances learning and research without undermining academic integrity (Oncioiu et al., 2025).

5. Future directions and desired improvements

In the end, it would seem that the following strategies may help achieve further progress in AI to enhance ChatGPT's educational and research potential (fig. 5).

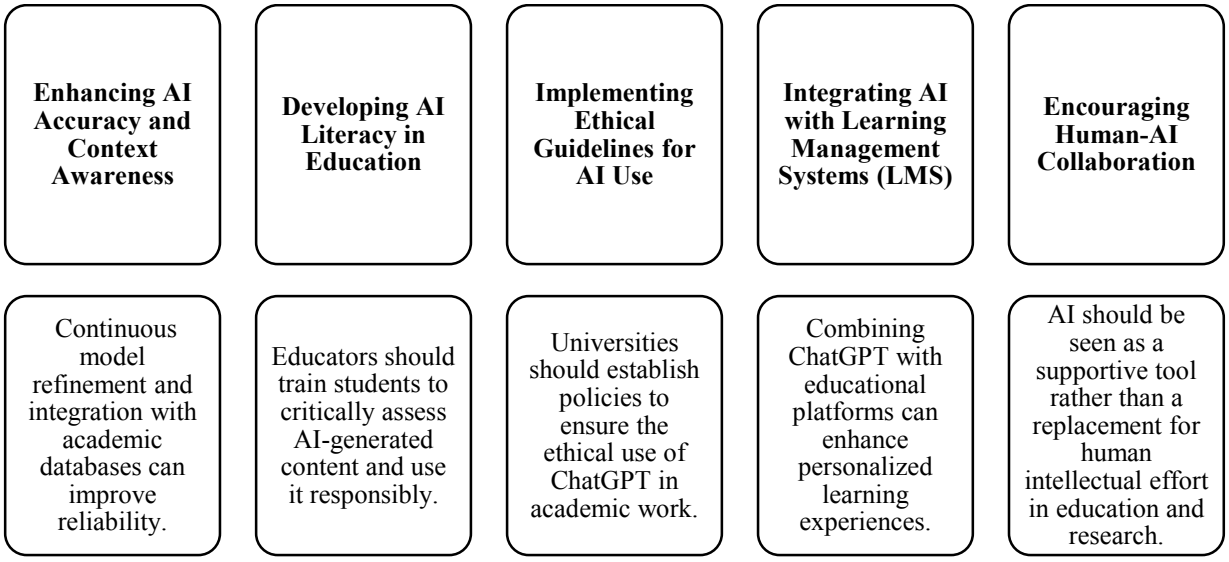

Figure 5. Future directions and recommended strategies.

These directions will help balance technological innovation with ethical and pedagogical responsibility.

6. Conclusions

The study highlights the significant potential of AI, particularly tools like ChatGPT, to transform education and research. AI can enhance academic processes across a wide range of areas, including personalized learning, research support, automation of routine tasks, ethical compliance, faculty development, and integration into educational programs. By supporting adaptive learning environments, AI can accommodate students' individual needs and learning styles, while intelligent tutoring systems provide targeted guidance and immediate feedback, encouraging self-paced and self-governing learning. At the same time, AI streamlines administrative and research-related tasks, such as grading, data management, and data analysis, allowing educators and researchers to focus on higher-order cognitive activities, including critical thinking, hypothesis development, and innovative problem-solving. In a research context, AI facilitates the analysis of large datasets, enabling the identification of patterns, trends, and correlations, while also assisting in generating hypotheses and new ideas, supporting both exploratory and interdisciplinary scientific research.

The ethical and social implications of AI use in academia are equally important. Ensuring data privacy, security, and adherence to ethical standards is critical to maintaining fairness, transparency, and academic integrity. Responsible integration of AI minimizes the risks of bias, misinformation, and plagiarism while promoting equitable and effective learning and research practices. Faculty development is essential for the successful implementation of AI,

as educators must acquire the skills to use AI tools effectively in teaching, research, and administrative functions. Training programs, workshops, and ongoing support enhance the ability of faculty to integrate AI into their professional practice, increasing instructional quality and research productivity. Similarly, incorporating AI into educational programs prepares students for working with emerging technologies and provides opportunities for applied learning through practical exercises, laboratory work, and project-based assignments, which develop hands-on skills alongside theoretical knowledge.

AI tools like ChatGPT represent a transformative opportunity for education and research. Their successful adoption relies on careful management of accuracy, ethical considerations, and adaptability across disciplines. When used responsibly as a complementary tool rather than a replacement for human expertise, AI can enhance academic productivity, foster innovation, and support effective learning while maintaining scholarly integrity. With a balanced and responsible approach, AI can serve as a valuable asset in shaping the future of education and scientific research.

Furthermore, to ensure responsible and sustainable adoption of AI-assisted tools, universities should establish institutional frameworks for AI governance. These frameworks could include regular monitoring of AI use in academic activities, ethical review procedures for AI-generated work, and the creation of dedicated committees for digital integrity. Establishing transparent policies, audit mechanisms, and continuous training for both students and staff would make the proposed model operational and measurable in real academic environments. This would bridge the gap between conceptual recommendations and institutional practice, enhancing the practical contribution of the study.

Acknowledgements

I would like to express my sincere gratitude to Dr. Mariia Holovchak for her valuable advice during the writing of this article and her great assistance in preparing the manuscript.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

ART COLLECTIONS OF FINANCIAL INSTITUTIONS— FROM PRESTIGE TO SOCIAL AND CULTURAL IMPACT

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Purpose: Financial institutions gather art collections. The goal of this paper is to compare collections of international and Polish financial institutions, identify the main goals of creating such collections, and determine how those goals, together with art market conditions, impact the structure of those art collections.
Design/methodology/approach: Key information on art collections of international financial institutions is followed by more detailed descriptions of Deutsche Bank and UniCredit art collections. Those collections are compared to collections of Bank Pekao, PKO Bank Polski, ING Bank Śląski, and mBank.
Findings: Established international financial institutions focus on prestigious art pieces that are exhibited and loaned. Both European and Polish financial institutions do not attempt to gather expensive, prestigious art pieces but rather focus on the social impact they can have by supporting young artists.
Research limitations/implications: Further research into art as an investment asset and art investing strategies can explain to what extent collections of financial institutions can be perceived as investments.
Practical implications: Corporations willing to collect art must consider not only the resale value of art but also the social and cultural impact collecting art creates. Together with the maturity of the local art market, those factors imply whether corporate art collection should focus on young artists or gather prestigious art pieces of well-established creators.
Social implications: Corporate art collections can maximize social impact through the right art collecting strategy. Proper balancing between prestige brought by collecting and exhibiting art versus supporting young artists can maximize the social impact of such collections.
Originality/value: This research contributes to discussion on art as an investment asset that has profound social impact. Collecting strategy does not have the same structure as investment strategy. In this paper, the social impact of collecting art is considered the main driver of financial institutions' investments.
Keywords: art investments, financial institutions, art valuation, social impact of art.
Category of the paper: research paper.

1. Introduction

Art has historically been regarded as a source of prestige and as a confirmation of the social status of its owner. Early patrons of the arts supported artists out of recognition of the broader social significance of art. For example, Leonardo da Vinci received support from the Medici family. Enterprises also engaged in art collecting. The purpose of this text is to examine how financial institutions assemble their art collections and to consider whether these collections can be viewed as portfolios of investment assets. Nevertheless, it is also necessary to consider these collections primarily as attestations of the market position of these institutions.

To frame this inquiry, the strategies of financial institutions pertaining to the art market are also a subject of interest. Analyzing and comparing these strategies enables a deeper understanding of how financial institutions perceive not only the art market itself but also their social responsibility and the impact of investing in works of art on the development of this market.

In the context of banking activities, the literature on "art banking", as defined by M. Zaleska (Zaleska, Kozińska, 2022), provides a definition of art banking, which is central to that discourse. However, the subject of our inquiry concerns a different phenomenon, which can be termed "art in banking". This refers to the perspective of banks on art and the art market as integral elements of their broader social and market environment. This is particularly relevant for European banks, which, in accordance with the Sustainable Finance Disclosure Regulation (SFDR), are required to disclose their social impact and broader influence not only on financial markets but also on society at large.

When we consider the investment market, we usually think about financial markets. Those are markets in which the objects of trade are mostly financial assets. These assets are easily valued and relatively liquid. This means that if we wish to treat works of art similarly, we must thoroughly understand the limitations inherent to art as an asset. These limitations include restricted liquidity and a valuation based on the perceived value of the asset, rather than on its fundamental value reflected in its future cash flows (Evans et al., 2017; Szyszka, 2023).

Against this backdrop, the transformation of artistic patronage in the financial sector refers to the shift in the role of financial institutions—from traditional cultural sponsors to active creators of image and social strategies through art. Banks and other financial institutions increasingly treat art collections as a tool for building brands, stakeholder relationships, and symbolic capital, which, according to Bourdieu (1989), functions as a form of social currency. At the same time, scholars have argued for broadening the investment spectrum to include asset classes traditionally excluded from mass trading, such as art and other collectibles. From this perspective, art is analyzed as a financial asset, with researchers applying market-based tools to evaluate its returns and attractiveness to investors (Mei, Moses, 2002; Biey, Zanola, 1999; Li et al., 2022; Barro et al., 2023).

These two perspectives—art as symbolic capital and art as a financial asset—are often presented separately in the literature but rarely synthesized. The symbolic approach emphasizes art's capacity to generate prestige, legitimacy, and social differentiation, while financial studies highlight its measurable risk-return profile and market volatility. A conceptual integration suggests that in the banking sector, art functions simultaneously on both levels: as symbolic currency that enhances institutional legitimacy and as a financial instrument embedded in uncertain markets. This duality reveals a tension but also a complementarity between symbolic and financial interpretations, indicating that the value of art for banks cannot be reduced to a single dimension.

In an attempt to synthesize these points, two trends can be identified. On the one hand, art is ceasing to be merely a confirmation of status or prestige and is instead becoming an instrument for building social and cultural capital. On the other hand, many investors postulate that art, owing to its limited supply, can be treated as an investment asset comparable to others. These two trends are not mutually exclusive, but their significance in the contemporary art market is highly varied. It is evident, however, that while the first trend is successfully developing and is confirmed by the decisions of financial institutions, the second case is less straightforward (Mei, Moses, 2002). The revealed preferences of financial institutions indicate a marginalization of art's role as an asset. This stems from its risk profile, the illiquidity of the market—even for works by established artists—and the challenges associated with the valuation of art assets.

A comprehensive study was conducted on significant art collections held by European and Polish financial institutions. The selection focused on large collections that can serve as benchmarks for trends in art collecting within the financial sector. The selection of the Deutsche Bank Collection and the UniCredit Art Collection for analysis stems from their significance and scale within the financial sector. Both rank among the largest and most recognizable corporate art collections in the world. They share the characteristic of having been developed within an internal model, that is, within the structures of the existing organization, and of being utilized in brand building, CSR strategies, and stakeholder relations. They differ, however, in strategy and profile: Deutsche Bank focused on contemporary art, primarily works on paper and photography by living artists, whereas UniCredit assembles works ranging from the fifteenth century to the present, combining the heritage of several European countries. The analysis also includes a comparative overview of art collections held by selected Polish banks, providing additional context and enabling the identification of similarities and differences between domestic and international approaches to corporate collection, and is followed by an overview of trends and strategic implications.

2. Literature review

Throughout history, the relationship between banking and the arts has been closely intertwined. Artistic patronage has long served as a tool for bankers to enhance their social status—a prime example being the Medici family, whose sustained support for artists helped them achieve public acclaim, political power, and noble rank (Campa, Zijlmans, 2019).

Corporate art collections are typically owned by the business entity rather than by individuals within the organization. These collections may be distributed across multiple office locations or stored at a central site. Initially, such collections were regarded as long-term investments, intended to be passed down from generation to generation. The emergence of corporate art collections dates to the 1950s, with David Rockefeller's initiative at Chase Manhattan Bank serving as a notable example. The phenomenon gained momentum in the 1960s, when companies increasingly recognized the potential of art to enhance their brand identity and corporate image (Forster, 2024). In the 1960s—and even into the 1990s—investment value and reputation-building were primary motivations for many corporate collections. Strategically placing significant artworks in spaces such as lobbies or conference rooms served both aesthetic and symbolic functions related to prestige-building and communication of the company's values and standing. However, contemporary corporate collections have shifted away from acquiring expensive, high-profile works, opting instead for more accessible pieces created by emerging artists. This change reflects a broader evolution in the goals and motivations behind corporate collecting. Today, corporate art collections are used not only to support brand-building and convey a company's heritage (Wu, Shen, 2013) but also to attract talent and reflect core values and organizational culture, foster greater employee engagement by enhancing creativity, motivation, and overall productivity (Lewandowska, 2015; Nissley, 2010). Financial motives have clearly taken a back seat. Greater emphasis was placed on the artworks' content, artistic expression, and the promotion of emerging talents.

Building and managing corporate art collections with banks constitutes a form of cultural asset management (Apollonio et al., 2019) embedded in both organizational and strategic structures. It combines branding, risk management, image building, and social value creation—precisely the core concerns of contemporary cultural asset management.

The literature on art valuation remains relatively limited, though it highlights the complexity of the process (Beckert et al., 2017). As Galbraith and Hodgson (2018) note, valuation can be carried out using hedonic models, forecasting methods, or a combination of both—especially in cases where clear market data is lacking. Plante (2021), on the other hand, emphasizes that the value of an artwork is influenced not only by specific factors (such as certification or value projections) but also by how these factors are assessed and interpreted by experts. Thus, what is considered valuable depends heavily on context, such as the market, institutional settings, or the views of the art world. Although the valuation of artworks is applied in numerous

areas—such as collection building, investment decisions, sales transactions, tax planning, and insurance—the practices related to determining the value of cultural assets remain poorly defined. As Çalışkan and Callon (2009) point out, there is a lack of clear frameworks and definitions describing how the valuation process operates in relation to art.

The literature on art investment presents a nuanced picture of its profitability and risk. The study by Barro et al. (2023) suggests that art can effectively diversify an investment portfolio due to its attractive risk-return profile and low correlation with other assets, performing well in portfolio optimization models with limited liquidity and seasonal return patterns. In turn, Li et al. (2022) demonstrate that paintings and drawings offer moderate but stable returns, especially when sourced from reputable channels. Although their Sharpe ratio is lower than that of traditional assets, they can still complement a well-diversified portfolio. Ultimately, overseeing art assets enables companies to broaden their investment portfolio, although determining the ideal share of capital to allocate to art remains difficult to define precisely (Mei, Moses, 2002). Meanwhile, research by Stoppelmann (2008) points out that although art achieved a high annual return (12%), investing in it involves substantial risk, low market correlation, and high transaction costs, making it a more complex investment area that requires knowledge, capital, and personal commitment.

In the global context of corporate bank art collections, those of Deutsche Bank (57,000-60,000 artworks; Argun, 2024) and UniCredit (60,000 artworks; Maida, 2021) clearly stand out as the most extensive in terms of size. By comparison, other notable bank collections are Bank of America (60,000 artworks; Khan, n.d.), Intesa Sanpaolo (30,000 artworks; Piras, 2019), Montepaschi Banca (30,000 artworks; Piras, 2019), JPMorgan Chase (30,000 artworks; Khan, n.d.), BANCO BPM (19,000 artworks; Piras, 2019), BPER Banca (10,000 artworks; Piras, 2019), UBI Banca (6000 artworks; Piras, 2019), Belfus Bank (4300 artworks; *Inspired by Love, n.d.*), UBS (around 1500 artworks inherited from Credit Suisse; Heeb, 2025), Société Générale (1,320 artworks; Khan, n.d.), and Crédit Agricole (several hundred artworks; Khan, n.d.).

It is worth noting, in addition to building their own corporate art collections, banks also provide *art banking* services, which refer to the acquisition of artworks as investment assets within private banking services (Zaleska, Kozińska, 2022).

3. Methods

The research method applied in the study was based on analysis of key information concerning the art collections of both international and Polish financial institutions, with particular focus on the detailed description and comparison of Deutsche Bank and UniCredit collections with those of Polish banks: Bank Pekao, PKO Bank Polski, ING Bank Śląski, and mBank. The choice of the Deutsche Bank Collection and the UniCredit Art

Collection for analysis was determined by their significance and scale in the financial sector, as they are among the largest and most renowned corporate art collections in the world. Both collections have developed within an internal organization model and are utilized for branding, CSR strategies, and stakeholder relations. The analysis also includes a review of the art collections held by selected Polish banks, aimed at providing additional context and enabling the identification of similarities and differences between approaches of different financial institutions.

We base our research on publicly available information. There are several sources discussing DB and UniCredit collections, while there is very limited information on mBank, ING, and Pekao collections. We acknowledge this as a limitation of our research, but nevertheless we can demonstrate relevant trends in the development of art collections of financial institutions.

4. Results

The research analyzes key information on the art collections of international and Polish financial institutions, with a focus on Deutsche Bank and UniCredit due to their scale and global recognition. These collections are examined in terms of organizational models, branding, CSR strategies, and stakeholder relations. For context, the study also reviews selected Polish banks (Bank Pekao, PKO Bank Polski, ING Bank Śląski, and mBank) to identify similarities and differences between domestic and international approaches.

4.1. Deutsche Bank's Art Collection: A Strategic Investment in Corporate Image

With over 55,000 works by artists of the 20th and 21st centuries, the Deutsche Bank Art Collection ranks among the largest corporate art collections in the world. Its core focus lies in contemporary works on paper and photography (Deutsche Bank versteigert Kunstwerke in Millionenwert, 2020). The Deutsche Bank Collection represents not only an aesthetic enrichment of the workspace but also a key component of the institution's social responsibility and cultural engagement—integrating art into the everyday working environment and making it accessible to a broad audience (*Concept*, n.d.).

4.1.1. Genesis and Development (from 1978 onwards)

Deutsche Bank's engagement with art began in the late 1970s with a modest yet pioneering concept: that works on paper should be accessible to a broad audience rather than confined to storage rooms or executive offices. The initiative took shape in 1978 with the first curated display in the bank's New York premises and culminated in 1986 with the opening of its new global headquarters in Frankfurt's Twin Towers (Khan, 2021). The collection is distributed across numerous locations worldwide, primarily within the bank's office spaces. However,

three principal locations—Frankfurt, London, and New York—are of particular importance, as they feature the most prominent and representative parts of the collection. The Deutsche Bank Collection in Frankfurt is housed in the bank's refurbished towers, which exemplify contemporary standards of sustainable development. Initially, beginning in the 1960s, the space served exclusively as a survey of postwar German art. Today, however, the collection has a global scope—reflecting the diversity of contemporary art scenes in Asia, South America, and Africa. Each of the 60 floors is dedicated to a single artist, with the collection encompassing approximately 100 artists from over 40 countries. The works are presented according to a geographic structure: Tower A showcases the European *avant-garde*, while Tower B features artists from other regions of the world (*Concept*, n.d.). The Deutsche Bank Collection in the United Kingdom is primarily displayed at the bank's London headquarters at 21 Moorfields. Like the bank's other collections worldwide, it focuses on works on paper and photography by contemporary international artists. It has not only supported the work of innovative artists from around the globe but also clearly reflects Deutsche Bank's values of diversity and inclusion. The collection features work by over 100 artists from 27 countries, 49% of whom identify as women, transgender, or non-binary, and 48% as members of ethnic and racial minority groups (*The UK Collection*, n.d.). The Deutsche Bank Collection in America is primarily displayed in the bank's offices in New York and Jacksonville. At the Deutsche Bank Center in New York's Columbus Circle, the collection reflects the city's dynamic and globally recognized contemporary art scene. The artists featured across the building's communal spaces embody the international character of the bank's operations, clients, and employees. The collection includes artists from over 20 countries, with full gender representation; more than 40% of the artists identify as members of racial and ethnic minority groups. This reflects the bank's ongoing commitment to diversity and inclusion (*The Americas Collection*, n.d.). Apart from its headquarters, Deutsche Bank displays artworks in over 600 of its offices and branches worldwide (Davis, 2022).

4.1.2. Ownership Structure and Governance

The decision not to establish a separate foundation reflects a strategic intention to integrate art directly into the operational structure and corporate identity of the bank. Deutsche Bank treats its art collection as an integral part of its corporate identity, unlike many companies that, following the financial crisis, deemed such collections non-essential. This collection has operated continuously for many years, which is unusual; corporate collections typically have a lifespan of only 11 years (Preece, 2016).

Deutsche Bank Collection is coordinated by the "Art and Culture" division, which consolidates the bank's global sponsorship programs and cultural initiatives. The department is also responsible for the direct management of the art collection, the development of international exhibition programs, and strategic partnerships with leading art fairs (*Art and Culture*, n.d.). The operational management of the collection is entrusted to Deutsche Bank's

internal curatorial teams, which are complemented by external experts, particularly within programs such as "Artist of the Year" (Kinsella, 2014).

4.1.3. Art Collection Strategy and Artistic Orientation

Deutsche Bank's art collection strategy demonstrates that artworks can serve a function far beyond mere decoration—they can become an integral component of corporate identity and communication. The collection, primarily composed of contemporary works on paper by living artists, reflects core institutional values such as modernity, diversity, and creativity. The bank regards its collection as an expression of its evolving, open organizational culture, while the acquisition of works by international artists aligns with its global and inclusive character. Art also fulfills a strategic marketing role: it is utilized during client events, displayed throughout office spaces, and featured in promotional materials, thereby enhancing brand prestige and contributing to the attraction of investors and talent alike. Equally significant is the collection's capacity to stimulate employee creativity. Art functions as a catalyst for dialogue, reflection, and the disruption of routine office dynamics. Deutsche Bank actively involves employees in the selection process (senior managers select artworks for their offices) and offers lectures and guided tours, fostering a sense of ownership and engagement. The bank's emphasis on emerging artists is also a deliberate strategy—such works are relatively affordable, support the broader art ecosystem, and reduce financial exposure associated with speculative investments. Oversight is provided by a dedicated art committee, which ensures coherence between acquisitions and corporate values, as well as the professional management of the collection. Transparent communication of the collection's purpose helps to mitigate reputational risk—art is positioned not as a luxury, but as a strategic asset that reinforces organizational culture and fosters long-term stakeholder relationships (Kottasz et al., 2007).

4.1.4. Acquisition and Divestment Practices

The bank acquires artworks exclusively on the primary market rather than through auctions, with a deliberate focus on living artists to support the art economy. The conceptual value of a work constitutes a central criterion in the selection process, which leads curators to prioritize conceptual rather than decorative art. Deutsche Bank rarely sells works from its collection. In cases where high-value pieces are divested, the proceeds are reinvested into the acquisition fund designated for purchasing new works. Notably, the collection is financed through the bank's operational budget, which varies by branch and region and is subject to annual revision (Kinsella, 2014). In the years 2008-2020, Deutsche Bank has reduced its art collection, narrowing its focus primarily to drawing and photography. These changes stem from the bank's financial challenges and spatial limitations in its new office locations, including New York. Several significant works have been sold, including Gerhard Richter's monumental triptych *Faust*, as well as pieces by artists such as Emil Nolde and Max Pechstein. The collection has taken on a more "breathing" character. Works that no longer align with its current focus are selectively sold, while new acquisitions emphasize young, emerging artists. The goal is to

maintain the collection's relevance and coherence while controlling costs and adapting to shifting institutional conditions (Hickley, 2020).

4.1.5. Dynamics of Valuation and Financial Context

Both the number of works and the value of the collection can only be estimated. It comprises between 57,000 and 60,000 objects with an estimated value ranging from 60 to 65 million EUR (Argun, 2024; Davis, 2022).

C. Schicktanz, one of the curators of the Deutsche Bank Collection, emphasizes that the primary focus is not the financial appreciation of the artworks, but rather on their content, artistic expression, and the promotion of emerging talents. In this context, the collection is not regarded merely as an investment asset. Its principal function is to enhance Deutsche Bank's public image, contribute to its social engagement aligned with broader CSR and ESG strategies, and support the overall brand narrative by positioning art as both a symbolic and functional component of its global identity (Hamann, 2013).

4.2. The UniCredit Art Collection: From Aggregation to Social Investment

The UniCredit Art Collection, held by one of Europe's leading corporate financial institutions, distinguishes itself through both its scale and diversity. This collection did not originate as a uniform whole; rather, it is the result of the merger of art collections from entities acquired by UniCredit. These entities were based in Italy, Austria, and Germany (Maida, 2021). UniCredit applies a distinctive approach to the monetization of its art collection. The acquired works of art are regarded as a source of funding for the further development of the collection. This means that the managers of the collection possess the resources necessary to support new artists whose works are deemed significant in terms of social impact and market relevance. As a result, the UniCredit Art Collection is highly dynamic and maintains considerable significance within the art market.

4.2.1. Origins and Organizational Framework

The UniCredit Collection, recognized today as a consolidated body of artworks, is the result of the aggregation of art collections from several financial institutions that were successively acquired by the UniCredit Group. This legacy explains its substantial size—comprising approximately 60,000 works, including more than 4000 photographs—and its extraordinary diversity, encompassing objects from ancient artifacts to contemporary art (Maida, 2021). Among the most significant contributors to the UniCredit Collection are Rolo Banca 1473, Bank of Austria, HypoVereinsbank, and Capitalia (Piras, 2019). The Bank of Austria collection included around 10,000 works, with a notable emphasis on secession art and works representing Viennese Expressionism (Bank Austria Collection, 2025). The HypoVereinsbank collection was composed of 20,000 pieces, featuring works by German Impressionists and Expressionists. Capitalia contributed 25,000 artworks spanning from the fifteenth century to the present.

This extensive diversity underscores the European identity of the UniCredit art collection (*HypoVereinsbank Art Collection*, n.d.).

Initially, management of the collection was the responsibility of the bank's real estate division. However, organizational changes subsequently led to the transfer of responsibility for the art collection to the communications department. This transition reflected a strategic repositioning whereby the collection was redefined as both a vehicle for brand building and an affirmation of the institution's commitment to social engagement. Thus, the artistic assets, once regarded primarily as permanent holdings, have increasingly become instrumental in shaping UniCredit's brand and confirming its social responsibility (O'Neill, 2019).

4.2.2. Scope and Artistic Profile of the Collection

UniCredit's collection is distinguished by its breadth and diversity. It encompasses works ranging from ancient archaeological artifacts and paintings by old masters to modern and contemporary art. Among the old masters and modernists represented are artists such as Dossi, Guercino, Crespi, and Morandi, as well as works by Gustav Klimt and Giorgio de Chirico (O'Neill, 2019). The contemporary segment of the collection is likewise extensive, including works by Robert Bury, Otto Dix, and Hans Hartung, as well as more recent acquisitions by Gerhard Richter, Yves Klein, and Andreas Gursky (Scarale, 2020). Beneath this element of the UniCredit collection are photographic holdings. Comprising over four thousand photographs—both historical and contemporary—these make the UniCredit collection one of the largest corporate photographic collections (Maida, 2021).

4.2.3. Strategic Transformation: Divestiture and Its Social Impact

In 2018, UniCredit introduced the Social Impact Banking initiative (Masturzo, 2019). This undertaking focuses on providing microcredits and financing for social entrepreneurs as well as disadvantaged groups. To fund this initiative, UniCredit's approach to managing its corporate art collection shifted. This entailed a strategic decision to divest part of its art holdings. The decision to sell artworks to finance other initiatives represented a significant departure from the management practices observed in similar collections by other financial institutions. A portion of the proceeds from the sale was also allocated to support young artists (*UniCredit Art Collection*, n.d.). All changes regarding the disposition of a given collection, as well as changes in its valuation, are linked to the perception of the collection as an asset. A more pragmatic approach to this asset has emerged—one that prioritizes liquidity and social impact.

In addition to the sale of selected works of art through leading auction houses, decisions were also made to donate certain pieces to local museums (Masturzo, 2019). This shift in strategy maximizes social impact rather than viewing the art collection solely as a source of prestige and affirmation of the institution's standing within the financial sector (Muster, 2019).

4.2.4. Valuation Dynamics and Financial Implications

The expected revenue from the sale of artworks earmarked to finance the Social Impact Banking initiative was approximately 50 million EUR. However, UniCredit's historic accounting practices significantly underestimated the market value of its art collection. This reflected a conservative approach to illiquid assets. The UniCredit collection was valued at acquisition cost. As a result, by the end of 2017, the total book value of such movable assets—including the art collection—stood at approximately 38 million EUR (Piras, 2019). For the 60,000 works of art, this meant an average book value of around 630 EUR per piece. This indicates that UniCredit's art assets in fact possessed a market value considerably higher than their book value. Among the works sold were Gerhard Richter's *Abstraktes Bild*, which fetched over 7 million EUR (Piras, 2019), as well as Andy Warhol's *Flowers* (Art for Future, 2020). The millions of euros realized from these sales attest to the significant gap between book and market values.

UniCredit's experience confirms the hypothesis that treating art collections as assets recorded at acquisition cost most likely results in a substantial undervaluation of this balance sheet component. At the same time, regarding artworks as highly liquid assets that can be divested at any given moment is also not an appropriate approach. Current market prices reflect the value perceived by collectors. However, individual artworks cannot serve as a reliable basis for the valuation of the entire collection. Of course, the true value of the entire collection could only be determined if it were sold in its entirety. Nevertheless, such a scenario is not feasible due to the unique nature of these collections (O'Neill, 2019).

Art divestiture strategies entail not only significant financial risks but may also give rise to reputational and ethical concerns. Market demand for individual works of art is highly volatile and strongly dependent on collectors' preferences as well as broader macroeconomic conditions, which generates uncertainty regarding the actual revenues realized from sales. Furthermore, for institutions such as UniCredit, which present themselves as long-term patrons of culture, the disposal of iconic works may be perceived as undermining their cultural commitment. This, in turn, can weaken relationships with stakeholders in the cultural sphere, even when the proceeds from sales are directed toward social initiatives. While divestiture in the case of institutions such as UniCredit may release liquidity for socially oriented programs, it simultaneously exposes the institution to financial and reputational risks, as well as to the erosion of symbolic capital.

4.3. Art Collections of Polish Financial Institutions: The National Dimension of Social Responsibility

In contrast to international financial institutions such as Deutsche Bank or UniCredit, Polish banks do not disclose detailed data on the value of their art collections. The absence of such data, and thus the lack of transparency, can be attributed to several factors. First, there is no reporting obligation requiring these assets to be included in annual reports, and their

valuation is generally based on a conservative approach that relies on acquisition cost. Second, the limited transparency and relatively small scale of the domestic art market hinder the reliable valuation of large collections. Third, reputational concerns play a role: disclosing high valuations could raise questions about the legitimacy of such expenditures in the case of financial institutions that publicly declare their commitment to social and ESG goals.

4.3.1. The Art Collection of PKO Bank Polski

The PKO Bank Polski collection consists of two separate sets: the "20th Century Art Collection" and the "New Collection for the New Century". PKO Bank Polski began developing its own contemporary art collection, the "20th Century Art Collection", in 1998, becoming the first Polish bank to undertake such an initiative. The initial collection included over 70 works representing several generations of artists—sculptures, paintings, prints, and collages—reflecting the diversity of artistic movements in 20th-century Polish art (*Bankowa kolekcja sztuki*, 2019). In 2019, a new collection was launched to mark the 100th anniversary of PKO Bank Polski. The "New Collection for the New Century" has a focus on promoting the work of young and emerging artists encompassing painting, sculpture, drawing, video, textiles, and performance (*O kolekcji*, n.d.). Since 2013, PKO Bank Polski has served as a patron of the Gallery of Medieval Art at the National Museum in Warsaw (*Sztuka*, 2019).

Public access is ensured through exhibitions held at the bank's headquarters, loans to external exhibitions, and a publicly available online gallery (*O kolekcji*, n.d.). Through the "Art of Helping" initiative, during a charity auction, the bank "lends" works of art to corporate clients for a period of three years. All funds raised in this way are donated to charitable causes, such as supporting shelters for single mothers (Wardziak, 2023).

4.3.2. The mBank Art Collection

The mBank collection, initiated in the early 1990s, comprised numerous outstanding works by old masters of Polish paintings, including pieces by artists such as Józef Brandt, Juliusz Kossak, Stanisław Witkiewicz, and Bernardo Bellotto (known as Canaletto). Selected works from this collection had previously been auctioned for charitable purposes—for example, the sale of an exceptional oil painting by Julian Fałat during the 2020 Grand Finale of the Grand Orchestra of Christmas Charity (WOŚP), which reached a record-breaking price of 850,000 PLN. In June 2020, mBank decided to refresh its collection by selling the old master artworks and simultaneously launching a new initiative focused on contemporary Polish art. The new project—a fund titled "M jak Malarstwo" ("P as in Painting")—was dedicated to supporting the work of young, talented Polish artists and to stimulating the Polish art market. The project was an initiative aligned with mBank's corporate social responsibility strategy (Tylcz, 2020). In June 2025, an impressive collection of 152 works of contemporary Polish paintings, assembled over five years through the "M jak Malarstwo" fund, was donated to the National Museum in Gdańsk (*Nasza kolekcja prac,* 2025).

4.3.3. Bank Pekao S.A. Art Collection

Bank Pekao's relationship with art dates back almost to the very beginning of its operations. As early as the post-war years, the institution engaged with its clients through works created by artists of the Polish School of Poster Art. Over the years, the bank has built an impressive collection of works by renowned female and male artists. The Pekao collection includes nearly 1000 pieces spanning both historical and contemporary art, featuring works by outstanding figures such as Stanisław Wyspiański, Jan Matejko, Wojciech Kossak, Józef Mehoffer, Julian Fałat, and Tadeusz Dominik. Part of the collection has been digitized and is available online through the virtual Art Gallery of Bank Pekao S.A. (*Kolejna odsłona Art Branding w Banku Pekao*, 2024). Since 2022, Bank Pekao has been actively applying cutting-edge technology in the context of art. That year, as part of its private banking services, the bank carried out the world's first tokenization of an artwork within a universal financial institution. Selected elements of the tokenized pieces were printed on a limited edition of credit cards. Following the success of this groundbreaking initiative, Bank Pekao decided to expand the project by tokenizing additional artworks from its collection (*Sztuka zamrożona w czasie*, 2024).

4.3.4. The ING Art Collection

For many years, ING has been actively involved in promoting the arts, building two independent collections—an international collection and a Polish one. The international collection was initiated in the Netherlands in the 1970s, at a time when tax incentives introduced by Western European governments encouraged the development of corporate art collections. Its growth was also influenced by the Netherlands' deeply rooted tradition of art collecting. The collection includes works by artists from various countries and has expanded along with ING's international presence, encompassing branches in Belgium, the United Kingdom, and Poland, among others (Wolniewska, 2021). In parallel, the ING Polish Art Foundation, established in 2000, has been building a collection of works by contemporary Polish artists from the very beginning of its activity, focusing on pieces created after 1990. The collection includes nearly 300 works—paintings, photographs, drawings, videos, sculptures, and installations—by both established artists and a younger generation born in the 1990s. The foundation's mission is to support Polish art and showcase the most current trends in the contemporary art scene ("O fundacji" n.d.).

5. Discussion

We demonstrate that treating art as an investment asset is not substantiated by the decisions of financial institutions regarding the creation and management of their corporate art collections. This finding undermines the argument that art can be considered a viable investment asset. Characteristics of the art market, such as illiquidity, limited demand,

and valuation difficulties (Evans et al., 2017; Li et al., 2022), combined with the observed behavior of financial institutions, make it challenging to defend the thesis of the investment-driven nature of the contemporary art market. Our research synthesizes the perspectives of art as social and cultural capital (Bourdieu, 1989; Ostrower, 1998) and as an investment vehicle. Our study indicates that the cultural and social aspects of art investment significantly outweigh the financial ones.

Previous authors have typically examined art solely from the perspective of a social and/or cultural asset (Ostrower, 1998; Belfiore, Bennett, 2008) or as an investment asset (Mei, Moses, 2002; Li et al., 2022; Barro et al., 2023). Our study provides a synthesis of these two perspectives, highlighting the revealed preferences of financial institutions.

A clear departure from treating art as an investment asset is observable in the contemporary corporate art collections of financial institutions, both in Poland (Bank Pekao SA, PKO Bank Polski, mBank, ING Bank Śląski) and across Europe (Deutsche Bank, UniCredit). Instead, these collections are increasingly viewed as tools for brand image enhancement, fostering organizational culture, and fulfilling corporate social responsibility (CSR) and ESG objectives, particularly within the social dimension. A dominant trend is the focus on modern and contemporary art, with a strong emphasis on supporting young, emerging artists. This strategy allows banks to support the art ecosystem while simultaneously limiting their financial exposure. These institutions actively promote public access to their collections through exhibitions at their headquarters, loans to external exhibitions, and publicly accessible online galleries and educational programs designed to stimulate dialogue and strengthen community ties. Furthermore, diversity and inclusion are increasingly integrated into collecting policies, as exemplified by Deutsche Bank. All analyzed banks are divesting or have divested parts of their historical art collections to align them with contemporary strategic and branding goals.

The main differences relate to the scale, scope, and genesis of the collections. International institutions like Deutsche Bank and UniCredit possess vast, globally recognized collections with tens of thousands of works (over 55,000 at Deutsche Bank and approximately 60,000 at UniCredit; Argun, 2024), often resulting from the aggregation of collections from acquired entities and spanning a wide historical range. Polish financial institutions, such as the ING Polish Art Foundation or Bank Pekao, typically have smaller, ranging from several dozen to several hundred pieces of art, yet significant collections, often focused on Polish contemporary art.

In the context of original motivations, international institutions historically concentrated on prestigious artworks. In contrast, Polish banks, from their inception, did not aim to accumulate expensive, high-prestige works, focusing instead on social impact by supporting young artists. Acquisition and disposal strategies also differ. Deutsche Bank acquires works exclusively on the primary market from living artists and rarely sells them, reinvesting any proceeds. UniCredit strategically divested a portion of its collection, including valuable works for millions of euros, to finance its Social Impact Banking initiative and support young artists. Similarly, mBank sold

old master paintings (e.g., a Julian Fałat painting for PLN 850,000 for charitable purposes) and subsequently transferred its collection to the National Museum. PKO Bank Polski, in turn, "lends" artworks to corporate clients through its "Art of Helping" initiative, donating the funds raised to charity.

The evolution of how financial institutions perceive art reflects broader changes in the role of banks in society. They have transformed from purely financial entities into significant components of social functioning. This shift is mirrored in their art collection strategies, which are now dominated by social and cultural values rather than purely financial considerations.

The development of an art collection by an institution involves decisions concerning the institutional framework within which the collection operates. Figure 1 presents a diagram outlining various models for building an art collection, which may be developed internally within an organization or established as a separate entity managed in the form of a trust, fund, or foundation. Regardless of the specific approach adopted, the objectives assigned to art collections held by financial institutions tend to be similar. Building brand recognition and supporting organizational culture have become main motivators for major financial institutions in developing art collections. These objectives are pursued through the support of emerging young artists and educational initiatives. In this context, the role of art as an asset is relegated to a secondary position. However, it should be emphasized that, from the perspective of the broader environment, the value of an art collection nevertheless plays a determining role in its significance to the surrounding community, serving as an indicator that the collection is perceived as meaningful.

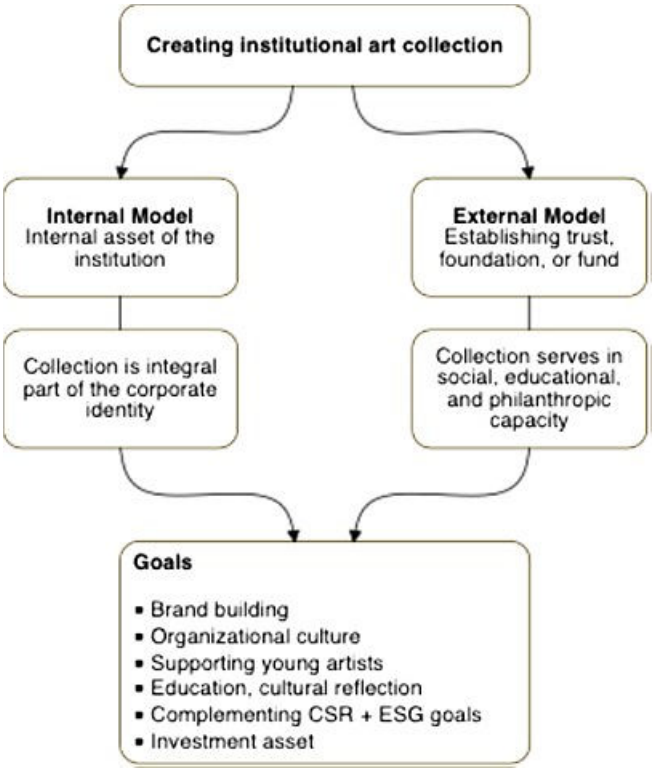

Figure 1. Models of building art collections by financial institutions.

Source: own elaboration.

Art collection management in financial institutions is typically entrusted to dedicated internal teams composed of art market professionals. Acquisition decisions are made in line with broader corporate strategies, such as promoting diversity and sustainability, rather than being driven by financial motives. The value of corporate art collections often remains opaque, with available estimates varying significantly. In the case of Polish financial institutions, the primary motivation behind building collections is cultural patronage and the support of the arts. When financial aspects are mentioned, they are usually framed in terms of sustaining or expanding cultural initiatives. The consistent emphasis on public access, educational programs, and direct support for emerging artists highlights that the collections are valued primarily for their cultural contribution rather than their investment potential.

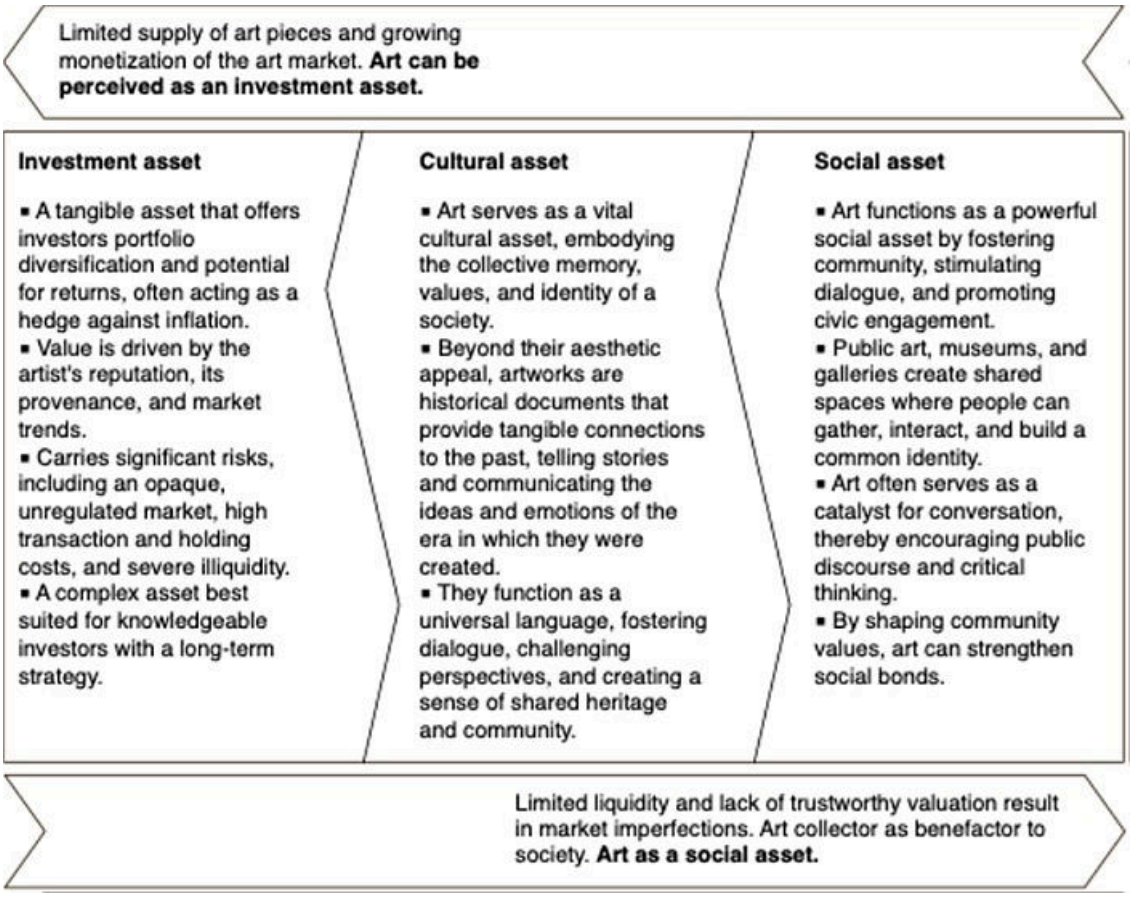

Figure 2. Roles of art collections as different types of assets for financial institutions.
Source: own elaboration.

Figure 2 summarizes how art collections can be perceived as different types of assets, ranging from investment assets to cultural and social assets. The varying interpretations of these asset classes determine the approach to art as an asset. The phenomena observed in the case of bank art collections indicate an evolution in perception—from viewing art as an investment asset to regarding it as a social asset.

The evolution in banks' perception of art should be considered in the context of the changing role of banks themselves. Banks, originally purely financial institutions, have become an essential element in the functioning of every society. Money determines the functioning of modern societies, particularly in highly developed countries. From this perspective, the social responsibility of banks has evolved from viewing art as an asset to perceiving it as a means of building their image and affirming their social role. The liquidity of the art market and the possibilities for valuing art as an asset have undoubtedly also influenced this shift. All these factors have contributed to the transformation in the way art collections are perceived by financial institutions abroad—from being regarded as carriers of value to being considered bearers of social and cultural significance.

It is therefore necessary to pose the question of whether works of art can, in fact, be regarded as investment assets at all. It seems more appropriate to view them from a fundamentally different perspective. Treating artworks as investment assets entails numerous limitations that are not encountered with other asset classes, such as bonds or equities. If financial institutions are shifting their approach, it is highly likely that a similar re-evaluation should extend to other entities and individual investors who may seek to perceive art as an asset class whose valuation is not directly correlated with fluctuations in financial markets.

6. Conclusions

The key conclusion from the presented study is the finding that the role and strategies of banking art collections have undergone a significant evolution, transforming from investments or symbols of prestige and status into advanced strategic tools with profound social impact. Today's bank collections are focused on contemporary art, emerging artists, and themes related to diversity and inclusivity. They are aligned with modern corporate values and consistent with corporate social responsibility (CSR) strategies. Importantly, the artworks are not treated as investment assets, and thus such collections cannot be regarded as portfolios of financial assets.

The presented results support the hypothesis that although art serves both a social and an investment function, revealed preferences of financial institutions put much stronger emphasis on the latter. At this point, it should be emphasized that a comprehensive understanding of the functioning of the art market requires a synthesis of both the social and investment perspectives. When the social and investment functions are considered separately, in each case we observe the growing importance of each approach. However, when these perspectives are examined jointly and synthetically, it is possible to discern a misalignment and tension between the cultural-social and investment approaches. In this context, decisions of investors from the financial sector may provide a valuable point of reference for understanding the relative prominence of the cultural-social dimension of art purchases within the broader field.

Earlier studies have focused on approaching art either as a social and cultural asset (Ostrower, 1998; Belfiore, Bennett, 2008) or as an investment asset (Mei, Moses, 2002; Li et al., 2022; Barro et al., 2023). Our study contributes to this literature by synthesizing these two perspectives and by highlighting the revealed preferences of financial institutions in managing their art collections. To the best of our knowledge, no prior research has combined these approaches within a single analysis, which underscores the originality of our contribution.

This synthesis deepens the understanding of the relationship between banks and art while at the same time opening new directions for further research on the role of art in the strategies of financial institutions, particularly in the context of cultural patronage, corporate social responsibility, and investment decision-making.

A natural limitation of our study stems from the restricted access to information and to institutions within the financial sector, as well as from the lack of direct interviews with their representatives. Including a more diverse range of institutions, and, if possible, individuals responsible for art collection management within companies, would allow us to adopt a more comprehensive perspective. Nevertheless, we believe that the results obtained offer valuable insights into the viewpoints of enterprises, which may be regarded as representative and informed investors.

Art is not easily comparable to other asset classes, particularly financial ones, in terms of risk, liquidity, valuation, and investment function. A limitation to this observation is provided by the decisions of financial institutions that are building their own collections and training personnel about the art market to think more in terms of social impact and ESG considerations rather than solely in investment terms. In this context, the emphasis is placed on the 'S' component of ESG, that is, social impact.

On the other hand, individual investors may treat art as a long-term investment and store of value. In such a case they focus on the observed returns of art investments and compare their profitability to that of investments in financial markets. In this context, market segmentation may play a crucial role in studying the profitability and the interest of collectors in selected works of art. Collectors considering future monetization may evaluate various artists in terms of their attractiveness to the broadly understood investment market. However, one must consider current collectors' interests as well as the trends in art that are perceived as most influential. From this perspective, globally recognized artists will be valued differently from works of art that attract interest on the local market.

Future research should focus on assessing the monetary profitability of art investments and comparing them to financial assets. One may evaluate the rates of return observed in the art market or attempt to assess the potential rates of return from art investments. The perception of the art market and the value of artworks may be crucial for current interest and valuation. Further research on the art market and its analysis from a financial and a behavioral perspective may enable a more in-depth understanding of the functioning of this market, as well as the potential directions of its evolution in response to the growing interest in art as an investment asset and a store of value.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

WHY DO FAMILY BUSINESSES ENGAGE IN SOCIAL ACTIVITIES? MOTIVATIONS, VALUES, AND ENGAGEMENT STRATEGIES IN POLAND AND GERMANY

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Purpose: The purpose of article is to find the reasons and motivations behind the social engagement of family businesses, with particular emphasis on the cultural contexts of Poland and Germany.
Design/methodology/approach: A mixed methods strategy was used. Empirical data from qualitative and quantitative research was used to identify the impact of cultural, institutional, resource, and relational factors on family businesses' decisions regarding pro-social activities.
Findings: The results indicate clear differences between the countries: in Poland, value-based motivations dominate - family values, traditions, and the need to build local relationships - while in Germany, instrumental and institutional motivations play a key role, related to responding to stakeholder expectations and complying with regulations.
Research limitations/implications: The study is exploratory in nature and does not allow for the generalization of results to the entire population of family businesses in both countries. Limitations also result from recruitment difficulties and differences in the availability of registers.
Practical implications: The results emphasize the need to take into account the specific nature of family businesses when designing support policies.
Social implications: The findings highlight that the social engagement of family businesses strengthens local communities by fostering trust, reciprocity, and long-term relationships, which may improve overall quality of life and social cohesion. Moreover, the study suggests that tailored CSR policies acknowledging cultural differences could guide both public policy and industry practice, encouraging more context-sensitive and sustainable approaches to corporate social responsibility.
Originality/value: The article contributes to the literature by developing a typology of motivations for social engagement and highlighting cultural differences in the perception of corporate social responsibility among family businesses.
Keywords: family businesses, social engagement, motivations, CSR, social capital.
Category of the paper: Research paper.

1. Introduction

Family businesses, which constitute a significant part of the small and medium-sized enterprise (SME) sector in many countries, are distinguished by their specific management structure and strong family ties, which imply a long-term approach to business. As a result, they play a unique role in the socio-economic system, combining an economic function with a strongly emphasized social role.

Family businesses are increasingly involved in initiatives aimed at the well-being of local communities, including support for education, culture, sports, and environmental protection. Unlike corporate CSR programs, this involvement in family businesses is often personal, deeply rooted in family values and traditions.

Previous research on socially responsible family businesses has focused mainly on individual dimensions of motivation, such as the protection of socio-emotional wealth (SEW) (Gómez-Mejía et al., 2007), institutional pressure (DiMaggio, Powell, 1983), or resource availability (Barney, 1991). Other authors (Bromiley, Rau, 2014; Miller et al., 2008) have emphasized the role of routines, practices, and organizational culture as sources of competitive advantage. However, there is a lack of studies that integrate these approaches in a cross-cultural perspective, particularly comparisons of family business motivations in different countries of Central and Western Europe. This research gap justifies the need for comparative studies that show how different cultural, institutional, and resource contexts influence decisions to engage in pro-social activities.

The aim of this article is to examine the motivations and cultural, institutional, and resource conditions that lead family businesses in Poland and Germany to engage in social activities. The study has both theoretical significance – by integrating the SEW, institutional, RBV, and PBV perspectives – and practical importance, as it provides insights into how public support and CSR strategies can be tailored to the specific characteristics of family businesses.

In order to address the stated objective, a set of research hypotheses was formulated to structure the analytical framework and provide a basis for the empirical validation of the underlying theoretical assumptions:

H1. The motivations of family businesses for social engagement are multidimensional and cannot be explained within a single theoretical approach.

H2. In Poland, identity-based and relational motivations dominate, rooted in family values and the local socio-cultural context.

H3. In Germany, institutional and instrumental motivations play a greater role, linked to regulatory pressure and stakeholder expectations.

These hypotheses were subsequently elaborated into specific research questions, designed to operationalize the study and to direct the course of the empirical investigation:

RQ1. What are the main motivations of family businesses to engage in pro-social activities?

RQ2. How do the cultural and institutional contexts of Poland and Germany differentiate these motivations?

RQ3. How do resource availability and organizational practices influence the scope and forms of CSR in family businesses?

The novelty of this study lies in integrating theoretical perspectives (SEW, institutional theory, RBV, PBV) into a multidimensional model of motivations and in applying a comparative perspective that takes into account not only national differences but also potential regional contexts.

The structure of the article is as follows: Section 2 presents the theoretical background, including the main approaches explaining family business motivations for CSR. Section 3 describes the research methodology, Section 4 presents the findings, Section 5 discusses them in relation to the literature, and Section 6 formulates theoretical and practical conclusions.

2. Theoretical background

The analysis of the motives for social engagement of family businesses requires reference to several well-established theoretical concepts that form the basis for the study of family businesses in the literature, including the theory of socio-emotional wealth (SEW), institutional theory, resource-based theory (RBV), and the practice-based view (PBV) approach (PBV). Each of these approaches contributes a different dimension to explaining the motivations and mechanisms of engagement.

2.1. Social-Emotional Wealth (SEW) theory

According to the SEW concept (Gómez-Mejía et al., 2007), decisions in family businesses are not limited to economic criteria, but are also motivated by the need to protect socio-emotional resources such as reputation, heritage, company identity, and intergenerational relationships. In the context of social activities, this theory interprets the involvement of companies as an expression of concern for maintaining their reputation, loyalty to the local community, and the continuation of family philanthropic traditions.

This approach is particularly relevant for countries with strong local and family traditions, such as Poland, where social engagement can be culturally rooted and go beyond economic benefits, even with limited resources.

2.2. Institutional theory

Institutional theory (DiMaggio, Powell, 1983) suggests that organizational behavior is shaped by external pressures such as legal regulations, industry norms, and stakeholder expectations. In this context, the social responsibility of family businesses can be seen as a way of legitimizing their activities - adapting to CSR standards and market requirements.

In countries with a developed regulatory system, such as Germany, this theory explains the formalization of social strategies, ESG reporting, and cooperation with non-governmental organizations as an expression of professionalization and compliance with institutional norms.

2.3. Resource-based view (RBV)

The resource-based perspective (Barney, 1991) refers to competitive advantage based on a company's unique resources – material, human, organizational, and reputational. In the context of social engagement, this means that family businesses with greater resources are able to implement more complex and long-term socially responsible activities.

Empirical data confirm that larger, often multigenerational companies invest in lasting partnerships and sustainable development initiatives that distinguish them from smaller companies with limited financial and organizational capabilities.

2.4. Practice-Based View

The practice-based view (Bromiley, Rau, 2014) draws attention to routine, historically conditioned patterns of action embedded in organizational contexts. In family businesses, many pro-social activities do not result from formal strategies, but from practices passed down from generation to generation and adapted to local conditions.

Such practices, which persist as "proven methods", can be a significant source of competitive advantage due to their difficulty to imitate and their strong roots in the organizational culture.

2.5. Integration of approaches

An approach that integrates SEW, institutional, resource-based, and PBV theories provides a comprehensive explanation of the motivations for social engagement in family businesses as a complex, multi-factor phenomenon. This integration takes into account identity motives and family values, institutional pressure, resource availability, and established organizational practices.

This approach indicates that family values can initiate intentions to act, institutional pressure can impose norms and expectations, available resources can ensure feasibility and scale, and established organizational practices can create repeatable patterns of action. Furthermore, integration allows us to describe the temporal dynamics of engagement, e.g., the evolution of motivation along with generational or economic changes.

Another strength of the integrative approach is its ability to explain cultural and institutional differences between Poland and Germany and to predict which forms of engagement will be more durable and resistant to organizational change.

In summary, the proposed integration provides a theoretical framework for analyzing the social responsibility of family businesses, taking into account the complexity of their motivations and the conditions of their activities.

3. Research methodology

3.1. Methodological assumptions

The essence of the study was to understand the motivations and conditions for the social engagement of family businesses in two different cultural contexts: Poland and Germany. An exploratory approach was adopted, which allows for the identification of decision-making and cultural mechanisms that are insufficiently described in the literature. A mixed methods strategy was used, combining qualitative case analysis with quantitative analysis of survey data. This approach allowed for an in-depth interpretation of the phenomenon in its natural context, while estimating statistical relationships in a large research sample.

3.2. Sample selection criteria

Companies meeting two key criteria were selected for the study: (1) formal registration as private companies, independent of external capital, and (2) control and management by family members, with at least one generation involved in operational or strategic activities. The selection of companies was carried out using a purposive and snowball sampling method, utilizing business networks, chambers of commerce, and organizations supporting family businesses in both countries.

In the quantitative part, 73 companies (57 from Poland, 16 from Germany) were surveyed, diverse in terms of size (micro, small, medium) and industry (manufacturing, services, trade, agriculture), which translated into the representativeness of the SME sector. In the qualitative study, 24 in-depth individual interviews were conducted with owners or members of families managing companies (15 in Poland, 9 in Germany).

3.3. Research tools

The qualitative part used a semi-structured interview scenario, including questions about the history and values of the company, relations with the local community, experiences with pro-social activities, and the perception of the role of the company in the social environment.

All interviews were recorded with the consent of the respondents, transcribed, and analyzed with the support of dedicated qualitative data analysis software.

The quantitative part was carried out using a survey questionnaire containing closed and semi-open questions concerning, among other things, the scope and forms of social activities, the motives for undertaking them (values, reputation, peer pressure, public incentives), the nature of relations with social partners, and the level of formalization and available organizational resources.

3.4. Analytical procedures

Qualitative data were subjected to thematic content analysis, identifying recurring patterns and motivational mechanisms. Coding based on an iterative approach by two independent researchers increased the accuracy and reliability of the results. On this basis, a preliminary typology of motivations and links between values and styles of engagement was formulated.

Quantitative data analysis was performed using SPSS software, employing descriptive statistics, Student's t-tests, Mann-Whitney U tests, and correspondence and cluster analysis to identify patterns of prosocial behavior. In addition, cross-country comparative analyses were used to account for institutional and cultural differences.

3.5. Limitations of the study

The study is exploratory in nature and does not allow for the generalization of results to the entire population of family businesses in both countries. The German sample was particularly limited in the quantitative part, which was due to recruitment difficulties and differences in the availability of registers. In addition, the self-identification of companies as family businesses may introduce subjective distortions, as may the varying levels of formalization of prosocial activities.

An additional limitation of the study is the treatment of Poland and Germany as homogeneous units, while regional differences (e.g., East and West Germany, rural and urban Poland) may significantly affect family firms' motivations. Considering these subnational contexts could provide a more comprehensive picture of motivational diversity.

Despite these limitations, the triangulation of qualitative and quantitative methods allows for a multidimensional picture of the phenomenon and the formulation of model conclusions that can serve as a basis for further, in-depth research.

4. Research results

4.1. Motives for pro-social engagement – a comparative approach

The analysis of the results showed that family businesses in Poland and Germany undertake pro-social activities based on different motives, which can be classified into four main categories: value-based, instrumental, institutional, and relational. All types of motivation were present in both countries, but the intensity of their impact and their links to the organizational structure differed significantly.

In Polish companies, value-based motives dominated, referring to family traditions of helping others, a belief in moral obligation, and strong local roots. Pro-social activities were seen as a natural extension of the company's identity, which was personally recognizable in the local community. These motivations were particularly strong in companies with a long history, operating on a succession basis.

In German companies, instrumental and institutional motives played a more important role. Social activities were part of professional CSR strategies, linked to HR and marketing activities. Undertaking social initiatives was largely a response to stakeholder expectations, industry pressure, and legal and environmental requirements. Family values, although present, were subordinated to rationalization and adaptation to the environment.

4.2. Relationships between motivations and company characteristics

Analyses have shown significant correlations between the type of motivation and the characteristics of the company (Table 1). Smaller and first-generation companies are more likely to declare value-based and relational motivations, while larger, multi-generational companies show instrumental and institutional motivations. Having a formal CSR strategy and reporting practices correlates with greater motivational diversity, which indicates the professionalization of social activity.

Table 1.
Relationship between type of motivation and company characteristics (N = 73)

Company characteristics	Dominant type of motivation	Conclusions
Microenterprises	value-based, relational	Strong role of personal relationships, lack of formalization
Small and medium-sized companies	Instrumental, institutional	Greater resources → more formal CSR activities
First-generation companies	value-based	No CSR strategy, spontaneous actions
Second+ generation companies	Hybrid, strategic combination	Integration of values with professionalization of activities

Source: Authors' own elaboration based on primary data.

An interesting phenomenon is the emergence of so-called "adaptive motivation", which occurs in companies undergoing generational transformation. In such cases, the new generation of owners transforms family motives into more formal structures, integrating them with a modern approach to management. This is often a process of hybridization - combining emotional involvement with rational analysis of results.

4.3. Cultural differences in pro-social narratives

The narratives of business owners in Poland and Germany differed significantly in style and content (Table 2).

Table 2.
Differences in the understanding of corporate social responsibility

Country	Dominant style	Key features
Poland	Personal, emotional	References to family, locality, community
Germany	Formal, strategic	References to procedures, standards, regulations

Source: Authors' own elaboration based on primary data.

In Poland, the tone was predominantly personal, emotional, and based on local relationships and community values. Owners emphasized their specific responsibility towards the local community and their personal involvement. In Germany, the narratives were more formalized and referred to procedures, CSR policies, and compliance with regulations, which were treated as standard elements of business strategy and image building.

Quantitative data confirmed these differences: in Poland, personal, emotional stories based on relationships with specific individuals or local institutions predominated. Business owners emphasized that they "know who they are helping", "are part of this community", and "it is not appropriate to be indifferent".

In Germany, the narratives were more formalized, referring to CSR strategies, public-private partnerships, and compliance with ESG policies. Respondents spoke of "social responsibility as a standard" and "sustainable investments in the organization's image". Accordingly, the results lend empirical support to Hypothesis 2 and Hypothesis 3, although further research is needed to confirm these relationships across broader samples.

4.4. Typology of pro-social motivations of family businesses

Based on qualitative and quantitative data, four types of motivation for engagement were formulated (Table 3):

1. **Value-based motivation** – based on the belief that helping the local community stems from family heritage, values passed down from generation to generation, and the personal commitment of the owners. Examples include spontaneous actions, without a CSR plan, often carried out "from the heart". In interviews with business owners, phrases such as "you have to take care of your own", "who has the to take care of our people", and "I'd rather support the local soccer team, because our people play there, than organize a forest cleanup" were used.

2. **Instrumental motivation** – treats social activities as a way to increase the company's competitiveness, build its brand, employee loyalty, and attract customers or contractors. These activities are often measurable and included in the business strategy.
3. **Institutional motivation** – stems from the need to meet formal, industry, certification, or market expectations. This category includes activities undertaken with a view to maintaining legitimacy in the eyes of the community.
4. **Relational motivation –** focuses on building social relationships and support networks, including relationships with employees and their families, as well as with local social organizations, schools, and local governments. These are often joint, partnership-based activities that create bonds based on reciprocity.

Table 3.
Typology of pro-social engagement motivations of family businesses

Type of motivation	Description	Examples of activities	Domain
Identity	Rooted in local values and the local community	Sponsorship of local events, donations	Poland
Instrumental	Focused on strategic benefits	CSR as an employer branding tool	Germany
Institutional	Response to regulatory and industry pressure	ESG reporting, compliance with CSR standards	Germany
Relational	Building networks of relationships and reciprocity	Partnerships with NGOs, employee support	Poland

Source: Authors' own elaboration based on primary data.

These motivations often coexist, creating complex configurations. In Polish companies, value-based and relational combinations prevail, while in German companies, instrumental-institutional combinations prevail (Figure 1). Thus, the findings lend support to Hypothesis 1.

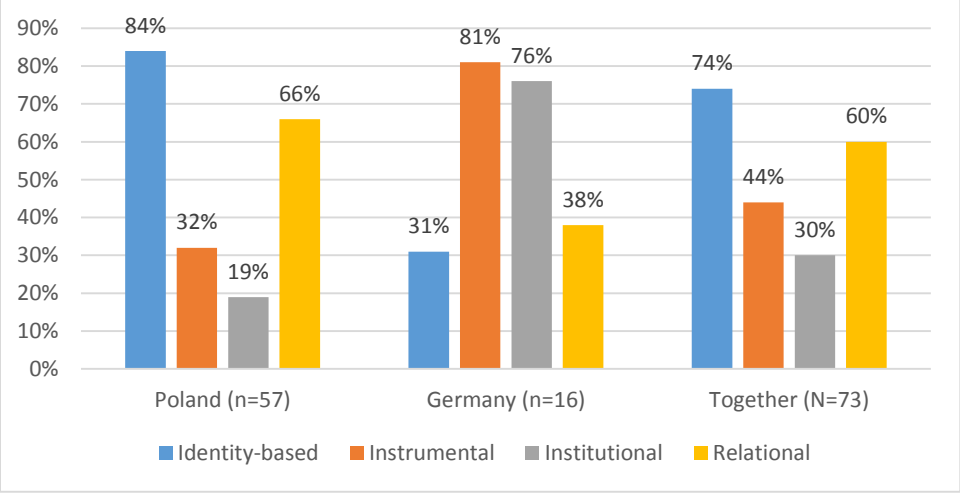

Figure 1. Comparison of motivations by country (quantitative data, N = 73).

Source: Authors' own elaboration based on primary data.

5. Discussion

The results of the study are consistent with and expand upon the resource-based view (RBV), confirming that the availability of organizational resources – financial, human, organizational and reputational – significantly influences the scope and sustainability of socially responsible activities in family businesses (Barney, 1991). As Craig and Moores (2006) point out, our results emphasize that companies with greater capital can undertake more structured and impactful social initiatives. Empirical data also confirm that larger, often multi-generational companies invest in lasting partnerships and sustainable development initiatives, which distinguishes them from smaller companies with limited financial and organizational capabilities.

The research conducted has shown that the motivations of family businesses to undertake pro-social activities are complex and multidimensional. Social engagement is not only the result of economic calculations or adaptation to market expectations, but also an expression of deeply rooted family values, interpersonal relationships and local identity. In the Polish context, these activities often serve to protect social and emotional wealth (SEW), aimed at maintaining reputation, family heritage and strengthening intergenerational bonds. Entrepreneurs' narratives emphasize their symbolic and identity-related significance, regardless of the degree of formalization and integration with the company's strategy.

From a practice-based perspective (Bromiley, Rau, 2014), the persistence of informal, historically rooted practices in Polish family businesses highlights the importance of routines and embedded social norms as sources of competitive advantage. This phenomenon complements the findings of Miller et al. (2008), who point to the role of organizational culture and tradition in shaping the behavior of family businesses. However, the informal nature of these practices may also limit scalability and formal reporting, which is consistent with Maxwell's (2013) criticism of informal approaches to CSR.

In Germany, on the other hand, institutional mechanisms such as stakeholder expectations, certification requirements and industry pressure have a strong influence, leading to the professionalization and formalization of CSR activities. Social engagement is becoming part of the systemic framework of responsibility management, confirming the relevance of the institutional approach in this context.

The study also reveals clear cultural differences. In Poland, CSR is often interpreted in ethical and community terms, while in Germany a systemic and managerial approach prevails. This diversity indicates that the decisions of family businesses are not only the result of their internal resources and values, but also the effect of social learning processes in specific cultural contexts. Moreover, it should be noted that this study treats Poland and Germany as homogeneous units, whereas regional socio-economic differences may significantly influence family firms' motivations. For instance, East and West Germany still reveal disparities in

institutional development and business culture, while in Poland contrasts between rural and urban regions shape the forms and meanings of pro-social engagement. Acknowledging these subnational contexts further strengthens the cross-cultural argument by showing that motivations are conditioned not only by national cultures but also by regional trajectories and socio-economic environments.

Despite the results obtained, the limitations of the study should be emphasized. The relatively small sample size, especially in the German group, limits the possibility of generalizing the conclusions. Furthermore, the self-identification of companies as family businesses may introduce bias in terms of declared motivations and the level of formalization of activities. In the future, research should triangulate self-reported data with objective indicators of effectiveness and social impact.

In summary, the results provide in-depth insights into the cultural and institutional conditions shaping CSR in family businesses. They point to different models of engagement in Poland and Germany and emphasize the need to integrate the SEW, institutional, RBV and PBV approaches in order to capture the dynamics and multidimensionality of the social behavior of family businesses.

6. Conclusions

The study confirms that the motivations of family businesses for social engagement are multifactorial and conditioned by the cultural, institutional and resource context. A one-dimensional model, focusing exclusively on economic or value-based aspects, proves insufficient to explain the complex mechanisms of engagement. In its place, a Multidimensional Model of Strategic Determinants in Family Businesses has been proposed, which emphasizes the integration of three key elements – economic, social and values – when choosing a social support strategy (Fig. 2).

A comparative analysis shows that in Poland, identity and relational motivation, rooted in family values and the local socio-cultural context, predominate, while in Germany, CSR takes a more rationalized and formalized form, embedded in management strategies and subject to institutional requirements. This diversity proves that the effectiveness of pro-social activities does not always require formalization – Polish companies also implement valuable initiatives in an informal manner, which undermines the generalized assumptions of Western literature and points to the need for contextual research.

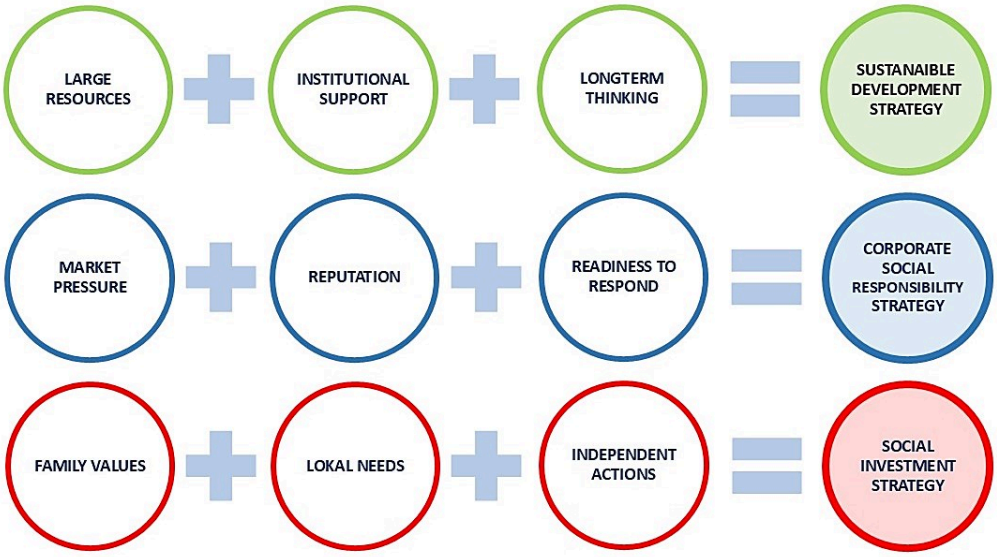

Figure 2. Multidimensional Model of Strategic Drivers in Family Businesses.
Source: own study.

Practical implications include recommendations for organizations supporting family businesses, which should adapt their programs to the specific motivations and needs of companies. Companies with value-based and relational motivations primarily require local cooperation and networking platforms, while strategically oriented companies need formal management tools and CSR performance indicators. At the public policy level, it is necessary to combine financial incentives with education and the development of CSR management skills, especially in the SME sector.

The study proves that formalizing social activities is not necessarily a prerequisite for effectiveness – family businesses in Poland implement valuable initiatives despite the lack of formalized strategies. This challenges the generalized assumptions of Western literature and points to the need for contextual research.

Finally, recognizing the role of generational change in shaping motivation paves the way for supporting the transition from informal to formal CSR, which is important for sustaining the long-term contribution of family businesses to the development of local communities. This points to the need for further research on the dynamics of motivation over time, its effectiveness in generating real social change, and international comparisons that take into account different degrees of CSR institutionalization and local family traditions.

Acknowledgements

The publication of the research findings presented in this article was supported by a university grant (no. WZNJ/2025/PZ/09).

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANISATION AND MANAGEMENT SERIES NO. 231

ECONOMETRIC MODELLING OF MEDICAL INFORMATION IN PATIENT-CENTRED CARE

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Purpose: To develop an econometric medical information model based on the author's theoretical model in patient-centred care. The study analyses the determinants of medical information's quality, availability, and perception in patient care.
Design/methodology/approach: A literature review and econometric modelling were used. In the first step, the key independent variables affecting the quality and accessibility of medical information were identified: the sources of information, the form of communication, the empathy of medical staff and the level of information asymmetry. An attempt was made to develop an econometric model to quantify the relationship between these factors and the dependent variable, medical information.
Findings: The quality and accessibility of medical information are determined primarily by the empathy of medical staff, the form in which information is communicated and the level of information asymmetry, indicating the need to improve communication competence, use understandable forms of communication and increase the availability of reliable educational materials.
Research limitations/implications: The CAWI survey had limitations due to non-random sampling, which makes it impossible to generalise the results to the whole population, and the econometric modelling only considered selected factors. Additionally, dimensionality reduction by PCA may have led to the loss of information, the models tested had a low R^2, and the lack of validation on independent datasets makes it impossible to assess their long-term relevance.
Practical implications: The findings suggest the need to optimise communication strategies in health care by improving forms of communication, training staff in empathy and using digital technologies to reduce information asymmetry.
Social implications: Improved availability and quality of medical information strengthens patient autonomy, increases patient involvement in the treatment process and contributes to an improved doctor-patient relationship.
Originality/value: The study represents a novel attempt to analyse medical information in patient-centred care quantitatively. Combining a theoretical model with econometric modelling can accurately identify the factors shaping the quality and perception of information in the treatment process.
Keywords: econometric modelling, patient, medical information, patient-centred care.
Category of the paper: Research paper.

1. Introduction

Modern healthcare is increasingly patient-centred, shaping a patient-centred care model. In this context, the quality and accessibility of medical information, which plays a crucial role in the patient's diagnostic, therapeutic and decision-making process, is becoming a key element. Appropriate management of medical information not only strengthens patient autonomy and involvement in the treatment process but also contributes to improving the doctor-patient relationship and the effectiveness of treatment.

Despite numerous studies on the role of information in the health care system, there has been a lack of a comprehensive econometric model to quantitatively analyse the determinants of medical information's quality, availability and perception. Existing approaches focus mainly on qualitative aspects, neglecting the possibility of precisely identifying the relationships between variables. In response to this challenge, this thesis attempts to develop an econometric model of medical information in patient-centred care based on the author's theoretical model. In particular, the analysis focuses on identifying and quantifying the impact of key factors such as the empathy of medical staff, information delivery, the availability of educational materials and the level of information asymmetry.

The study refers to the author’s original conceptual framework, previously published in the multi-author monograph Horizons of Information 6 (Czerska, 2024), which integrates relational and informational determinants of patient-centred care into a structured model. The work also offers an empirical attempt to operationalise soft variables—such as empathy or asymmetry—into quantifiable predictors in econometric modelling.

To achieve the stated aim, the following research questions were formulated:

1. How do factors such as the empathy of medical staff, the form of information delivery and the availability of educational materials affect the quality and accessibility of medical information in patient-centred care?
2. Is, and to what extent, the level of information asymmetry in the health care system determined by the way the doctor and patient communicate?

The significance of this study lies in its interdisciplinary approach, combining the conceptual achievements of patient-centred care theory with statistical modelling tools. The attempt to build and test an econometric model fills a methodological gap in health communication and supports the development of evidence-based solutions for public healthcare institutions.

The structure of the paper is as follows: the next section presents a literature review on medical information and patient-centred care. The Methods section outlines the research design, CAWI procedure, data reduction (PCA), and modelling approach. The Results section provides an overview of model performance, followed by the Discussion, which interprets the findings. The paper concludes with implications for practice, limitations, and future research directions.

2. Literature review

Patient-centred care emphasises a partnership between patients and healthcare professionals, focusing on patient preferences, values and holistic well-being rather than solely on diseases or medical interventions. This type of care involves joint management of health conditions by patients and healthcare providers, promoting shared goal-setting and decision-making. (Bauman et al., 2003; Delaney, 2018; Lewin et al., 2001). Patient-centred care implements a holistic approach, considering the patient as a whole person, integrating the patient's beliefs, values and social contexts into care rather than focusing solely on medical conditions (Delaney, 2018; John et al., 2020; Lewin et al., 2001). In engaging and empowering patients, they are encouraged to actively participate in their care, which can lead to better adherence to treatment plans and improved health outcomes (Bauman et al., 2003; McMillan et al., 2013). In addition, patient-centred care is associated with higher patient satisfaction and perceived quality of care because it aligns healthcare delivery with patients' expectations and needs (Delaney, 2018; McMillan et al., 2013). Finally, the pillars of patient-centred care are communication and relationship building, as effective communication and a strong therapeutic alliance between patients and healthcare providers promote trust and understanding (Kitson et al., 2013; Mead, Bower, 2000).

In patient-centred care, it is important to point out its benefits and challenges. Firstly, such care can lead to reduced morbidity, improved quality of life and better management of chronic diseases such as diabetes and asthma (Bauman et al., 2003; John et al., 2020). It also increases patient satisfaction and can improve clinical outcomes (John et al., 2020; Okeny et al., 2024). Regarding challenges, there are some concerns about the potential conflict between patient-centred care and evidence-based care, as they are sometimes seen as mutually exclusive (Delaney, 2018). In addition, implementing patient-centred care requires a commitment from health systems and may involve training providers to adopt this approach (Lewin et al., 2001; McMillan et al., 2013).

In summary, patient-centred care is a comprehensive approach that prioritises the patient's role in their healthcare journey, aiming to improve satisfaction and outcomes by tailoring care to individual needs and preferences. While it offers numerous benefits, its successful implementation requires systemic support and may face challenges in balancing it with traditional evidence-based practices.

The quality and accessibility of medical information in patient-centred care are significantly influenced by the medical staff's empathy, information delivery, and availability of educational materials. Empathy and effective communication on the part of healthcare professionals increase patient satisfaction and engagement, which is crucial for patient-centred care. Patients' perceptions of the trustworthiness and reliability of healthcare professionals influence their willingness to participate in clinical communication, especially among older people (Gaffney,

Hamiduzzaman, 2022; Okeny et al., 2024). Patient-centred care is facilitated by healthcare practices that include optimal communication and family involvement (Jardien-Baboo et al., 2021).

Regarding information delivery, electronic health records empower patients by informing them about their health and engaging them in their care. However, there are mixed results regarding their impact on the patient-doctor relationship (Benjamins et al., 2020, 2021). Online access to medical records improves patient satisfaction, self-care and communication with physicians, although it may increase the burden on healthcare professionals (Mold et al., 2015).

In the context of the availability of educational materials, educational factors, including staff and patient education, are essential to promote patient-centred care. Providing relevant and understandable healthcare information is crucial for patient participation, especially for older patients (Gaffney, Hamiduzzaman, 2022; Jardien-Baboo et al., 2021). Furthermore, patient-centred e-health systems that support value co-creation through patient empowerment and shared understanding can improve the perceived quality of healthcare (Yan et al., 2022).

In summary, empathy on the part of medical staff, adequate information provision and accessible educational materials are key to improving the quality and accessibility of medical information in patient-centred care. These factors improve patient satisfaction, engagement and empowerment, leading to better health outcomes. Addressing these elements can help to overcome barriers related to socioeconomic status and disparities in access.

How doctors and patients communicate significantly influences the level of information asymmetry in the healthcare system. Effective communication can reduce information asymmetry and improve trust and collaboration in healthcare relationships. Effective communication goes beyond simply sharing information and includes sharing interpretive schemas and values, which can increase the co-creation of healthcare services and reduce information asymmetry (Barile et al., 2014).

In turn, the quality of patient-physician interaction, which is influenced by communication, significantly affects trust. Online health information and doctor guidance can improve patient-physician interaction and trust, thereby reducing information asymmetry (Peng et al., 2019). In addition, patients who actively seek information and second opinions can put pressure on doctors, encouraging them to do better and reducing information asymmetry (Rochaix, 1989).

Information asymmetry can lead to conflict and aggression in the doctor-patient relationship. Better communication and information sharing can alleviate these problems by increasing trust and reducing misunderstandings (Xu, He, 2019). Reducing information asymmetry through better communication can lead to more efficient healthcare delivery and potentially lower costs, as it better aligns treatment recommendations with patients' needs and expectations (Blomqvist, 1991; Mascarenhas et al., 2013).

Different strategies to reduce information asymmetry can be distinguished. Firstly, education and public awareness. Indeed, educating the public about common diseases, relevant medical regulations, and general health awareness can help reduce information asymmetry and prevent conflicts. This can be achieved through public health campaigns and educational programmes. Secondly, systemic change. This involves establishing systems for information exposure, patient rights and independent evaluations of health services, which could further reduce information asymmetry.

In summary, how doctors and patients communicate plays a key role in determining the level of information asymmetry in healthcare. Effective communication that includes sharing interpretations and values and systemic changes to improve information transparency can significantly reduce information asymmetry, increase trust and improve healthcare outcomes.

3. Methods

This paper attempts to build an econometric model of medical information in patient-centred care based on the author's theoretical model of medical information in patient-centred care. The aforementioned theoretical model is described in detail in the article "Medical information as a key resource in patient-centred care". “Medical information as a key resource for patient-centred care” was published in a multi-author monograph by the Jagiellonian University and the Jagiellonian Library in Krakow. “Horizons of Information 6” in 2024. (Czerska, 2024) (Figure 1).

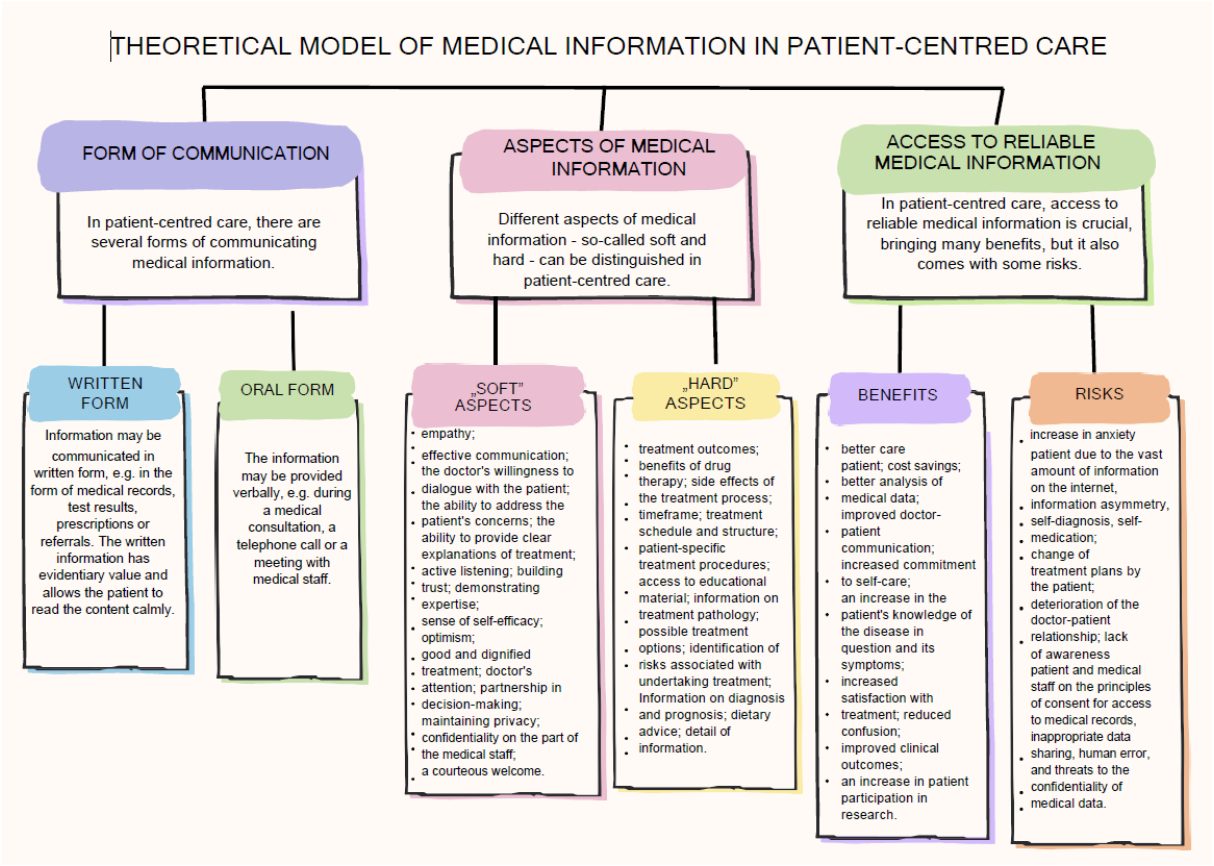

Figure 1. Theoretical model of medical information in patient-centred care.

Source: (Czerska, 2024).

The explanatory variable in the econometric model is "Quality and accessibility of medical information" based on the following responses: very low (no access to reliable information) - 1; low (difficult access, unclear information) - 2; medium (partial accessibility, need to search for information by oneself) - 3; high (suitable educational materials, availability of consultations) - 4; very high (complete transparency, high quality of information) - 5; no opinion - 0. On the other hand, as explanatory variables, it was planned to take into the model, firstly, synthetic variables, which would be formed as arithmetic averages of the assigned scores for the answers: very low - 1; low - 2; medium - 3; high - 4; very high - 5; I have no opinion - 0, for the following variables:

- Assessing the reliability of different sources of medical information in public health care: general practitioner, nurse, NHF website, information brochures and leaflets, medical telephone helplines, information obtained from the pharmacist, websites of hospitals and clinics, e-registration and patient portals (e.g. Internet Patient Account), social media (e.g. Facebook, LinkedIn, Twitter), online health forums, educational programmes on TV and radio, mobile health monitoring apps, medical articles and research, patient organisations, WHO (World Health Organisation) recommendations. New synthetic independent variable "Credibility of medical information sources".

- Assessment of the reliability of different forms of medical information transmission in public healthcare: verbal information from a doctor, verbal information from a nurse, written recommendations after a visit, websites of medical facilities, patient portal (e.g. Internet Patient Account), SMS appointment reminders, telephone medical consultations, information brochures and leaflets, mobile health management apps, video medical consultations. New synthetic independent variable "Credibility of forms of medical information communication".
- Assessment of different aspects of empathy of medical staff: ability to listen to the patient, showing understanding and support, giving sufficient attention to the patient, patience when talking to the patient, politeness and respect when interacting with the patient, and giving clear and understandable explanations. The new synthetic independent variable is "Empathy of medical staff".

Secondly, the variable "Level of information asymmetry", denoting the difference in access to information between doctor and patient, was planned to be taken into the model: very low asymmetry (complete transparency of information to the patient) - 5; low asymmetry (patient has access to most information) - 4; medium asymmetry (some information difficult to obtain) - 3; high asymmetry (relevant information is not made available to the patient) - 2; very high asymmetry (patient has minimal knowledge, complete domination by the doctor) - 1; no opinion - 0.

The article combines "Results" and "Discussion", which allows the results of the medical information modelling in patient-centred care to be presented and verified, and its implications are discussed in the same section. This arrangement made the article more concise and focused by allowing the results of the econometric modelling to be directly linked to the research questions.

4. Results

In February-March 2025, the self-administered survey was conducted using CAWI (Computer-Assisted Web Interviewing). A baseline survey followed the pilot. The survey sample consisted of 247 respondents. The sample selection was non-random. Firstly, voluntary selection was used, and a link to the survey was posted on Facebook and LinkedIn. Secondly, purposive selection - students and employees of Wrocław University of Economics and Business were invited to participate in the study. Thirdly, snowball selection - the study participants shared the link with their friends and family, who then shared it with others.

The study aimed to identify key factors influencing the quality and accessibility of medical information in public healthcare. The analysis focused on assessing the reliability of different sources of information, forms of medical information delivery, the level of empathy of medical staff, and information asymmetry between patients and medical staff.

The first step in building an econometric medical information model was to check collinearity for potential synthetic variables. The results are as follows. For the synthetic variable "Credibility of medical information sources", the mean VIF = 19.42, which indicates very high collinearity. The result indicates that the components of this variable are highly correlated, which may lead to instability in the model. For the second synthetic variable, "Credibility of forms of medical information transmission", the mean VIF = 25.23, indicating extreme collinearity. Such a high level of correlation within the component variables implies the need to reduce collinearity. The highest collinearity among all synthetic variables concerns the variable "Empathy of medical staff", for which the mean VIF = 28.96. This variable, in its current form, could cause serious problems in the regression model

Due to VIF values > 10 indicating strong collinearity and VIF values > 25 indicating critical collinearity, an attempt was made to apply PCA analysis to create one optimised synthetic variable for each group. The results of the PCA analysis allowed the synthetic variables to be optimised as follows:

- For the synthetic variable "Credibility of medical information sources (PCA1)", the variance = is 34.71%, meaning that one principal component retains 34.71% of the information from the original variables.
- For the synthetic variable "Credibility of forms of medical information communication (PCA1)", explained variance = 47.78%, meaning that this component retains almost half of the information, so the collinearity was successfully reduced.
- For the synthetic variable "Empathy of medical staff (PCA1)", the explained variance = is 76.33% (a very high value), meaning that PCA1 represents this variable well and effectively eliminates redundant information.

In summary, PCA effectively reduced the impact of collinearity, producing optimised synthetic variables. The best fit was obtained for "Empathy of medical staff" (76.33%), suggesting that the component captures the original information well.

In the next step, an attempt was made to build an econometric model of medical information in patient-centred care, considering the PCA synthetic variables. The analysis started with a linear regression, but it turned out that the model fit was very low, so the model was rejected. Another attempt was, therefore, made to create a non-linear medical information model. Unfortunately, the various non-linear models did not yield the expected results. In addition, several other statistical analyses and predictive models were conducted to explain the variation in the dependent variable. The results show that none of the models tested achieved a high fit (Table 1).

Table 1.
Summary of different approaches to modelling the dependent variable "Quality and accessibility of medical information" for PCA variables

Approach	R^2 on the learning set	Most significant variables ($p < 0.05$)	Interpretation
Linear regression	0,116	Credibility of forms of medical information communication, Empathy of medical staff, and Level of information asymmetry	Linear regression indicates significant variables but low fit
The power model	0,069	No significant variables	The power model does not improve the results
Exponential model	0,064	No significant variables	The exponential model does not improve the results either
Polynomial regression	0,150	No significant variables	Polynomial regression slightly improves the result but is still a poor fit
Decision tree	0,379	Lack of interpretation	The decision tree is well-matched to the learning data but may be overfitting
Random Forest	0,490	Lack of interpretation	Random Forest is a better fit, but generalisation is poor
LASSO	0,120	No significant improvement	A slight improvement over linear regression, but not useful
Ridge	0,122	No significant improvement	No significant improvement
Support Vector Regression	0,238	No significant improvement	Did not improve fit relative to a linear model
Neural network (MLP)	0,113	No improvement	A neural network gives a better match in validation, but still has a low

Source: own study.

5. Discussion

Table 1 shows the results of the predictive model analysis, considering only the PCA synthetic variables "Credibility of medical information sources (PCA1)", "Credibility of forms of medical information communication (PCA1)", "Empathy of medical staff (PCA1)" and the variable "Level of information asymmetry". Linear regression, non-linear models (power, exponential, polynomial), decision trees, regularised regression (LASSO, Ridge), Support Vector Regression (SVR) and neural network (MLP) were tested. The best fit was achieved by linear regression on the PCA variables, in which "Credibility of forms of medical information communication (PCA1)", "Empathy of medical staff (PCA1)", and "Level of information asymmetry" were statistically significant. However, the R^2 was still low (~0.12), meaning that the model explains only a tiny part of the variation in the dependent variable. The power and exponential models did not improve the results, and the polynomial regression produced minimal improvement but still had a low fit.

Tree models (Decision Tree and Random Forest) fit the learning set well (R^2 up to 0.49) but tended to overfit and have poor generalisation. Regularised regression (LASSO, Ridge) and SVR did not significantly improve. The neural network had a slightly better fit in validation, but it was still low, indicating the difficulty in capturing significant relationships in the data.

In summary, the inclusion of the PCA synthetic variables did not improve the quality of the modelling. The most significant predictors are "Credibility of forms of medical information communication", "Empathy of medical staff", and "Level of information asymmetry", but their impact on the quality and accessibility of medical information is limited. The low R^2 in all the models tested suggests that other factors not included in the analysis influence the variability of the dependent variable, such as the demographic characteristics of the respondents, the information policy of the medical facilities or the patients' health education level. Further research could explore new variables, analyse the interactions between predictors, and use more advanced machine-learning techniques.

These results indicate that empathy, information asymmetry, and communication credibility are statistically significant but account for only a small portion of the overall variability. This suggests that medical information perception is shaped by a more complex set of factors than initially expected. The results should be interpreted in the context of broader patient-centred care models, where factors such as health literacy, institutional trust, and individual digital competencies may play a crucial role (Delaney, 2018; Nutbeam, 2008; Yan et al., 2022). The low explanatory power of the tested models confirms that the perception of medical information is multidimensional and influenced by behavioural, systemic, and psychological determinants (Epstein, Street, 2011; McMillan et al., 2013).

This is consistent with the findings of (Epstein, Street, 2011), who emphasised that the perception of information quality is shaped by the depth of communication and trust in the patient–provider relationship. Similarly, (Nutbeam, 2008) Highlighted health literacy as a key determinant in patients' ability to interpret and act on medical information (Mead, Bower, 2000) also noted that communication and shared understanding are fundamental to patient-centredness. Kitson et al. (2013) further emphasised the role of relational continuity and empathy in improving care quality.

Compared to previous research—often qualitative or survey-based—this study contributes by proposing a quantitative, model-based approach that integrates a theoretical framework with PCA and regression techniques. It offers a novel operationalisation of soft constructs in econometric modelling.

While prior studies confirmed the importance of empathy and trust in patient-provider communication, this research attempted to validate these findings through structured quantitative modelling. For example, H. Gaffney & Hamiduzzaman (2022) showed that older patients' participation in clinical dialogue depends strongly on perceived empathy and clarity of communication. Jardien-Baboo et al. (2021) confirmed the significance of evidence-based guidelines for patient-centredness in nursing care. These observations are echoed in the present

study's results, although the quantitative modelling reveals that these factors alone do not fully explain variability in perceived information quality.

The findings emphasise the need for hybrid approaches incorporating behavioural, psychological and organisational dimensions. Additionally, the weak explanatory power of the tested models raises the question of whether context-specific or longitudinal data may be more suitable for future analyses.

The study provides empirical support for the assumption that key factors—such as empathy, credible forms of communication, and perceived information asymmetry—play a statistically significant role in shaping how patients assess the quality and accessibility of medical information. However, the relatively low explanatory power of the models suggests that additional, unmeasured factors may also be important.

The novelty of the findings lies not only in the use of PCA and machine learning techniques but also in the attempt to translate intangible constructs into empirical data. The methodological triangulation enhances the robustness of the conclusions, although the lack of generalisability due to the sample structure remains a limitation. This approach reflects the recommendations of Barile et al. (2014), who argued that addressing information asymmetry in healthcare requires systemic analysis and co-creation of communication strategies with patients. Similarly, Mascarenhas et al. (2013) proposed reducing asymmetry through multi-level educational and institutional strategies.

In terms of future research plans, the author intends to extend the model by including cross-sectoral comparisons (public vs. private healthcare institutions) and test dynamic models using longitudinal data. Another direction involves incorporating health literacy scales, perceived trust, and digital engagement variables into the econometric framework.

In conclusion, this study demonstrates the challenges of modelling complex, human-centric variables such as medical information quality. It also opens new research directions, encouraging interdisciplinary methodologies and deeper investigation into how patients process, trust, and act upon the information they receive.

6. Conclusions

The conclusions presented below are directly linked to the modelling results and take into account both theoretical assumptions and practical implications for health communication systems.

The literature review showed that the quality and accessibility of medical information in patient-centred care depend mainly on the empathy of medical staff, sufficient consultation time, the form of information delivery, and access to educational resources. Econometric analysis confirmed that these factors significantly impact patients' perception of information,

with the level of information asymmetry in the healthcare system playing a key role in limiting access to reliable medical data.

The findings have important practical implications for the healthcare sector. Firstly, they point to the need to optimise the communication strategies used by healthcare professionals. Indeed, improving forms of communication, including digital technologies, can increase the transparency and accessibility of data, reducing the information asymmetry between patients and doctors. Secondly, it is also crucial to train medical staff in effective communication and empathy, which can significantly improve the quality of interactions with patients. Thirdly, from a health policy perspective, the study's results suggest a need for greater emphasis on standardising and sharing medical information. Indeed, implementing standardised e-health systems, improving access to electronic patient records and providing patients with easier access to reliable and understandable educational materials can increase their autonomy and involvement in treatment. Finally, taking measures to reduce information asymmetries can lead to better-tailored treatments for patients and, thus, higher efficiency in the healthcare system.

In summary, improving the quality and accessibility of medical information requires comprehensive measures that include changes in medical facilities' communication strategy and systemic information access reforms. The integration of an empathetic approach by staff, the digitalisation of information and the reduction of information asymmetries can contribute to better patient-centred care and increased patient satisfaction and engagement.

The article contains limitations. Firstly, the CAWI survey had limitations related to the availability and quality of data - the sampling was non-random, which makes it impossible to generalise the results to the whole population, as the results are only specific to the surveyed group. Secondly, the modelling included variables related to information reliability, staff empathy and information asymmetry but did not include other potentially relevant factors, such as patients' digital competence or cultural context. Thirdly, the collinearity problem required dimensionality reduction through PCA, which could lead to some information loss. The econometric models tested had low R^2 values, suggesting that important variables were not captured. The model was not fully validated on independent datasets, and the analysis was static, making it impossible to assess long-term changes, which limits the possibility of assessing long-term trends or causal relationships.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

CREATING COMPETITIVE ADVANTAGE BASED ON A QUALITY-COST MODEL FOR IMPROVING CAST PRODUCTS

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Purpose: The aim of the study was to develop a quality and cost model for improving cast products, which supports optimisation activities and the resolution of quality issues in a structured manner.
Design/methodology/approach: The model utilises a sequential combination of the following techniques: Pareto chart correlated with the ABC principle, ranking, brainwriting, Ishikawa diagram (5M+E), five-point Likert scale, and matrix diagram.
Findings: During the proceedings, the main causes of critical non-compliance of castings were identified. These were: insufficient mould temperature, poor mould venting, insufficient mould filling temperature, incorrect gating system, excessive mould and core moisture.
Research limitations/implications: Future work will focus on expanding the model towards its integration with real-time data and broadening analyses related to quality assurance costs. A limitation of the model is the need for access to historical data, which is the starting point for the analyses.
Practical implications: The model has been verified in practice, confirming its correctness and usefulness in solving quality problems, taking into account the quality-cost relationship. The implementation of the model's assumptions in foundry companies will assist management in improving complex foundry processes, leading to the creation of competitive advantage.
Originality/value: The model includes an integral methodological configuration that allows for assessing the significance of the causes of identified critical non-conformities in terms of quality and cost, and provides structured support for optimisation activities and solving quality issues.
Keywords: mechanical engineering, casting defects, leak testing, quality improvement, management and quality.
Category of the paper: Research paper.

1. Introduction

The dynamic changes taking place in the external environment of industrial enterprises are placing ever greater demands on organisations in terms of development and presenting them with increasingly difficult problems to solve. One of the key conditions for achieving market success and competitive advantage is the design and implementation of processes tailored to specific production capabilities and needs (Gajdzik, Wolniak, 2022; Pacana, Czerwińska, 2018). Products should not be implemented at any cost, paying attention only to the costs associated with a given implementation and the amount of potential profits (Khan et al., 2022). When undertaking implementation activities, the manufacturer should be confident that the expected level of product quality will be ensured and that the rate of return on the implemented product will be high enough to offset the costs incurred (Stawiarska et al., 2021; Ingaldi, Mazur, 2022).

In an era of intense and progressive globalisation in the field of production, quality has become an important distinguishing feature of industrial companies operating on the market. It is closely related to the manufacture of products, their sale and the level of costs incurred by the organisation. In the vast majority of cases, the buyer's decision to accept or reject a product determines the success or failure of the manufacturer or service provider (Dornelles, Sellitto, 2015; Gramegna, 2017). These issues have an impact on building a company's position in a competitive market. On the road to success, it is also important to build a strong brand through continuous improvement, consistent action and rapid response to market changes (Gijo et al., 2014; Siekanski, Borkowski, 2003).

Companies wishing to maintain a stable level of quality while increasing the economic efficiency of their resources and processes should implement effective management methods (Pietraszek, Skrzypczak-Pietraszek, 2014; Czerwińska et al., 2025). This requires, on the one hand, diagnosing whether the activities carried out so far have brought the expected results and, on the other hand, taking measures related to quality improvement while focusing on the reasonable use of production resources (Malinowski et al., 2013). Such a development strategy also affects the effectiveness of the tasks undertaken by the company and the building of a stable market position (Klimecka-Tatar et al., 2021).

An important aspect of managing a foundry company is striving to improve quality in the specialised process of casting (Bris et al., 2021). This involves technological parameters that can affect the quality of the finished product. The most significant problem in the production process of cast products is the inability to simultaneously control all the determinants of the technological process quality. This fact makes casting a very complex technique, and the implementation of individual stages of production in this technology is associated with many difficulties (Pacana, Czerwińska, 2023; Borkowski et al., 2016). As part of quality improvement and minimising deviations from the desired quality criteria, the measures taken

increasingly concern not only the testing and analysis of finished castings (with particular attention to non-conformities) but also the prediction and prevention of undesirable events (Prasad et al., 2016; Pacana, Czerwińska, 2023a). The possibility of reducing the level of potential costs associated with exercising full quality control over batches of manufactured castings encourages this approach. The desire to reduce costs may prompt changes, but full control contributes to longer production processes and is a labour-intensive task, the benefits of which in terms of quality assurance may not outweigh the potential slowdown (Khan et al., 2023; Pietraszek et al., 2020). It is crucial to identify critical products and related non-conformities. Analysis of these problems and their determinants will allow for effective maintenance of a stable level of quality of the cast product (Ulewicz, Novy, 2019; Greń, Zaziębło, 2019).

The aim of the study was to develop a quality and cost model for improving cast products. The implementation of the model's assumptions in foundry companies will assist management in carrying out complex processes leading to the creation of competitive advantage. The model contains an integral methodological configuration that allows for the assessment of the significance of the causes of identified critical non-conformities in terms of quality and cost, and provides structured support for optimisation activities and the resolution of quality issues. The model uses a sequential combination of the following techniques: Pareto diagram correlated with the ABC principle, ranking, brainwriting, Ishikawa diagram (5M+E), five-point Likert scale and matrix diagram.

2. Methods

The quality and cost improvement model for products was developed to improve quality by minimising deviations from the desired quality criteria and stabilising the production process for cast products while maintaining cost efficiency. The application of the model boils down to analysing the product by identifying and solving critical quality problems, which in most cases are product non-conformities. The procedure presented in the model allows for the identification of critical non-conformities, whose presence contributes most to the instability of the quality process and at the same time generates the highest costs. The model is based on the sequential integration of methods and techniques such as: the Pareto Lorenz diagram correlated with the ABC method, non-verbal brainstorming (Brainwriting), the Ishikawa diagram (according to the 5M+E principle), a balanced five-point rating scale, and a matrix diagram. The individual stages of the model are presented in Figure 1. The model diagram also takes into account the methods and techniques dedicated to each stage of the process.

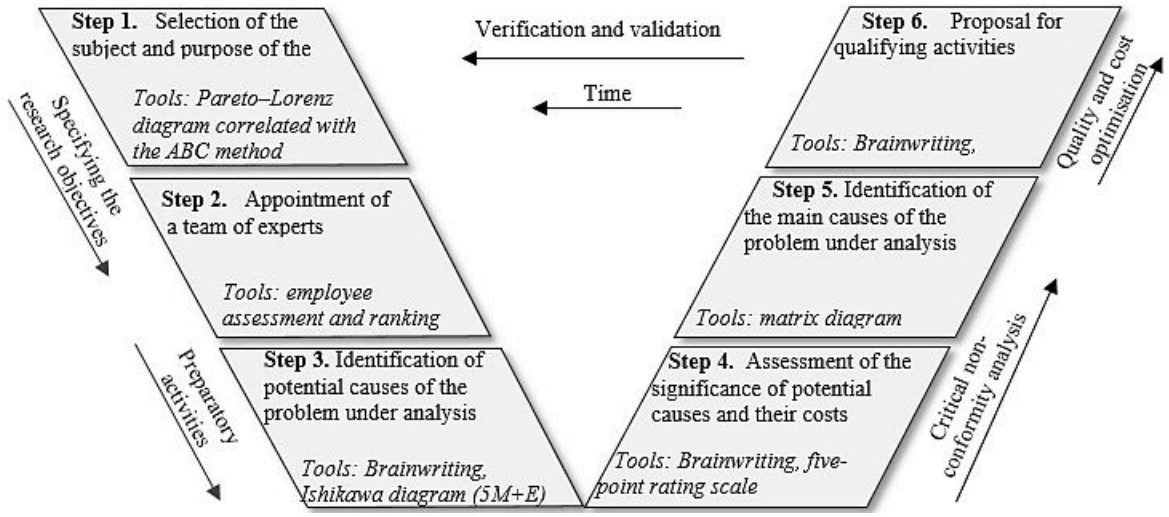


Figure 1. Diagram of the structure of a quality-cost model for improving cast products.
Source: own study.

The individual stages of the model's implementation are presented in the following subsections.

2.1. Selection of the subject and purpose of the research

The subject and purpose of the research should be specified by an authorised entity (expert). Defining the subject of the research allows researchers to focus their attention on a specific quality issue that will be examined, analysed and evaluated using appropriately selected research methods (Czerwińska, Pacana, 2025). Due to the purpose of the model, the subject of the research may be a cast product whose manufacturing process has lost its quality stability or a selected type of non-compliance (critical in terms of severity, effects, frequency and costs of occurrence). The selection of the subject of research may be supported by a non-conformity register (if kept in the company) or made using supporting tools - a Pareto Lorenz diagram correlated with the ABC method (Sułkowski, Wolniak, 2013). Next, the objective of the study corresponding to the current needs of the company should be specified. A well-defined research objective will guide the entire work and assist in the interpretation of the results. The application of the developed model supports the achievement of objectives related to:

- identification of non-conformities between the actual state and the expected standard, which may relate to a product or process,
- analysis of quality issues,
- analysis of the causes of critical non-conformities (root causes),
- analysing the cost severity associated with the presence of critical non-conformities,
- proposing adequate corrective actions while maintaining a reasonable relationship between the quality achieved and the costs of achieving it.

The accepted research objective should relate to the subject of the research and take into account the client's requirements in this regard.

2.2. Appointment of a team of experts

The team of experts analysing the problem related to quality improvement activities should consist of appropriately trained employees with extensive knowledge of the subject matter and experience in the area to be improved. The team leader coordinates tasks and supports team members (Wolniak, 2022; Ingaldi, Ulewicz 2025). The aim of the team of experts is to prevent the problem from recurring.

2.3. Identification of potential causes of the problem under analysis

This step should begin with an analysis of the current situation, taking into account the relevant area in relation to the subject and purpose of the research. These may include: processes, customer expectations, financial results, quality issues and product non-conformities. The analysis of the causes of loss of product quality stability should include the results of a specialist product diagnosis (Czerwińska et al., 2021). The task of the experts is to identify all the probable causes of the problem under investigation. This activity should be supported by a brainstorming session. This will make it possible to generate a large number of ideas. It is recommended to use a written form of brainstorming, as this will avoid the tensions and conflicts that can arise in a classic brainstorming session. The results of the session should be visualised and logically grouped according to the rules of creating an Ishikawa diagram in a 5M+E configuration (Wolniak, 2016).

2.4. Assessment of the significance of potential causes and their costs

In this step, the team of experts evaluates the potential causes of the problem under investigation, taking into account their impact on reducing quality and the associated costs. The assessment should use a five-point Likert scale, where, in relation to the model, the extreme points mean: 1 – the cause has a very small impact on the problem and generates very low costs, 5 – the cause has a very large impact on the problem and generates very high costs. In order to avoid conflicts in assigning ratings, it is worth supporting this step with a brainwriting tool. Individual ratings should be entered into an Ishikawa diagram or, for greater clarity, placed in a summary table.

2.5. Identification of the main causes of the problem under analysis

The main causes of the analysed problem should be understood/recognised as those that determine the occurrence of a quality problem and at the same time significantly increase costs. A matrix diagram should be used to identify critical causes in the quality-production cost relationship. The analysed causes of the quality problem should be placed in the diagram based on expert assessments in the quality and cost categories. Causes located in the critical area should be considered the main causes for further analysis.

2.6. Proposed improvement measures

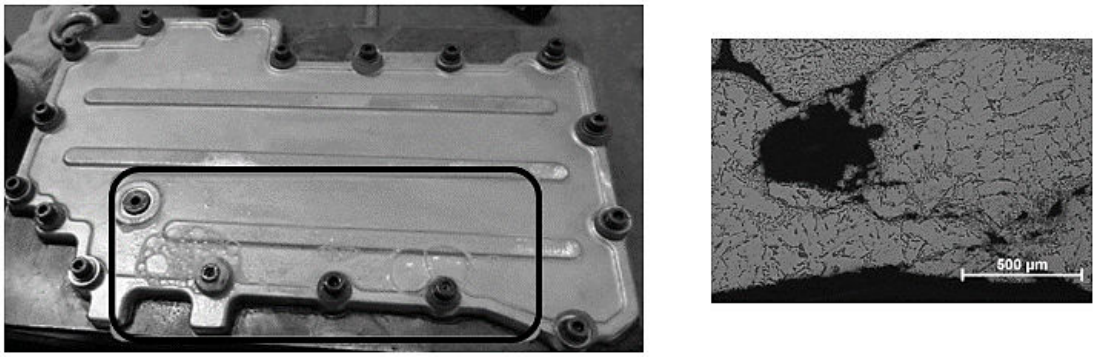
Improvement measures should include corrective and preventive actions. With regard to the root causes of quality problems, corrective actions should be developed and implemented to eliminate the root causes of existing irregularities in order to prevent their recurrence (Gajdzik, Sitko, 2016). Next, a team of experts should develop preventive measures in line with a proactive approach to permanently eliminate the potential causes of problems. Improvement measures should be developed using brainwriting.

3. Results and discussion

The developed model was tested in practice by applying it to a foundry located in south-eastern Poland. In order to test the model, production information was analysed, including historical data from the production process (production status and progress, number of units produced, material consumption, machine and employee working time, as well as data on quality and costs) and information on complaints and quality issues. The information analysed was from the first quarter of 2025.

The first step was to define the subject of the research and specify its objective. Based on data concerning the non-compliance of cast products and complaint records, a control panel cover cast using the gravity casting method from AlSi7Mg0.6 alloy was selected as the subject of the research. The design changes introduced in relation to the change in the shape and size of the casting contributed to a loss of stability in the production process, which led to the manufacture of a significant number of products outside the specified tolerance limits. The objective of the research related to the subject of the study was then specified. Analysis of the non-conformity records showed that the dominant type of non-conformity was the presence of oxides in the control panel cover. This non-conformity is identified in the leak test of castings. For this reason, the objective of the research was to identify the main causes of the presence of oxides in the control panel cover. Figure 2 shows the control cover casting with the result of the leak test and an example of a critical non-conformity in the marked area.

The next step was to appoint a team of experts. The team consisted of: chief technologist, product quality control manager, production manager, and complaints specialist. The appointed team carried out the subsequent stages of the analysis.



a) b)

Figure 2. a) Subject of testing with non-compliance revealed in the water sample, b) example of critical non-compliance – leakage (oxide inclusion through the casting wall).

Source: own work.

The next step was to identify the potential causes of oxygen inclusions in the casting. The probable causes of the quality problem were gathered by the team of experts during a brainwriting session. The result of the session – the ideas generated – were grouped and plotted on an Ishikawa diagram in a 5M + E configuration, taking into account six categories: man, machine, material, method, management, environment (Figure 3).

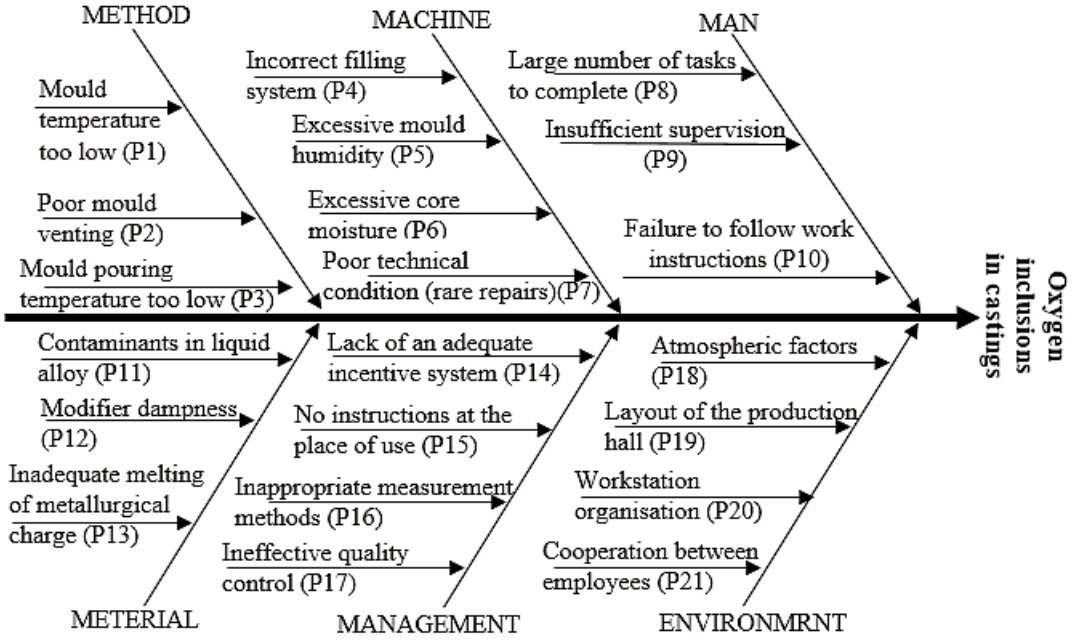


Figure 3. Ishikawa diagram for the problem of oxygen inclusions in castings.

Source: own work.

When assessing the significance of potential causes of the problem in the products and their costs, the team of experts adopted a five-point rating scale (1 – the cause has a very small impact on the problem and generates very low costs; 5 – the cause has a very large impact on the problem and generates very high costs). Assessment sheets were prepared on which team members anonymously assigned ratings. The final ratings of potential causes (Table 1) are the result of the average of the ratings assigned, rounded to the nearest whole number.

Table 1.
Assessment of the importance of potential causes and the costs of their occurrence

The analysed area	Identification of the potential cause	Assessment of the impact of potential causes on the analysed non-compliance	Assessment of the level of costs incurred due to the presence of potential causes of the problem
Method	P1	3	1
	P2	3	3
	P3	5	3
Machine	P4	4	3
	P5	5	4
	P6	5	4
	P7	2	4
Man	P8	2	2
	P9	1	3
	P10	2	2
Material	P11	4	2
	P12	5	2
	P13	4	2
Management	P14	2	2
	P15	2	3
	P16	3	2
	P17	3	2
Environment	P18	4	1
	P19	3	1
	P20	1	1
	P21	2	1

Source: own work.

In order to identify the main causes of the problem, i.e. those causes that significantly affect the loss of the expected level of quality and generate significant costs, the team of experts used a matrix diagram. The graphical representation of the assessment results on a four-quadrant matrix grid provides information that facilitates the analysis of the critical distribution of the causes of the problem. The result is shown in Figure 4.

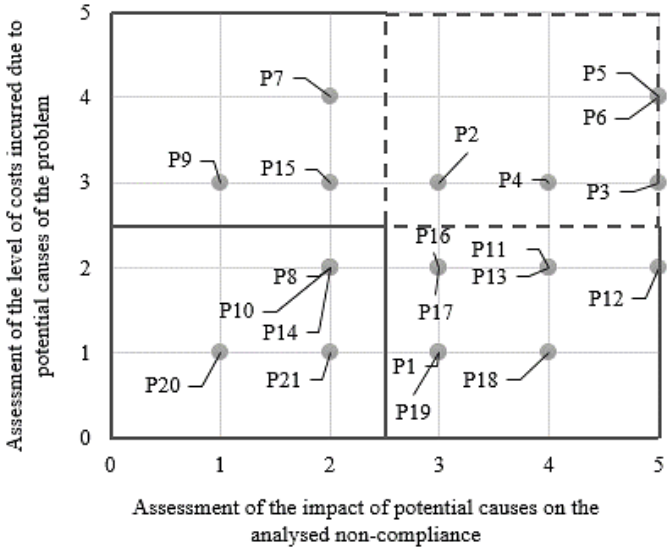


Figure 4. Assessment of the impact of potential causes on the occurrence of the investigated casting non-conformity in terms of quality and cost.

Source: own work.

The critical area, i.e. the upper right field marked with a dotted line, indicates the main causes of the quality problem. The following potential causes are located in this field: P1 – mould temperature too low, P2 – poor mould venting, P3 – mould filling temperature too low, P4 – incorrect gating system, P5 – mould moisture too high, P6 – core moisture too high. Table 2 summarises the impact of potential causes on the presence of the analysed non-conformity.

Table 2.
Synthetic analysis of the impact of potential causes on the presence of the analysed non-compliance

Possible reason		Synthetic description of the impact
P1	mould temperature too low	Too low a mould temperature affects the crystallisation time. Slow solidification increases the porosity of the alloy and the presence of oxides in the casting.
P2	poor mould venting	Incorrect selection of vacuum parameters causes improper venting of the mould, which 'traps' air in the casting, thereby increasing gas porosity.
P3	mould filling temperature too low	If the mould filling temperature is too low (the liquid alloy is kept in the ladle or heating furnace for too long), this may lead to an increase in its gas content.
P4	incorrect filling system	Its incorrect design of the pouring system, especially in castings characterised by complex geometry and varying wall thicknesses, contributes to increased porosity in the more massive parts of the casting.
P5	excessive mould humidity	Excessive moisture in the mould or casting core causes blisters to form in castings, as water evaporates rapidly on contact with hot metal.
P6	excessive moisture in the cores	

Source: own work based on: (Parlak, Emel, 2023; Song et al., 2021; Lichy et al., 2016).

After conducting a qualitative and cost analysis and identifying the main causes of leakage (oxide inclusions through the wall) in the control panel cover casting, a brainwriting session was held to generate a comprehensive list of improvement measures. The improvement measures included the following guidelines:

- selection of appropriate process parameters (analysis of vacuum parameter selection),
- simulation of mould cavity filling and solidification,
- introduction of precise stage and final control,
- constant monitoring of mould temperature, mould and core moisture levels,
- reconstruction and optimisation of the mould gating system,
- implementation of the TPM (Total Productive Maintenance) method, in order to achieve maximum efficiency in the use of machinery and employee engagement,
- development of workstation instructions in the Foundry area,
- training of foundry department employees and creation of a quality-oriented organisational culture.

The aim of implementing the proposed improvement measures was to improve the quality of cast products while minimising costs related to repairs, complaints and disposal of non-compliant products. The implementation of the specified measures in the analysed company will bring a wide range of benefits in terms of quality, costs, technology and management.

The developed model can support management in the event of quality problems. The application of the developed model enables analyses to be carried out while maintaining the quality-cost relationship. In the industrial sphere, this relationship is based on an analysis of the sum of all expenses related to the detection and correction of errors and the prevention of defects. Optimisation in this relationship involves investing in corrective, preventive and evaluative measures, which in the long term significantly increases and stabilises product quality and reduces costs associated with quality issues and failures (internal and external), leading to greater customer satisfaction and competitive advantage.

4. Summary and conclusion

The issue of leaks in aluminium alloy products is a serious one, given the current increase in requirements for the service life of cast components, which results from their use, increasingly aware consumers, growing competition, pressure for sustainable development and technological progress. For this reason, it was reasonable to set the goal of developing a quality and cost improvement model for cast products. The model contains an integral methodological configuration that makes it possible to assess the degree of significance of potential causes of identified critical non-conformities in terms of quality and cost, and in a structured way supports optimisation activities and the resolution of quality issues.

A practical verification of the developed quality and cost model for improving cast products was carried out, which confirmed its correctness and usefulness in the industrial sector. The analysis concerned the casting of a control panel, whose manufacturing process had lost its quality stability due to design changes. The critical non-conformities were identified as oxide inclusions throughout the casting wall, causing leaks. In the further course of the proceedings, the main causes of non-conformities were identified. These were: too low mould temperature, poor mould venting, too low mould filling temperature, improper gating system, too high mould and core moisture content. Improvement measures appropriate to the situation and capabilities of the company were also proposed. It was proposed to implement specific technological changes in the examined process, implement TPM, develop workstation instructions in the foundry area and conduct training.

The proposed model can be a component of activities supporting quality management processes. It is a logical model and relatively easy to apply in practice, and at the same time, this analysis significantly increases the amount of information about the analysed problem. Future research directions will focus on implementing the presented model in relation to products in the company in accordance with the concept of continuous improvement. Future work will focus on expanding the model towards integration with data collected and functioning in real time.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

LOGISTICAL ATTRACTIVENESS OF THE SILESIAN VOIVODESHIP

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Purpose: The subject of the research in this paper is the analysis of the logistic attractiveness of the Silesian Voivodeship. To this end, a number of key factors were identified as determining the competitiveness of the region in the area of transport and logistics.
Design/methodology/approach: The paper uses secondary data from national statistical databases and industry reports on transport infrastructure, logistic activity, investments and employment in the TSL sector.
Findings: The analysis demonstrated that the Silesian Voivodeship is positioned within the group of most attractive logistics regions in Poland. The region's strategic geographical location, well-developed road and rail infrastructure, the presence of an established industrial base, and a high level of investment activity in the TSL sector, are all factors that contribute to its competitive advantage. However, the identification of barriers to development was also a feature of the report, with spatial constraints, environmental burden and challenges related to the region's energy transition all being cited.
Practical implications: The findings of the research will inform the design of a regional development strategy for the province and the promotion of investment. The paper is likely to be of use to local governments, spatial planners, investors and TSL companies when making location decisions.
Originality/value: The paper makes a significant contribution to both academic discourse and business practice by providing a tool for analysing the competitiveness of regions in the context of the development of the transport and logistics sector. The present volume is intended for researchers in the fields of logistics and regional policy, as well as practitioners in the transport and logistics sector.
Keywords: logistical attractiveness, Silesian Voivodeship, regional development, transport infrastructure.
Category of the paper: research paper.

1. Introduction

The contemporary global economy is entirely dependent on the effective functioning of logistics systems. Logistics, with its technological, organisational and infrastructural solutions, exerts a significant influence on changes in the spatial development of cities, including, above all, the spatial allocation of transport flows and the location of appropriate warehouse space. The logistical attractiveness of a specific area therefore becomes a determining factor in the choice of location. This phenomenon can be attributed to the escalating competitive pressures between regions, as well as the aspiration to unlock and augment the latent potential inherent within these regions (Strahl, 2006). As posited by (Kuciński, 1999), two fundamental groups of determinants can be identified as primary factors influencing a region's logistical attractiveness and development potential. These determinants can be categorised as macro-regional and micro-regional. The first group includes elements that are independent of the characteristics of a given city, which are not influenced by the city, and their shaping is significantly limited. Micro-regional factors, by contrast, are those that can be directly stimulated by the self-governing bodies of a given area. In order to facilitate the decision-making process regarding the optimal investment location, a range of economic, demographic and geographical indicators are meticulously analysed by relevant parties, including but not limited to the unemployment rate, the purchasing power of the population, the price per square metre of land, the average cost of transport services, the expense of infrastructure access, tax concessions and long-term demographic forecasts. A further set of factors must be considered, which, though not indicative or criterion-based, are nevertheless of significant importance to investors when determining whether to commit their own capital. The extant literature identifies several key determinants of this type. These include regional and governmental programmes that support the development of logistics and transport infrastructure and the funds for their implementation, the state of road infrastructure and plans for its development, the attitude of public sector institutions towards the investment initiative, the cooperation of state administration bodies and local government units with the private sector, the possibilities of using sources of financing within the framework of public-private partnerships, legal, environmental and ecological conditions (Grondys, Dragolea, 2016).

Recent studies emphasise that logistical attractiveness is becoming a key element of regional competitiveness in the digital economy and e-commerce. According to the OECD (2022) and the World Bank (2023), logistics indicators such as the Logistics Performance Index are being used more and more to measure regions' ability to attract investment and serve global supply chains. In this context, the accessibility of transport and infrastructure, especially the location of warehouses, terminals and urban hubs, plays a particularly important role in shaping a region's potential (Pinheiro et al., 2024; Pourbaix et al., 2025).

Urban logistics and the 'last mile' are also becoming increasingly important. Reports by the ITF/OECD (2024) and the World Economic Forum (2024) highlight that metropolitan areas' attractiveness today depends not only on traditional cost indicators, but also on delivery systems' efficiency and sustainability. Modern solutions such as micro-logistics hubs and parcel locker networks play a significant role in determining the competitive advantages of cities (Ma et al., 2024; Pinheiro et al., 2024).

Researchers also highlight new determinants of logistical attractiveness relating to energy and environmental transformation. The literature emphasises that developing green transport infrastructure and implementing low-carbon solutions (e.g. electromobility and green logistics centres) is becoming a key criterion in assessing areas' attractiveness (Castillo et al., 2024; Schorung et al., 2024).

The following research questions were posed by the authors of the paper:

1. What factors determine the logistical competitiveness of the Silesian Voivodeship?
2. To what extent do infrastructural, economic and technological conditions influence the level of logistic attractiveness of the Silesian Voivodeship?
3. What are the advantages of the Silesian Voivodeship with regard to the development of the transport and logistics sector?
4. What development barriers limit further growth of the Silesian Voivodship's logistical attractiveness despite its favourable location and infrastructure conditions?
5. How can the identification of logistical attractiveness factors support decision-making processes in regional planning and investment location in the TSL sector?

Given the growing importance of logistics in determining regional attractiveness, it is essential to conduct research that identifies competitive advantages and development barriers in specific areas. This is particularly important in industrialised and urbanised regions such as the Silesian Province, where logistics and transport play a key role in generating economic advantages. This article attempts to evaluate this region's logistical attractiveness, considering infrastructural, economic, technological, and environmental factors, and to identify potential influences on its future development in the context of increasing interregional competition.

2. The concept of logistical attractiveness of a region – literature background

2.1. The presence of logistical attractiveness in the literature

As a preliminary measure, it is recommended to undertake a contemporary bibliometric analysis to delineate and appraise the extant scientific literature in the domain of regional logistical attractiveness. In the initial phase of the research, online bibliographic databases were

reviewed for their applicability to the research presented in this dissertation. Two bibliographic sources were selected for further analysis: The Web of Science (WoS) Core Collection and the Scopus database will be utilised in this study. These databases have been shown to provide reliable and relevant information on scientific papers and are the most common choice for bibliometric analyses. A comprehensive selection of scientific papers was collated from the WoS and Scopus databases for the purpose of analysis. A subsequent review of software tools for bibliometric analysis was then conducted. The authors' intention was to combine the information collected in the WoS and Scopus databases; therefore, VOSviewer was selected as the software tool for bibliometric analysis. In the subsequent stage, a list of search query words was identified:

- region development, city logistics, urban logistics,
- city attractiveness, logistical attractiveness, logistical attractiveness and city (LAC).

The list of formulated queries is presented in table 1. In the final step of this phase, the temporal scope of the analysis was defined. Initially, no initial publication date was entered in the search. However, due to the fact that the first publication in the analysed field (on the concept of LAC) appeared in 1983, the time range was narrowed down to 1983-2020.

Table 1.
Results of the initial bibliometric analysis

Item	Query wording (QW)	Web of Science		Scopus	
		QW Query in title (TITLE)	QW Query in subject (TOPICS)	QW Query in title (TITLE)	QW Enquiry in subject (TOPICS)
1	region development	10577	482 396	12 162	530 107
2	city logistics	815	23 180	1 036	25 115
3	urban logistics	814	27 699	1 103	27 492
4	city attractiveness	106	2 523	153	2 882
5	logistics attractiveness	8	482	9	479
6	logistics attractiveness and city (LAC)	0	71	0	69

Source: own work.

As can be seen from Table 1, by far the most common theme in publications is regional development. In the Web of Science database one can find over 482 thousand literature items on this subject, while in the Scopus database over 530 thousand items. This is justified by the rather general formulation of the question and the great interest of researchers in this issue in the area of very different scientific disciplines (Figure 1).

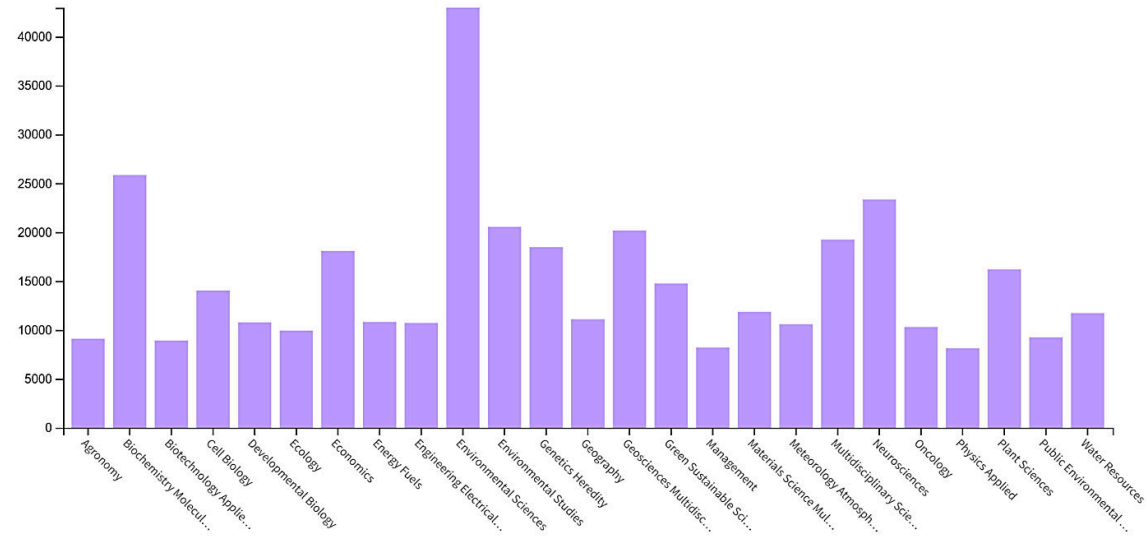

Figure 1. Scientific disciplines within which research topics concerning the development of cities and regions are undertaken.

Source: own work based on results of the analysis from the Web of Science database.

Urban logistics is a frequently addressed issue in scientific publications, with the phrase appearing 815 times in the title of a publication according to the Web of Science database and 1036 times according to the Scopus database. A formulation that appears relatively less frequently in the subject matter of publications is that of city attractiveness, with only 106 publications found in the Web of Science database. A total of 153 such publications were identified in the Scopus database. This finding suggests a paucity of research sophistication in this area. Conversely, the formulation of logistical attractiveness and the logistical attractiveness of a city (LAC) are seldom addressed in publications. Consequently, it is imperative to acknowledge the novelty and significance of the research topic explored in the papaer, both within the national context and on a global scale.

After obtaining the data, which are presented in Table 1 on the number of publications containing the analysed keywords in the title or subject, a web analysis was carried out using the VOSviewer software (Figure 2-4).

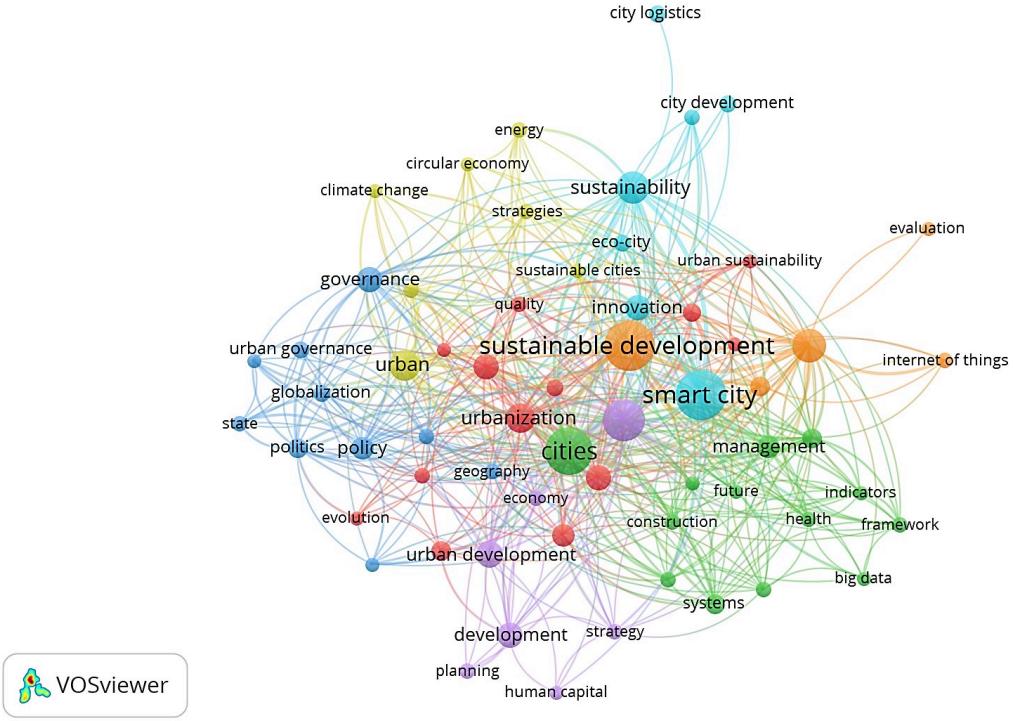

Figure 2. Map of research trends based on co-occurrence of keywords in publications for the words 'city' and 'development' from the Scopus database from 2005 to 2025.

Source: Own work using VOSviewer software.

Analysing the research trend map shown in Fig. 2, it can be concluded that 7 sub-clusters (clusters of author keywords) were identified, which were related to the following areas: red cluster grouping keywords such as: *economic development, economic growth, urbanisation, sustainable city development* (a total of 61 keywords); orange cluster grouping keywords such as: *sustainable development, smart city, internet of things* (a total of 38 keywords)*;* green cluster grouping keywords such as: *big data, city, governance* (42 keywords in total); light blue cluster grouping keywords such as: *smart city, eco city, sustainable cities, urban development* (27 keywords in total); yellow cluster grouping keywords such as: *urban development, circular economy, climate change*; purple cluster grouping keywords such as: *city, planning, strategy, development* (29 keywords in total)*;* dark blue cluster grouping keywords such as: *urban governance, globalisation, policies, government* (41 keywords *in* total). The results showed significant variation in the co-occurrence of author keywords across publications in the urban development literature. This demonstrates the multifaceted and multidimensional nature of this field of study.

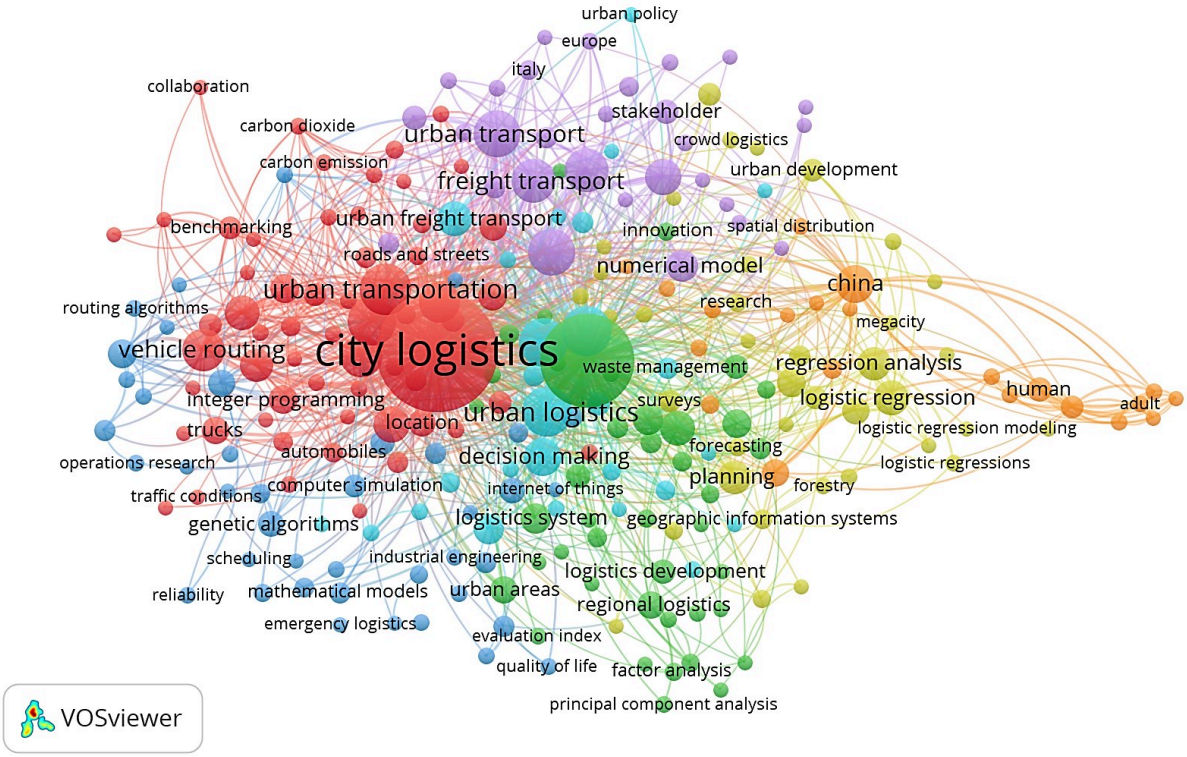

Figure 3. Map of research trends based on co-occurrence of keywords in publications for the words 'city' and 'logistics' from the Scopus database between 2000 and 2023.

Source: Own work using VOSviewer software.

A thorough examination of the research trend map presented in Fig. 3 reveals that the keyword co-occurrence network has demonstrated that research in the domain of city logistics (City Logistics) has predominantly focused on issues that fall within the purview of the field itself, along with associated domains such as urban transport, freight transport, passenger transport, and waste management. The map illustrates a total of seven research clusters, encompassing 259 keywords and a total of 5032 connections. This Figure is indicative of the multidimensionality of the research area in question, as well as the authors' profound interest in the subject matter.

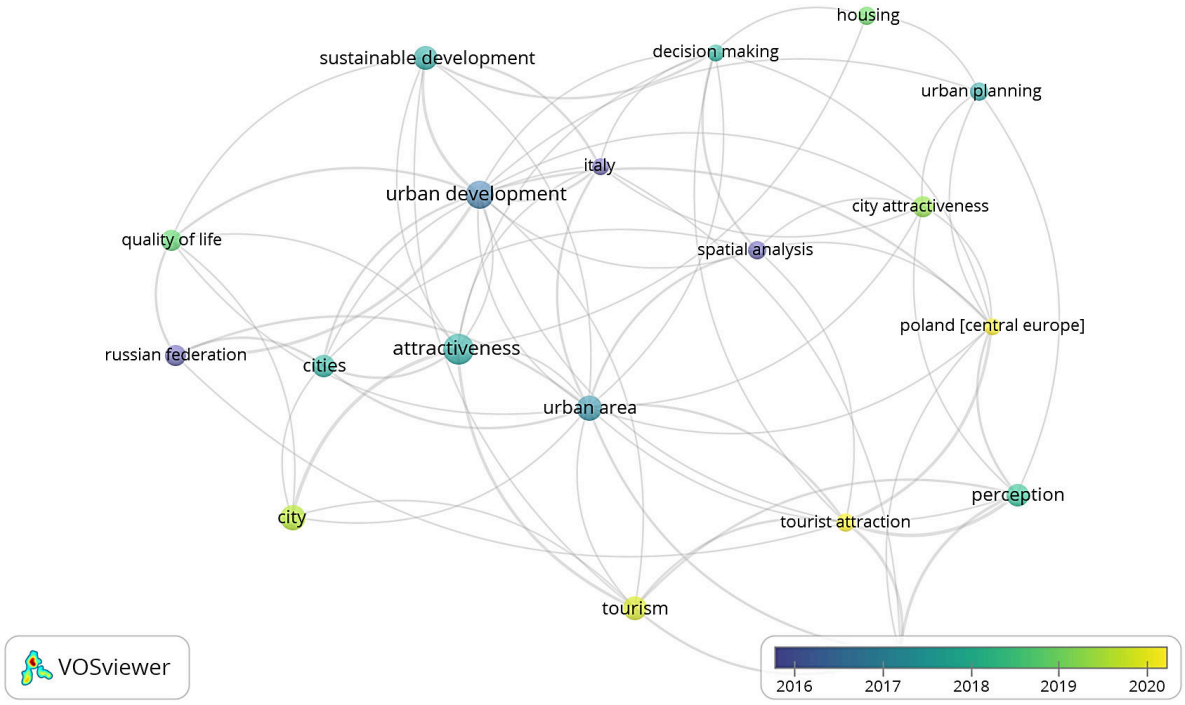

Figure 4. Map of research trends based on co-occurrence of keywords in publications on the words 'city' and 'attractiveness' from the Scopus database between 2015 and 2023.

Source: Own work using VOSviewer software.

Conversely, an examination of the research trend map (see Figure 4) reveals an absence of a predominant trend centred around the domain of city attractiveness. This demonstrates the high level of specialisation that is characteristic of this issue. Conversely, the magnitude of the selection (i.e. the diameter of the points) of the trend, which is associated with the number of paper published in this domain, signifies the limited popularity of the issue within the research topic. In addition, it is important to note that, in contrast to previous analyses, there is an absence of clearly delineated research clusters with a focus on the issue of city attractiveness. It is evident that research focusing on the previously analysed issues is considerably more abundant. With regard to the research topics related to logistical attractiveness, this tendency is indicative of the significant potential of the research undertaken.

The bibliometric analysis presented here is subject to certain limitations, arising from the fact that it was based exclusively on publications indexed by the WoS and Scopus databases. Consequently, it is not possible to assert that it is exhaustive, as there may be other significant publications in the field of analysis that have not been incorporated into these two databases. Moreover, it should be noted that the keywords employed for the analysis may not be exhaustive. It is evident that certain literature items do not align with the adopted inclusion and exclusion criteria, as they lack both keywords related to the attractiveness of the city and its logistical attractiveness. Consequently, these items have been omitted from the analysis. Furthermore, an alternative set of keywords could generate different clusters, resulting in different interpretations of the state of the art in this field. The expansion of keywords could

potentially result in a more comprehensive overview of the field, encompassing a broader range of work exploring the research area under investigation.

2.2. Logistics attractiveness - the conceptualisation

The extant literature does not address the concept of regional logistics attractiveness, a fact that is also evidenced by the bibliometric analysis carried out.

Nevertheless, the integration of scholarly output from the fields of city logistics and regional investment provides a rationale for identifying the relationship between the attributes that determine logistics attractiveness. This will facilitate the establishment of a coherent and comprehensive definition of the concept, thereby contributing to the partial filling of the theoretical gap in the area of management and quality sciences in this regard.

In order to define the concept of logistic attractiveness with precision, it is necessary to define the term 'attractiveness' itself as a theoretical category. In lexical terms, attractiveness is understood as an attractive force and a property of an object or phenomenon that is particularly interesting and at the same time capable of providing benefits in both cognitive and economic terms (SJP, PWN, 2025). This approach underscores the foundational dimension of the concept, emphasizing its role as a pivotal force influencing the decision-making processes of economic agents. Quantitatively, attractiveness can be regarded as a measure of the intensity of this force and the ability of an object to attract stakeholders by offering potential opportunities to satisfy pre-identified needs. In this context, stakeholders (i.e. individuals or organisations) act as active recipients of the impact of this force (Connell, 2010). As posited by various scholars, one of the extant concepts delineated in the extant literature sources, which incorporates the correlation of attractiveness with an identified economic area, is that of investment attractiveness. In a synthetic manner, the concept may be comprehended in terms of the ability to persuade investors to select a region as a location for investment (Gawlikowska-Hueckel, Umiński, 2000). Adopting this definition enables a subsequent evaluation of investment attractiveness to be conducted through the lens of the magnitude of the expenditures incurred. Nevertheless, this criterion, in spite of its simplicity and apparent obviousness, has a drawback in that it does not take into account the type of investment. This criterion favours capital-intensive activities, while knowledge-intensive activities may yield greater added value and non-financial benefits for the development of the area in which the investment is located (Hildebrandt et al., 2006, p. 13). The level of investment attractiveness of a given region is determined by the structure and quality of the combination of spatial, infrastructural, institutional and socio-economic conditions of a given territory (the so-called location factors). It is widely acknowledged within the investment community that locations which offer the optimum combination of location factors are of particular interest, since they enable the minimisation of capital expenditures and operating costs, while favouring the maximisation of the economic efficiency of the venture and the reduction of investment risk (Dziemianowicz, 2005).

In light of the intricacies inherent in the notion of investment attractiveness, R. Lubera (Lubera, 2019) asserts that logistic attractiveness constitutes a pivotal component thereof. It can be demonstrated that each determinant of logistic attractiveness (denoted by A) is simultaneously an element of the set of determinants of investment attractiveness (denoted by B). This can be formally expressed by a collective relation: It is hypothesised that $A \subseteq B$, on the basis that no extraneous factor exerts influence on the logistical location potential, which in turn exerts no influence on the overall investment attractiveness of a given area.

Conversely, the authors of the report on the attractiveness of Wallonia as an international logistics hub (PWC, 2017) defined the concept of a region's logistics attractiveness in terms of identified location factors that are taken into account when deciding where to locate a logistics facility. The factors were then grouped into seven clusters based on common characteristics. In order to arrive at a comprehensive evaluation, a rigorous methodology was employed, whereby each cluster and the individual location factors within it were assigned appropriate weights. The weights reflect the importance of a particular location factor and cluster in the decision-making process for selecting a distribution centre location in a specific region. During the data collection phase, a comprehensive analysis of numerous databases from various institutions (e.g. Eurostat, World Bank, World Economic Forum) was conducted to identify the information that best characterised the selected location factors. The incorporation of a location factor into the analysis was contingent upon the availability of a comprehensive dataset encompassing all 49 regions under scrutiny. Subsequent to the collection of a complete set of data, a quantitative analysis was conducted utilising a predefined scoring method and assigned weights. The resultant data were then subjected to statistical analysis, with the level of logistical attractiveness of each region being indicated by a score on a scale of 1 to 10 (Figure 5).

Figure 5. Logistical attractiveness factors with their weights.

Source: Logistics study on the attractiveness of Wallonia for international logistics hubs. Final report PWC, April 2017, p. 14.

For the purposes of this paper, the authors defined logistics attractiveness as a multidimensional characteristic of a region's space, reflecting the level of ability of that region to attract, maintain and develop a technological area in the field of transport and logistics. The assessment of logistical attractiveness was based on a deductive research approach (see Research Methodology), integrating quantitative and qualitative data. The concept of logistical attractiveness, as understood in this study, facilitates its application in the evaluation of regional development potential in the medium and long term, as well as in strategic planning processes. This is particularly evident in the context of supporting smart specialisations and the development of regional competitive advantages.

3. Characteristics of Silesian voivodship

The Silesian Province covers an area of 12,333 km^2, which accounts for 3.9% of Poland's total area and ranks it 14th among all provinces. The region is distinguished by its notably high degree of urbanisation and population density, with a population density of 374 people per km^2, which is the highest in the country. The province is located in the south of the country, in the so-called cross-border area (Figure 6) – it borders the Czech Republic (Moravian-Silesian Region) and Slovakia (Žilina Region). Furthermore, the voivodeship is adjacent to the following regions: The Opole Voivodeship is located in the western part of the country, while the Dolnośląskie Voivodeship is situated in the east. The Łódź Voivodeship is positioned in the north, and the Kielce Voivodeship is located in the north-east (Dohn et al., 2019).

The primary transport corridor of the TEN-T transport network traverses the region, namely the Baltic-Adriatic corridor and the route connecting Eastern Europe and Asia with Western Europe. The aforementioned factors contribute to the significant volume of goods flows involving the Silesian Voivodeship.

For several years, the Silesian Voivodeship has been one of the most attractive regions in Poland in terms of investment attractiveness. This phenomenon can be attributed to a number of factors, primarily associated with the region's abundant natural resources, which have played a pivotal role in shaping the economic development of the region. The primary benefits of the region are as follows (Investment Attractiveness of Regions, 2017):

- Poland's largest urban complex, creating exceptional investment potential.
- Poland's largest transport hub fostering the development of industry with numerous cooperative links. Good transport links provide: International Airport "Katowice", A4 motorway, E40 road (European route), E75 road (European route) and direct railway connections with cities such as Berlin, Vienna, Budapest, Bratislava, Prague, Moscow, Hamburg.

- The most highly industrialised region in Poland, with traditional specialisations (mining, metallurgy, engineering), but undergoing effective restructuring, allowing for the development of services, including transport and logistics.
- Numerous economic sub-zones offering attractive investment areas.
- Main courses of study in the voivodship related to sciences and technical majors (Silesian University of Technology, Częstochowa University of Technology, the University of Technology and Humanities).
- Broad investment opportunities, as confirmed by very high ratings for potential and real investment attractiveness for: national economy, capital-intensive industry, labour-intensive industry, trade, tourism, financial intermediation of business services and education.
- High labour ethos.

In turn, the evaluation of the voivodeship's competitiveness from the point of view of the international competitiveness index of European regions (European Regional Competitiveness Index), places the Silesian Voivodeship at a comparable level to other regions in Poland (national average) - see Figure 6.

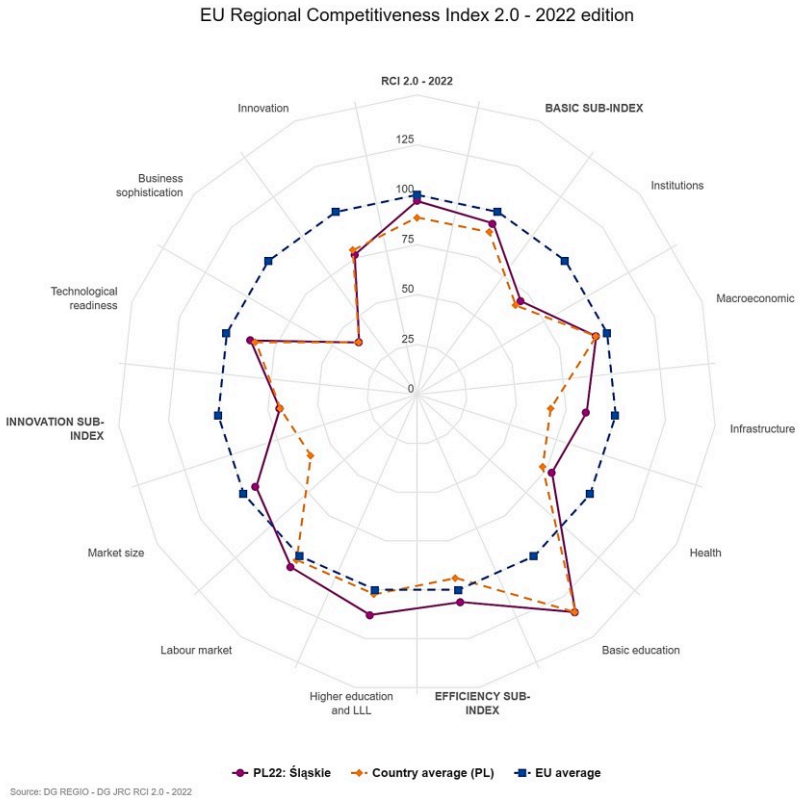

Figure 6. Values of selected sub-indices of the European Regional Competitiveness Index 2022 for the Silesian Voivodeship and other Polish and European regions.

Source: compiled on the basis of the EU Regional Competitiveness Index 2.0 - 2022 edition, https://ec.europa.eu/regional_policy/assets/regional-competitiveness/index.html#/PL/PL22.

The research indicates that, in general, the Silesian Voivodeship exhibits comparable values to the national average for specific sub-indices of regional competitiveness. The region's innovative potential, which is slightly higher than the national average, can be attributed to the relatively high quality of its universities and research institutes. However, the voivodship is characterised by a paucity of international research and development centres, design and engineering offices with export potential, and companies offering supra-local consulting or IT services. This situation may, in the long term, act as a barrier to the growth of labour productivity and thus also the level of prosperity in the region. Conversely, this domain, akin to the sphere of transport infrastructure and the efficacy of public institutions, continues to necessitate substantial reforms and an augmentation in the magnitude of financial resources. The Silesian Voivodeship's greatest asset is its high degree of urbanisation and good geographical location, which in itself makes it possible to attract investments to the region that are interested in a deep labour market or a large consumer market. In order to enhance the competitiveness of the Silesian Voivodeship, it is essential that both the central and regional authorities demonstrate a commitment to implementing a long-term modernisation policy. The advantages accruing from Poland's accession to the European Union, such as the enhancement of east-west transport links through road investments that expeditiously connected the Czech Republic and western Poland with German industry, have not been sufficient to counterbalance these disadvantages. Inadequate investment in transport infrastructure, specifically in the domains of road and rail transport, has been identified as a salient issue in the north-south direction. This concern pertains to the inadequate facilitation of connections between the region and the Czech Republic via the Moravian Gate and the Silesia-Poland-Baltic and Silesia-Wielkopolska-West Pomerania lines. Once these gaps are filled, the region's geographical assets will be strengthened through nationwide programmes to modernise road, rail and river infrastructure. Nevertheless, it is imperative that these changes are accompanied by reforms that extend beyond the confines of infrastructure, with the objective of enhancing the scientific potential of the region and achieving a substantial improvement in the international standing of local universities and research institutions (Bukowski, 2018).

4. Research methodology

The research methodology was adopted in accordance with the methodology used for the research task on *Foresight technologies of the Silesian Voivodeship 2050. Identification of priority technologies of the Silesian Voivodeship for the technological area of Transport and Logistics*, within the scope of the research project carried out by the Authors entitled *PPO WSL 2030. Establishment of the Regional Innovation Observatory.* In order to achieve the assumed

research objectives, a deductive approach was adopted, assuming the derivation of conclusions on the basis of previously established theoretical knowledge and available empirical data. A triangulation of research methods was used in the research process, combining quantitative data analysis with expert qualitative assessments.

The primary analytical instruments employed in this study were the Porter's diamond model, utilised to evaluate regional competitiveness from a sectoral standpoint, and the Emerald model, which facilitates an exhaustive examination of technological attractiveness, encompassing systemic conditions and the innovation milieu.

The selection of these methods was justified by their high potential for assessing the attractiveness and competitiveness of technological areas. The integration of the diamond and emerald concepts enabled a multidimensional approach to the problem, encompassing both structural factors and dynamic aspects of technology development. The approach adopted also permitted a flexible selection of evaluation criteria, adequate to the specifics of the sector under study.

A comprehensive analysis of the factors influencing the potential for technology development in the field of transport and logistics was conducted, encompassing four primary groups.

1. **Demand attractiveness of technology** - covering the assessment of the structure and dynamics of demand for products and technological solutions regionally, nationally and internationally.
2. **Supply-side attractiveness** of technology - taking into account the availability and quality of production factors necessary for technology development and implementation.
3. **Competitiveness of technologies** - understood as the ability of the analysed technologies to compete effectively on the market, taking into account both internal and external conditions.
4. **Development of complementary sectors and technologies** - referring to the degree of linkage with other industries and technologies that may support or stimulate the development of the technology area under study.

The applied research procedure was based on the analysis of secondary data (desk research), including both statistical and industry data, as well as market reports, strategic documents and expert opinions. This methodological approach facilitated a multifaceted and integrated evaluation of the technological domain under scrutiny, with a view to its future evolution.

5. Research results

The applied research methodology enabled the identification of the key determinants of technological attractiveness and competitiveness of the region. This identification took into account both supply and demand conditions, as well as systemic factors and the influence of related sectors.

The results of the research were presented in terms of four main groups of analytical factors: The factors to be considered are as follows: firstly, the technology demand attractiveness; secondly, the supply attractiveness; thirdly, the logistics competitiveness; and fourthly, the development of complementary sectors and technologies (Table 2). For each of these categories, a detailed assessment of the region's potential was made, identifying both its advantages and limitations in the context of further development of transport and logistics technologies.

The results presented herein provide a foundation for formulating strategic conclusions regarding the positioning of the Silesian Voivodeship as a centre of innovation development in logistics, and indicate key directions of activities that support the growth of the region's technological competitiveness.

Table 2.
Determinants of logistics competitiveness of the Silesian Voivodeship according to Porter's Diamond combined with the EMERALD method

Demand-side attractiveness	Supply-side attractiveness	Competitiveness in logistics	Development of related and supporting sectors/technologies
• Developing markets for technologies • Implementation of customer-reported technologies • Affordability and digital accessibility of technologies to residents	• Density of linear infrastructure • Availability of point infrastructure • Logistics operators • Availability of suprastructure • Integrated logistics systems of the region • Social capital • R&D potential	• 3D printing and additive manufacturing technologies (Reducing the need to transport components and finished products through local additive manufacturing - application areas: aerospace, automotive, medical) • Closed-loop economy (CLE) and recycling technologies (Reducing the need to transport raw materials and waste through local recycling and reuse of materials in the region) • Development of e-commerce in a decentralised model (based on local micro-distribution centres, e.g. "dark stores") • Development of renewable energy and local microgrids (The ability to generate and store energy locally reduces the need to transport fuels and energy raw materials)	• Internet of Things (IoT) and telematics systems • Digital twins • Robotisation of technologies • Advanced AI systems • Electric and hydrogen drives • Dynamic work management • Advanced materials and smart packaging • Intelligent waste management systems

		• Autonomous manufacturing robots and industrial automation systems • Blockchain technologies and smart contracts (Ability to digitally manage the supply chain without physically moving documentation and goods between intermediaries) • Technologies for local food production (agro-technologies)	

Source: own work.

The following graphic summary has been developed for the purpose of illustrating a synthetic assessment of the competitive potential of the Silesian Voivodeship in the area of transport and logistics technologies. The development of this summary has been informed by the results of analyses carried out in four key methodological dimensions, namely demand attractiveness, supply attractiveness, technology competitiveness and the development of related and supporting sectors (Fig. 7).

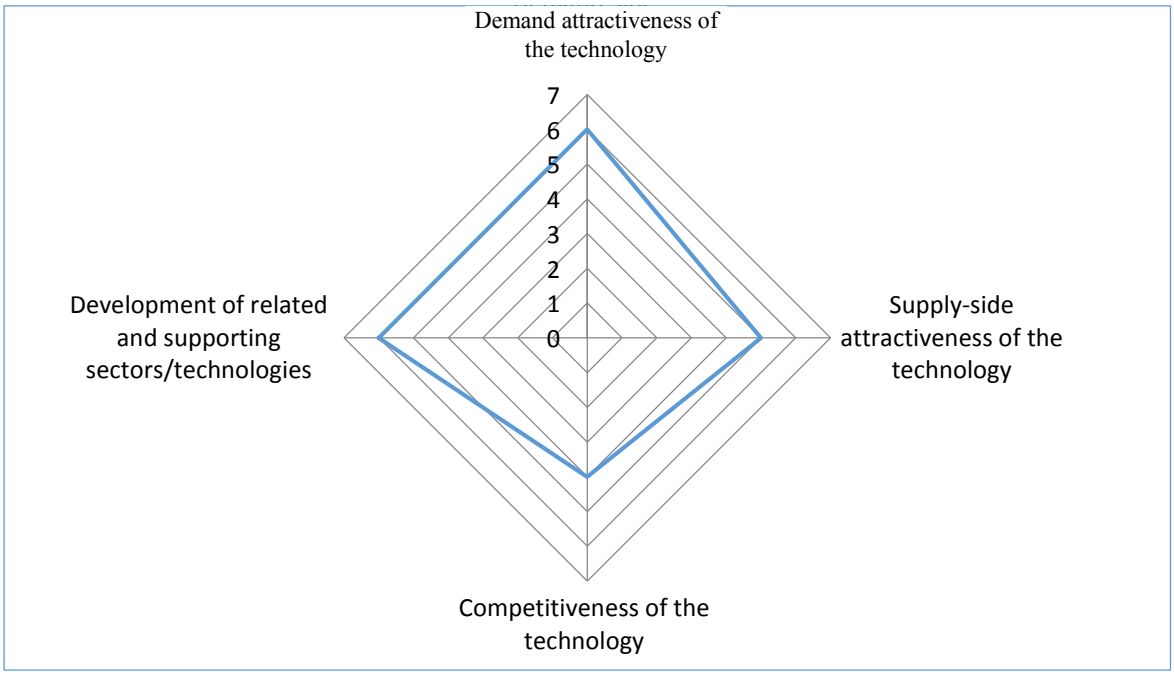

Figure 7. Assessment of competitive potential for the Transport and Logistics technological area.
Source: own work.

An analysis of the logistics competitiveness of the Silesian Voivodship was conducted using Porter's Diamond and the EMERALD method. This analysis enabled the identification of the key determinants influencing the region's position. With regard to the technological demands that have been observed, it is evident that there is a high demand for innovative transport and logistics solutions. This can be attributed to the favourable geographical location and developed transport and industrial infrastructure. Moreover, the expanding remit of the e-commerce sector, coupled with the escalating imperatives for enhanced transport efficiency, has given rise to the imperative for the implementation of sophisticated technologies, the automation of

warehouse operations, and the adoption of eco-friendly transport methods. The determiners of the supply-side attractiveness of technology in the region are the availability of research and development facilities and the cooperation of universities and research institutes with enterprises, which effectively promotes the implementation of innovative solutions in transport and logistics. Notwithstanding the presence of key players in the logistics services sector, a significant constraint is the shortage of qualified specialists and the high costs of implementing modern technologies. Moreover, the capacity to secure funding for the development of technologies pertaining to green transport transformation constitutes a substantial strategic advantage for the region, underscoring its capacity for an innovative approach to the development of the transport and logistics industry. A thorough examination of technological competitiveness has revealed considerable untapped potential in the domains of automation of logistics processes, intelligent transport systems and electromobility. In comparison to other Polish and European regions, the Silesian Voivodeship boasts a competitive logistics infrastructure. However, in order to further consolidate its position, it is essential that the region invests in digitisation and the implementation of sustainable transport solutions. The transport sector is characterised by high barriers of entry for new players, which have a detrimental effect on the development of innovative solutions. In order to address this issue, a number of actions must be taken, including the provision of financial support for transport start-ups, the simplification of administrative regulations, investment in education and competence development, and the creation of infrastructure to support modern transport technologies in the region. The development of associated sectors and supporting technologies has been shown to have a significant impact on the competitiveness of the region. A robust industrial and manufacturing base fosters conducive conditions for innovation in logistics and transport. The integration of Industry 4.0 technologies, including the Internet of Things, Big Data analytics and artificial intelligence, is a key direction for the modernisation of the sector. The mounting interest in green transport technologies, encompassing electromobility and the utilisation of hydrogen as an energy carrier, necessitates the augmentation of endeavours to establish suitable infrastructure and to foster research endeavours aimed at fortifying the transport and logistics sector.

The recommendations for the positioning of the Silesian Voivodeship on the technology market indicate the necessity to strengthen intersectoral cooperation, which will allow more effective technology transfer and faster commercialisation of innovations. Investment in digital technologies and automation should be accorded a high priority, and the development of intelligent transport systems and the digitalisation of logistics processes are pivotal in enhancing competitiveness. Concurrently, the cultivation of human resource competencies through the implementation of specialised education and training programmes adapted to the requirements of contemporary transport technologies remains an important aspect. Moreover, the advancement of ecological transport solutions, encompassing the development of intermodal transport infrastructure for electric and hydrogen vehicles, and the enhancement of

accessibility to funds from both EU and national sources, are pivotal factors in determining the subsequent technological development of the region. The promotion of the Silesian Voivodeship as a centre of logistics innovation by building a strong technological brand has the potential to attract investors and increase the innovative potential of the region. The consistent implementation of the aforementioned activities will enable the Silesian Voivodeship to consolidate its position as a leader in the field of modern transport and logistics technologies. This, in turn, will ensure the region's sustainable competitiveness on both the national and international stage.

6. Discussion

The obtained results are consistent with those of previous studies on investment attractiveness (e.g. Gawlikowska-Hueckel, Umiński, 2000; Dziemianowicz, 2005), which indicate that logistical factors are an integral part of regional competitiveness. At the same time, this study builds upon Lubera's (2019) approach, which emphasised the autonomous importance of logistical attractiveness in shaping smart specialisation strategies, rather than considering it as a subset of investment attractiveness. Similar attempts to operationalise the concept can be found in international studies, such as the PwC (2017) report on Wallonia, which used a location factor analysis with assigned weights. Unlike these approaches, however, this study not only highlights infrastructural determinants, but also technological and environmental ones. This is consistent with the new paradigm of sustainable regional development (Hildebrandt et al., 2006).

In this sense, the article contributes to the theoretical discussion by conceptualising logistical attractiveness as a multidimensional construct, while also highlighting its practical implications for regional policy and economic practice.

7. Summary

Research indicates that the logistical attractiveness of the Silesian Voivodeship is not solely attributable to its industrial heritage and location, but is increasingly attributed to innovative, adaptive and pro-environmental factors. The increasing significance of sustainable development and effective management of energy and information resources is precipitating a paradigm shift in logistics within the region, transitioning from a heavy infrastructure-based model to a more agile, intelligent, and low-carbon approach. It is therefore vital for the continued enhancement of the province's logistics attractiveness that not only are the

infrastructural advantages maintained, but that there is also consistent investment in competence, digitalisation, sectoral integration and the development of innovative regional logistics models.

The identification of the determinants of Silesia's logistic attractiveness is of paramount importance when utilising an integrated methodological approach (Porter's Diamond + EMERALD method). This will provide significant support for decision-making processes in spatial planning, investment location and the design of development policies. The results and recommendations presented in the paper are of an applied character and may be used by local authorities, companies and business support institutions in the Silesian Voivodeship seeking rational and perspective directions for the development of the TSL sector.

8. Limitations and further research directions

Despite taking a comprehensive methodological approach that combined Porter's Diamond model and the EMERALD framework, the study had some limitations. Firstly, the analysis relied heavily on secondary data (desk research) and expert assessments, which could introduce subjectivity and restrict the scope for generalisation. Secondly, the study primarily covered the regional dimension of Silesia without conducting a more in-depth comparative analysis with other European logistics regions that have a similar industrial structure and geographic location. Furthermore, the dynamic nature of technological and ecological transformation in the TSL sector means that some of the conclusions may become irrelevant in the medium term.

Future research should therefore focus on broadening the empirical base by incorporating primary research (e.g. surveys of logistics operators and investors and Delphi studies with experts) and developing comparative analyses across Polish and EU regions. A promising research direction is the integration of foresight methods with simulation models to test different development scenarios for logistics attractiveness. Furthermore, it would be beneficial to extend the perspective to include behavioural aspects of stakeholders' decision-making processes and to measure the long-term impact of innovative and green technologies on regional competitiveness.

Acknowledgements

The paper presents selected results of the regional project "Creation of Regional Innovation Observatory". The project is financed by the European Funds for Silesia programme and state budget (project number: FESL.01.03-IP.02-06CF/23).

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SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

DIVIDEND CONSISTENCY AND SHAREHOLDER RETURN: EVIDENCE FROM THE WARSAW STOCK EXCHANGE

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Purpose: The aim of the study is to determine if a consistent, multi-year increase in dividends by Polish firms listed on the Warsaw Stock Exchange generate abnormal returns for shareholders. The research also investigates how the market reacts to subsequent dividend increases in a consistent cycle, and if a buy-and-hold investment strategy following such announcements is effective.
Design/methodology/approach: The study is based on a sample of firms from the Polish stock market that consistently increased their dividends from 2000 to 2021. The researchers used a buy-and-hold methodology to assess medium-term abnormal returns over a period of one to three years after a dividend increase announcement, using the monthly return of the WIG as a benchmark.
Findings: The study found that the market generally responds positively to a company's first and second consecutive dividend increases, which is reflected in positive and statistically significant abnormal returns in the announcement month and the first year following the decision. However, this effect weakens with subsequent increases.
Research limitations/implications: A major limitation of the study is the relatively small number of companies in the sample that had long-term, consistent dividend increases. The number of firms with five or more consecutive increases was very small, with only one firm sustaining increases for ten consecutive years.
Practical implications: The findings are valuable for managers and investors. For managers, the results suggest that the market reacts positively to dividend increases, but the effect diminishes after the first two consecutive hikes as investors begin to anticipate them. For investors, the study indicates that investing in companies with a consistent dividend policy can yield abnormal returns, but the most profitable strategy appears to be a buy-and-hold strategy for up to two years following the first or second consecutive dividend increase.
Originality/value: The paper addresses a topic that has been under-researched in emerging markets, providing valuable insight into how the Polish capital market responds to a consistent policy of systematically increasing dividends. The research offers an empirical analysis of this phenomenon, which has been previously studied primarily in developed markets.
Keywords: dividend policy, capital market, abnormal returns, Warsaw Stock Exchange, dividend consistency.
Category of the paper: Research paper.

1. Introduction

Dividend policy constitutes one of the most important decisions in the field of corporate financial management, and it has long been a subject of interest for both practitioners and theorists in this area. Although financial theory has not yet developed a unified stance regarding the relationship between dividend payouts and stock prices, within it one can distinguish so-called anti-dividend approaches – which deny the benefits or rationale of paying high dividends – as well as neutral and pro-dividend perspectives. In general, most researchers and business practitioners consider signals such as high dividend payouts, dividend initiations or resumptions, and dividend increases as positive – and this is often reflected in a subsequent rise in stock returns (e.g., Benartzi et al., 1997; Lacina, Zhang, 2008; Dasilas, Laventis, 2011; Yolcu, Öztürk, 2022; and for the Polish market: Słoński, Zawadzka, 2012; Frasyniuk-Pietrzyk, Walczak, 2014; Czapiewski, Kubiak, 2017; Pieloch-Babiarz, 2018; Konieczka, 2024). Investment strategies have even been developed based on such assumptions – one example being the "Dogs of the Dow" strategy, which involves investing in stocks from an index of blue-chip companies that offer the highest dividend yields (Brzeszczyński, Gajdka, 2008; McQueen et al., 1997). However, a decision to increase a dividend tends to make an especially favorable impression on financial markets. In one of the earliest and now classic studies on dividend policy, Lintner (1956) demonstrated that for corporate managers, when making decisions about dividend payouts, the key issue is not so much determining the level of the dividend, but deciding whether to change it.

An increase in the dividend may be perceived as a positive signal, suggesting that the company is expected to perform well in the future, well enough to continue paying higher dividend on a regular basis. This is because managers are generally reluctant to reduce dividend payouts, and therefore tend to raise them only when they believe such increases are sustainable. As a result, managers are sometimes willing to increase dividends to signal financial strength, and announcements of dividend increases by companies are usually accompanied by rises in stock prices (e.g., Michalyuk et al., 2014). In this context, an important issue – both from a theoretical and practical perspective – is whether, in cases where companies systematically increase their dividends over a series of consecutive years, the market responds in the same way to each subsequent increase, or whether the market reaction changes – either weakening or strengthening – as the number of periods with consistent dividend increases grows. This issue has already been studied in the U.S. market; however, it remains significantly less explored in the context of less developed markets, as emerging markets, to which the Polish market is still sometimes classified, despite the fact that, according to some classifications, it may already be considered a developed market. The present article focuses on this topic, and the aim of the study described herein is to examine whether an increase in dividends consistently repeated multi-year cycles leads to the generation of abnormal returns for shareholders under the conditions of the Polish capital market.

2. Dividend Policy, Signaling, and Market Reactions

The claim that changes in dividends carry informational and signal content is a concept that has long been accepted among researchers studying dividend policy (e.g., Benartzi et al., 1997). In his seminal study, Lintner (1956) observed that companies tend to raise dividends only when management believes that earnings have increased on a permanent basis – implying that a dividend increase signals a sustained rise in profit distributions in future periods. Subsequently, during the 1960s through the 1980s, several researchers clearly suggested that dividends may convey information or signals about future cash flows or earnings (e.g. Miller, Modigliani, 1961; Bhattacharya, 1979; Miller, Rock, 1985; John, Williams, 1985). As a result, the view that dividend changes carry informational content has gained broad support within the field of corporate finance and constitutes one of the key arguments underlying the positive market reaction to announcements of dividend increases.

However, the question arises as to what empirical evidence exists to support the view that dividends provide information about future cash flows, and to what extent this information is actually reflected in future performance. There is certainly considerable evidence that the market perceives dividend changes as a positive and noteworthy signal. When dividends are increased or initiated, stock prices tend to rise, while when dividends are (less frequently) cut or omitted, prices tend to fall. However, the results of studies on actual changes in future earnings following a dividend increase are much less conclusive, and such changes do not always occur in the expected direction. Watts (1973) was among the first researchers to investigate the relationship between current dividends and future earnings. Applying regression analysis to examine the link between companies' current-year dividends and their next-year earnings, he found that although the average regression coefficients across firms were positive, their statistical significance was generally very low. Several other studies – for example, Gonedes (1978), Penman (1983), Grullon et al. (2005), Savov (2006), Kadioglu and Ocal (2015) and more recently Basse et al. (2023) and AlGhazali et al. (2024) – also concluded that changes in dividends alone convey little information about future earnings. Although the majority of studies have focused on the U.S. market, there is also evidence from other markets, both developed (e.g. Germany – Savov, 2006) and emerging (e.g. Oman – AlGahzali, 2024; Turkey – Kadioglu, Ocal, 2015), as well as from specific market segments (e.g. the European pharmaceutical sector – Basse et al., 2023). In terms of methodology, regression-based approaches in various specifications have been the most prevalent among the previously cited studies (e.g. Watts, 1973, Grullon et al., 2005; Savov, 2006; Kadioglu, Ocal, 2015; AlGhazali et al., 2024). Nevertheless, alternative methods have also been employed, including tests of the martingale hypothesis (e.g. Genedes, 1978; Penman, 1983) or Granger causality analyses (e.g. Basse et al., 2023).

Of course, there is also a substantial body of research, consistent with the predictions of financial theory, that shows a clear relationship between changes in dividend levels and the future financial performance of companies. For example, Aharony and Dotan (1994) found that unexpected increases (decreases) in quarterly dividends were, on average, followed by higher (lower) unexpected accounting earnings in subsequent periods compared with firms that maintained their dividend levels. Nissim and Ziv (2001) on a sample of companies from the U.S. market demonstrated that dividend changes and future earnings over the subsequent two years are statistically significantly and positively related, thereby supporting the information content hypothesis. Choi et al. (2011) showed that in the Korean market, the positive relationship between dividend increases and future firm performance – supporting the dividend signaling hypothesis – is observed particularly for non-Chaebol firms and low-growth firms. Lee et al. (2012), using a sample of companies listed on Bursa Malaysia, examined the relationship between dividend changes and firms' future profitability. They found that dividend changes were strongly associated with contemporaneous earnings changes, weakly associated with earnings changes one year ahead, and largely unrelated to earnings changes beyond the first year. More recently, Deng et al. (2024), based on an analysis of firms from 38 non-U.S. markets, examined whether dividend changes signal earnings growth, differentiating firms by their levels of investor protection. They found that on markets with stronger investor protection, the positive relationship between dividend increases and later changes in profitability is stronger, whereas on weaker-protection markets the effect is less pronounced but still present. In these studies, the analysis encompassed both highly developed capital markets, such as those of the United Kingdom, Germany, Australia or France, as well as emerging markets, including Argentina, China, Colombia, Indonesia or Saudi Arabia.

In this group of studies, the application of various forms of regression analysis also predominated (e.g. Nissim, Ziv, 2001; Choi et al., 2011; Lee et al., 2012; Deng et al., 2024), however, other methods were also employed, such as event-study analysis (e.g. Aharony, Dotan, 1994).

In summary, some studies report findings that support the hypothesis that dividend changes convey reliable information about future earnings, while many others do not confirm this relationship. It should be emphasized that the applied research methodologies are similar in many respects, with various forms of regression methods playing a dominant role. At the same time, it is worth noting that the literature occasionally contains criticism of certain methodological approaches. For example, the method applied by Nissim and Ziv (2001) was criticized by Grullon et al. (2005), who argued that the assumption of linear mean reversion in earnings adopted in that study was inappropriate, and therefore the positive correlation documented between dividend changes and future earnings might be spurious. Nevertheless, at this point we do not intend to challenge the validity of any of the methodologies applied in the reviewed studies. Regardless, it should be borne in mind that the research was conducted

on different samples, which may be also an important factor behind the discrepancies in the reported findings.

A few studies examining the relationship between dividend changes and future financial performance have also been conducted for the Polish market. For example, Pauka and Żyła (2017), investigating the association between dividend changes and firm earnings on Poland's alternative market NewConnect, found no significant relationship between these variables. Similarly, Kaźmierska-Jóźwiak (2017) did not find a correlation between dividend increases by Polish firms and their future financial performance. On the other hand, in the studies conducted by Snarska et al. (2020), the dividend signaling hypothesis was partially confirmed in the sense that their results indicate dividend changes convey information about future earnings, particularly gross profits. It should be noted, however, that the authors are not aware of any works examining the relationship between dividend growth and firms' future performance in other Central and Eastern European markets, although there are studies indirectly related to this issue that explore the connection between dividend policy and company performance in this region (e.g. Bukalska, Peša, 2025; Teral et al., 2012)**.**

So, given such varied empirical findings, it raises the question: why do theoretical approaches to dividends based on signaling theory still persist? Perhaps theorists remain unconvinced by studies that fail to support the signaling theory, citing doubts about their methodological soundness or the sample sizes used. On the other hand the fact that several companies have a long history of consistently increasing dividends suggests that managers believe establishing and maintaining such a pattern brings certain benefits. It is also worth noting that many managers consider it important to demonstrate a steady growth in accounting earnings.

Earnings are generally considered easier for managers to manipulate, thanks to the flexibility they have with accounting mechanisms like accounting reserves or accruals, enabling them to maintain long streaks of growing earnings. Dividends, however, are typically paid in cash and thus offer far less room for accounting manipulation. Empirical evidence suggests that firms meticulously structure their dividend policies to preserve the ability to continue increasing payouts and avoid cuts. Therefore surveys found that majority of managers would rather raise new capital than cut dividends when pursuing value-enhancing projects (Michalyuk et al., 2019). Although future cash dividends are uncertain, consistency in dividend policy implicitly helps companies, in a sense, "manage" investor expectations. By deliberately disclosing a historical record of a consistent, multi-year dividend policy with a sustained tendency to increase dividends over time, a company may signal that it is likely to maintain the same policy in the future. This raises the question of whether companies with a history of repeated dividend increases achieve long-term positive abnormal returns, and if so, how long those abnormal returns persist. Michayluk et al. (2019), conducting research on U.S. market firms, found that while a dividend increase is generally followed by an abnormal stock return, after the sixth consecutive dividend increase the abnormal returns over the subsequent 12 months become

statistically indistinguishable from zero. This finding suggests that companies maintaining a consistent dividend history are rewarded with a market premium, but this reward lasts only for a limited time, as the market learns to anticipate further increases once a certain dividend policy has been established. For managers, such findings provide an argument for maintaining a dividend policy that meets shareholders' perceived demand for consistency. However, the benefits of such consistency appear to diminish over time – that is, for investors, a buy-and-hold strategy focused on dividend-increasing companies does not yield abnormal returns for stocks that have already increased their annual dividend six or more times.

As previously mentioned, the study in question focused solely on the U.S. market, and on that basis, it is difficult to determine whether its findings are of a more universal nature and applicable to investors in less developed markets.

Although studies have been conducted showing the relationship between the payment of regular dividends and stock returns in other countries (e.g. Pieloch-Babiarz, 2018), they did not concern situations in which dividends are consistently increased from period to period. Therefore, from both the perspective of financial theory and the standpoint of capital market practitioners, it is useful to examine how capital markets other than the U.S. respond to a consistent policy of systematically increasing dividends. In our article, this issue is analyzed using the example of the Polish market.

3. Sample and methodology

The primary aim of the study is to answer the question of whether an increase in dividends – repeated consistently over multi-year cycles – leads to the generation of abnormal shareholder returns under the conditions of the Polish capital market. The study on the consequences of implementing a systematic dividend policy by Polish listed companies focuses on two issues. The first concerns the effectiveness of an investment strategy carried out by an investor, consisting of purchasing shares of companies announcing a dividend increase and holding them for a period of one to three years from the announcement date. The second issue relates to the monthly stock return in the month when the dividend increase decision is announced.

The effectiveness of a buy-and-hold investment strategy starting on the day of the dividend increase announcement is examined separately for companies that raise their dividend for the first time or for subsequent times (i.e., second, third, fourth, etc.) in an uninterrupted cycle of up to 10 years. In other words, the study aims to investigate whether an investor who buys a stock after the announcement that the company has increased its dividend again achieves abnormal returns after one, two, or three years from the start of the investment, regardless of which number dividend increase initiated that investment.

3.1. Sample

The study is based on a sample of companies listed on the Warsaw Stock Exchange that increased their dividend payments during the period from 2000 to 2021. For this timeframe, we identified all firms that raised their dividend relative to the previous year and continued this pattern for up to ten consecutive years. Table 1 presents the number of companies that increased their dividend for the i^{th} consecutive year.

Table 1.
Number of firms with i^{th} consecutive dividend increase

Consecutive dividend increase	Number of firms
1	233
2	130
3	72
4	34
5	19
6	12
7	7
8	3
9	2
10	1

Source: own elaboration.

The number of companies in the sample declines significantly as the length of the consecutive dividend increase cycle extends. While 233 companies raised their dividend for the first time during the analyzed period, only 130 maintained increases for two consecutive years. This number drops to 72 firms for three consecutive increases, and for example, just 19 companies managed five consecutive dividend hikes. Notably, only one firm sustained dividend increases for ten consecutive years. The final year included in the sample is 2021, as we calculate abnormal returns over the subsequent three-year period, ending in 2024.

3.2. Methodology

In the initial phase of the study, we employ buy-and-hold returns to evaluate medium-term abnormal performance following a dividend increase. This approach is inspired by the methodology used in Michayluk et al. (2019), who documented that companies earned positive abnormal returns following dividend increases—with the effect diminishing over time. In our study, abnormal return is defined as the difference between the sample firm's compounded monthly return and the corresponding return from the benchmark index. As the benchmark, we use the monthly return of the Warsaw Stock Exchange main index – WIG. The source for dividends is the Biznesradar Database (https://www.biznesradar.pl/), and the source for monthly returns is Stooq Database (https://stooq.pl/).

We use buy-and-hold methodology to calculate annual returns for the three years following a firm's consecutive annual dividend increase announcements. Firm returns are calculated as monthly compounded buy-and-hold returns. The return for the first year, $r_{s,j}$, following a dividend increase for firm *j* is calculated as follows:

$$r_{s,j} = \prod_{k=0}^{11}\left(1 + r_{j,p+k}\right) - 1 \quad (1)$$

where p is the month of the dividend increase announcement, and $r_{j,p+k}$ is the monthly return for sample firm *j* for month $p + k$.

We compute the annual buy-and-hold return for the benchmark using equation:

$$r_b = \prod_{k=0}^{11}\left(1 + r_{b,p+k}\right) - 1 \quad (2)$$

where $r_{b,p+k}$ is the monthly return for WIG for month $p + k$.

We recalculate equation (1) and (2) for each of the three years following the first dividend increase up to the 7th year. The buy-and-hold abnormal returns for each 12-month interval is calculated as follows:

$$ar_j = r_{s,j} - r_b \quad (3)$$

In the second stage of the study, the short-term, one-month abnormal return was calculated for the month in which the dividend increase was announced, by subtracting the monthly benchmark return from the monthly share return. The rate of return on shares examined in the study is the total return, taking into account both price changes and dividend payments.

4. Results

Table 2 presents annual abnormal returns for up to three years following the first dividend increase through the 7th consecutive dividend increase. There are 233 first-time dividend increases and 130 of these then announce another dividend increase year later, resulting in the track record length extending to two years. Table shows both mean and median buy-and-hold returns that accrue to dividend increasing firms. For the i[th] dividend increase, the firm has a track record of increasing the dividend for the past *i-1* years.

Table 2.
Annual buy-and-hold abnormal returns for dividend increasing firms

Year	Mean	p-value		Median	p-value		N
Returns following the first dividend increase							
1	0.1824	0.0060	***	0.0187	0.0149	**	233
2	0.0770	0.0199	**	-0.0154	0.3948		233
3	0.0456	0.2024		-0.0600	0.3143		233
Returns following the second dividend increase							
1	0.1529	0.0016	***	0.0508	0.0087	***	130
2	0.0993	0.0759	*	-0.0218	0.9029		130
3	0.0340	0.3212		0.0432	0.4735		130
Returns following the third dividend increase							
1	0.1207	0.1228		-0.0290	0.9017		72
2	0.0729	0.0610	*	0.0589	0.0234	**	72
3	0.0917	0.1432		0.0208	0.3968		72
Returns following the fourth dividend increase							
1	0.0866	0.0992	*	0.1015	0.0889	*	34
2	0.1371	0.1432		0.0947	0.0740	*	34
3	0.0256	0.6850		0.0173	0.8175		34
Returns following the fifth dividend increase							
1	0.1528	0.1184		0.0959	0.0361	**	19
2	-0.0411	0.6758		-0.0702	0.5412		19
3	0.0356	0.6037		0.0523	0.4653		19
Returns following the sixth dividend increase							
1	0.1259	0.2259		0.0277	0.4238		12
2	0.1680	0.0392	**	0.1677	0.0425	**	12
3	0.1157	0.2165		0.1609	0.2036		12
Returns following the seventh dividend increase							
1	0.1671	0.2139		0.2643	0.2969		7
2	0.1455	0.2218		0.1488	0.1563		7
3	-0.0801	0.4717		0.0247	0.5781		7

* significance at 0.1, ** significance at 0.05, *** significance at 0.01.

Source: own elaboration.

The data presented in the table shows that only in the case of the first and second dividend increases did the buy-and-hold strategy produce a noticeable effect in terms of profitability within one year after the increase, both when measuring results by the mean and the median return (with statistically significant results). These effects were visible for up to two years. However, the decision to invest in stocks paying a dividend increase for the third, fifth, or sixth time did not yield noticeable results (in the form of positive mean returns significant at the required level) even in the first year after the investment.

Table 3 presents the results concerning the abnormal monthly stock returns obtained in the month of the announcement of the (i^{th}) dividend increase.

Table 3.
Abnormal returns in the announcement month

Dividend increase	Mean	p-value		Median	p-value		N
1	0.0391	0.0001	***	0.0196	0.0004	***	233
2	0.0290	0.0007	***	0.0210	0.0021	***	130
3	0.0104	0.3040		-0.0002	0.6294		72
4	0.0181	0.0793	*	0.0139	0.1260		34
5	0.0274	0.1710		0.0319	0.1819		19
6	0.0447	0.0100	**	0.0361	0.0024	***	12
7	0.0098	0.6625		0.0280	0.6875		7

* significance at 0.1, ** significance at 0.05, *** significance at 0.01.

Source: own elaboration.

As shown by the data presented in the table, following the announcement of the first and second consecutive dividend increases, the abnormal returns in the month of the announcement were positive and statistically significant at the 1% level. However, for subsequent dividend increases, this growth was no longer as consistent and only occurred in certain years. In the sample studied, a significant increase was still observed at a high level of significance after the 6th consecutive dividend increase. However, this last analysis was conducted on a sample of only 12 companies, as only that many firms increased their dividends for the 6th consecutive time, which calls for increased caution when generalizing the results presented for this particular dividend increase.

5. Discussion

The results of the study on the capital market's reaction to dividend increases indicate that the market generally responds positively to announcements of dividend hikes when such increases are declared for the first or second time. This is reflected in a positive and statistically significant abnormal return achieved by companies both in the month of the dividend announcement and in the first year following the decision to raise the dividend. However, subsequent increases no longer yield such consistently positive outcomes for investors. For example, in the case of the third consecutive dividend increase, no statistically significant abnormal return was observed either in the month of the announcement or during the first year following the decision.

Moreover, in the case of the third consecutive dividend increase, the median abnormal return was negative both in the month of the announcement and in the first year following the announcement, although this result was not statistically significant. This finding aligns with earlier research on the U.S. market, particularly the study by Michayluk et al. (2014), which employed an event study methodology to analyze short-term stock returns surrounding each dividend increase announcement by U.S. firms. The authors found that market reactions are

positive and significant for the first and second dividend increases, but become insignificant thereafter. The obtained results suggest that investors generally react positively to information about a dividend increase; however, only the first and second increases are accompanied by a clearly observable positive reaction from the capital market. After this period, the market may become accustomed to the fact that it is dealing with a company that systematically raises its dividend year after year and thus incorporates this expectation into the stock price. In this situation, further increases no longer trigger such consistent market reactions. Although in the studied sample, with few exceptions, the announcements still led to positive abnormal returns, only in a limited number of cases were these returns statistically significant. A similar pattern was observed with regard to middle-term returns (over one to three years) earned by investors who adopted a buy-and-hold strategy following a company's subsequent dividend increase announcement. Statistically significant positive abnormal returns were also observed in this case for one or two years following the first or second dividend increase, while such effects appeared only sporadically after subsequent increases. A similar pattern was observed in the U.S. market (Michayluk et al., 2019), where a statistically significant market reaction persisted until the fifth consecutive dividend increase, disappearing from the sixth onwards.

6. Conclusions

In summary, the results of the study indicate that, under Polish market conditions, the capital market responds positively to dividend increases through abnormal stock returns for the companies announcing them. However, this effect is strongest during the first two consecutive increases and weakens with each subsequent dividend hike.

The results obtained may be useful for managers making decisions regarding dividend policy. They indicate that the market generally reacts positively to information about a dividend increase. However, under Polish market conditions, investors tend to quickly adapt to such announcements, and starting from the third increase, subsequent decisions are perceived as expected events, which no longer generate strong effects.

These findings may also be valuable for investors, suggesting that investing in dividend-increasing companies can yield abnormal returns. However, the most profitable strategy appears to be holding shares for up to two years in companies that have announced a dividend increase for the first or second time. This effect tends to weaken or even disappear with further consecutive increases.

The results should, however, be interpreted with caution due to the relatively small number of companies in the sample that consistently paid increasing dividends. Starting from the fifth consecutive dividend increase, the group consisted of fewer than 20 firms.

To complement the findings regarding the effects of a consistent dividend growth policy, it would also be valuable to investigate the factors influencing the magnitude of abnormal returns following consecutive dividend increases, as well as the market's reaction to an interruption in the sequence of dividend hikes. However, these issues may be the subject of future research.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

RISK IDENTIFICATION PROCESS IN THE MANAGEMENT OF CRITICAL MARITIME INFRASTRUCTURE

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Purpose: The main purpose of the article is to identify the basic groups of risks during the process of managing maritime critical infrastructure.
Design/methodology/approach: The methodological approach chosen by the author of the article is thinking guided by preconceived conclusive and explanatory sentences. The methodology of the research was mainly focused on the process of managing maritime critical infrastructure - it was based on the analysis of activities carried out by selected entities in the maritime industry. To achieve the research goal, the author used critical analysis with reference to the collected literature, the observational method (allowed to identify the risk flux in changing external and internal conditions) and the intuitive method (consisted of considering a number of concepts, problems and terms in the field of risk management).
Findings: Organizations in the maritime industry that manage maritime critical infrastructure are aware of the challenges they face due to the new risk groups accompanying the above process. According to the author, in the face of new market determinants, organizations, should include in this process unprecedented risks, risk intelligence and quantification of cognitive approaches to critical infrastructure management.
Practical implications: The practical nature of the study stems from the author's intended goal of identifying new risks in the process of managing maritime critical infrastructure. In addition, the author of the article is tasked with the fact that these very new risks, which are a consequence of economic changes, will become a permanent part of management.
Social implications: For organizations and their employees, properly identified new risk groups should help in their daily work, and in combination with decision-making issues, in this area of management, affect the security of entire societies.
Originality/value: Thanks to the research process carried out - the analysis of activities in the area of management of maritime critical infrastructure in selected organizations, the main purpose of the prepared material has been realized. In turn, the conclusions obtained can find theoretical and practical application, in the creation of new methods and tools for risk management.
Keywords: critical infrastructure, risk, risk management.
Category of the paper: Research paper.

1. Introduction

Risk management is a key element in the operation of all modern organizations, regardless of industry. Today's businesses face numerous threats, both internal and external, which can affect their ability to achieve their strategic objectives. This is even more so when considering those with so-called critical infrastructure. It is the management of critical infrastructure that has become a major issue in the area of national security and the stability of economic and social systems, and risk management a fundamental element of their functioning, regardless of the industry. Therefore, the aim of the article is to identify the main risks when managing maritime critical infrastructure.

In the article, the author provides a definition of critical infrastructure and the main types of risks. He also discussed the challenges of managing it in the face of economic and technological uncertainty and presented good practices in the context of protecting, developing and maintaining these assets in the face of various risks. In addition, the author conducted an analysis of the basic principles and techniques of risk management - describing the main types of risks.

The content of the paper covers theoretical and practical aspects, taking into account the latest trends and technological solutions. On the other hand, the author's intention of the paper is to initiate a discussion on risk in the process of security management of critical infrastructure, under the conditions of civilization progress, because, as is evident from numerous scientific studies, awareness of the negative consequences of progress is essential for taking correct actions to minimize their negative impact.

2. A definition of risk management in critical maritime infrastructure

Critical infrastructure is a set of resources and systems that are essential to the functioning of society and the economy, and their damage or destruction can lead to serious consequences, both locally and globally. Critical infrastructure includes, but is not limited to, energy, water, transport, telecommunications, information systems, as well as emergency and defense services. Managing such infrastructure requires specialized planning, organizing, monitoring, securing and responding to threats that may damage or destroy it. Critical infrastructure protection encompasses both prevention and response to potential threats, including cyber-attacks, natural disasters, technical failures or terrorist activities (Nowak, 2020).

Today's critical infrastructure is highly complex and many of these systems are interconnected. Problems in one area can lead to disruptions in others. For example, a failure in the power grid can affect the operation of telecommunications systems, which in turn can have a negative impact on the operation of emergency services. These interdependencies mean that

effective management of critical infrastructure requires a holistic approach, taking into account different sectors and systems. Strategies need to be developed that are able to address potential contingency scenarios in different areas of infrastructure (Prabaswari et al., 2024).

With the increasing digitalization of critical infrastructures come new threats of cyber-attack. Hackers can take control of energy, transport or water supply systems, which can lead to major crises. Protecting against cyber threats is crucial, and safeguards must include both hardware and software. Climate change, on the other hand, is leading to an increase in extreme weather events such as hurricanes, floods and heat waves. Such phenomena can have a serious impact on the operation of critical infrastructure, especially with ageing systems. For this reason, it is also becoming necessary to integrate climate change protection aspects into infrastructure management strategies. Depending on the country and the specifics of the infrastructure in question, we can observe a range of management models, some examples of which are described by the author in Table 1.

Table 1.
Main models of critical infrastructure management

№	Name	Description
1.	Centralized management	In a centralized model, all decisions concerning critical infrastructure are taken centrally. Such a model has its advantages in terms of rapid decision-making and uniform oversight of the entire infrastructure, but may be less flexible in responding to local problems.
2.	Decentralized management	In a decentralized model, responsibility for individual infrastructure sectors is distributed among different local government units, agencies and organizations. Such a system can provide greater flexibility and a faster response to local crises, but involves difficulties in coordinating activities at the national level.
3.	Public-private partnership (PPP)	In the PPP model, the public and private sectors work together, where responsibility for managing critical infrastructure is shared. In this case, private companies are often responsible for the design, construction and operation of the infrastructure, while the government handles its supervision and regulation. Such a model can combine the advantages of both sectors, but requires very precise contracts and strict controls.

Source: own study based on Prabaswari et al., 2024.

Nor can we forget modern technologies, which are playing an increasingly important role in critical infrastructure management. Among them, it is worth mentioning (Wiśniewski, 2022; Dąbrowski, 2021):

1. Monitoring and data analysis systems, which allow to keep track of the state of infrastructure, detect anomalies and predict potential failures.
2. The Internet of Things (IoT), which enables the integration of different infrastructure components - this allows remote monitoring and control of systems.
3. Artificial intelligence (AI), which is used to analyses large data sets, among other things, which can help detect threat patterns and optimize management.
4. Blockchain, which ensures the secure transfer and storage of data - this can be particularly important in the context of protection against cyber attacks.

In many countries, standards and good practices for critical infrastructure management have been developed based on the above tools. An example is the US CISA[1] (Cybersecurity and Infrastructure Security Agency) guidelines, which include, among other things, preparing contingency plans, conducting regular training and investing in new security technologies.

Given the information on critical infrastructure management presented by the author above, the issue of existing risks and their management cannot be ignored in this area. This process is commonly equated with the process of identifying, assessing and taking action to minimize the negative effects of risks and maximize the benefits associated with potential opportunities. The aim is to create structures and processes that allow an organization to respond to risks and exploit opportunities in a way that does not threaten its stability and growth. Various definitions can be found in the literature, but the aspects of anticipating, monitoring and controlling risks, as well as the adaptability of the organization to a changing environment, are most commonly emphasized). This is probably a result of the fact that this concept covers a wide range of risks that can occur in different areas of an organization's activities. Several key types of risk can be identified in the literature, including (Krzysztofowicz, 2012):

1. Strategic risk - associated with long-term decisions and the direction of the organization's development. This includes the risk of wrong strategic choices, inadequacy of resources, changes in the market or unpredictable technological trends.
2. Operational risk - associated with the day-to-day processes of the organization, including human error, system failures, inadequate quality management or problems with suppliers.
3. Financial risk - associated with the unpredictability of financial markets, changes in exchange rates, interest rates, inflation or credit risk.
4. Legal and regulatory risk - includes the risk of changes in laws, industry regulations or the risk of the organization's activities not conforming to current standards.
5. Market risk - arising from dynamic changes in the market environment, such as changing demand, increased competition, changing consumer preferences or economic crisis.

Therefore, in order to manage risks effectively, methodical approaches should be used together with appropriate tools (described by the author in Table 2). In contrast, the most commonly used model is the so-called risk management cycle, which includes the following stages[2]:

1. Risk identification - involves identifying and understanding the risks that may affect the organization. Various tools are used for this purpose, such as SWOT analysis, PESTLE analysis or risk mapping.

[1] https://www.cisa.gov/critical-infrastructure-security, 31.01.2025.
[2] https://www.iso.org/obp/ui/en/#iso:std:65694:en, 31.01.2025.

2. Risk assessment - in this step, the organization assesses the likelihood of a hazard occurring and the potential impact it may have on the business. An important tool here is a qualitative and quantitative analysis of risks, including a so-called risk matrix that helps to priorities.
3. Risk response - includes taking action to reduce the risk (e.g. through insurance, implementing control procedures), transferring the risk (e.g. outsourcing, working with partners), avoiding the risk (e.g. changing strategy) or accepting it if the cost of counteracting it is too high.
4. Risk monitoring and control - the process of continuously overseeing identified risks, including assessing the effectiveness of actions taken, and adjusting strategies in response to changes in the organization's environment.

Table 2.
The most common tools used in risk management

№	Name	Description
1.	SWOT analysis	Helps to identify an organisation's internal strengths and weaknesses and external opportunities and threats.
2.	Ishikawa diagram (Fishbone)	Used to analyse the causes of risk, it enables the identification of factors that can lead to problems.
3.	Monte Carlo analysis	Used in the assessment of financial risks, it is based on computer simulations to estimate the probability of various scenarios.
4.	Risk matrix	Allows risks to be classified according to their probability of occurrence and potential impact on the organisation, helping to prioritise actions.

Source: own study based on Tarczyński (2011).

Below, in Figure 1, the author of the article proposes a risk classification matrix for maritime critical infrastructure (MIC), which includes basic risk categories, examples of risks, potential consequences, and areas of risk management.

In summary, today's organizations face a number of risk management challenges. In an era of globalization, a rapidly changing technological environment and economic uncertainty, identifying and controlling risks has become more difficult. Some of the most significant challenges include:

1. The complexity of risks - risks are becoming increasingly complex, interconnected and difficult to predict.
2. Dynamic technological change - rapid developments in technology are associated with new risks, e.g. cyber-attacks, which pose a serious threat to the security of the organization.
3. Market uncertainty risk - changes in economic policy, trade wars, pandemics and other crises can trigger rapid changes in the market environment that are difficult to predict.
4. Global risk management - organizations operating in multiple international markets must take into account the risks associated with different legal systems, organizational cultures and economic differences.

RISK CLASSIFICATION MATRIX

Maritime Critical Infrastructure

	Category	Sources or threat	Examples	Potential impacts	Risk management
	Natural	Storms, hurricanes, tuunamis, floods, sea-level rise-	Demage to ports, docks, terminals, supply chain disruptions	Damage to ports. docks, terminals, supply chain	Soatial planning protective engineering eatly warning systems
	Technical	infrastructure san-tem failures, cargo handi-ng equipment failures	Shipment delays, financial losses, accident risk	Paralysis of traffic management systems,	Preventive maintenance technical safety systems contingency plans
LONV	**Cyber**	ITIOT attacks, system failures, ransum-mare attacks on port	P20AMscu of traffic, management.systems, delays in handling	Destruction of infrastructure, casualties, economic	Cybersecurity policy network segmentat-tion. setioms, rations
	Physical	Bombings in ports, subsea cable sabotage maritime route bac	Destruction of infrastructure, casualties economic destabiliza-	Disruptions in energy supply and trade, political esciation	International coopera-tion, strategic monitor-ing, crisis exercises
	Hybrid/ Geopolitical	State conflicts, hybrid warfare, incortsRerece in subsea pipelines·	Disruptions in energy supply, trade	Unrcupion of energey escala	Route diversification business continuity management, contrac-
	Economic/ Logistic	Disruptions in global trade and supply chains port-strives	Shipment delays, increased transport costs production stoppages	Accidents, reduced efficiency, increased risk of secondary	Training, safety procedu-res. satety culture: crisis communications

Figure 1. Risk classification matrix for critical maritime infrastructure.

Source: own study.

Therefore, risk management in critical maritime infrastructure is a key element in ensuring its continuity of operation, safety, and resilience to natural, technical, and deliberate threats. In terms of definition, this process includes the identification, analysis, assessment, and control of risk, as well as the implementation of measures to minimize its effects. The essence of risk management is a systemic approach that combines technical, organizational, and legal aspects, enabling effective response to threats and reduction of their potential consequences. This makes it possible not only to ensure the safety of maritime infrastructure, but also to protect the economic, environmental, and social interests of the state.

3. Materials and methods

In order to talk about the identification of the main risks in the process of security management of maritime critical infrastructure, it is necessary, according to the author, to "start" from the problem of making decisions and judgements under conditions of uncertainty and cognitive errors. During security management, many decisions are based on beliefs about the probability of uncertain events, which are central to the choices made in the context of risk (Wódkiewicz, 2019). These risks can result in serious and systemic errors due to: a lack of

acknowledged representativeness of the premises, an illusion of the accuracy of one's own predictions, a lack of so-called cognitive strain and giving the outcomes under investigation their own interpretative framework by misstating the problem, e.g. the identified threat (Kahneman, 2022).

On the other hand, the doctrinal position points to the complexity, diversity and relativity of the concept of risk itself, which, in research, makes it difficult to attempt any classification of this problem in definable terms. However, in this situation, for the purposes of the study, on the basis of the definitions cited earlier, let us assume that risk is: the estimated probability of a particular type of hazard or loss occurring, as well as the gain and benefit associated with decisions made, which are relevant to the future. In this situation, the intended objectives of critical infrastructure security management, as implemented in the decision-making process, should include a strategy for situations of their destruction within a certain risk tolerance band (Ficoń, 2007).

The cited definition is closely related to the ontological view of security, from which it follows that the general definition of the formation of any type of security, boils down to the fact that it is the design of a specific state of relatively valued positively ensuring persistence, survival, improvement and development. In contrast, its identical and developed formulation, boils down to (Beck, 2004):

- the shaping of a certain state, through the assessed risks relating to it,
- risk understood as a useful application, which should be balanced by a decision in the management process on the basis of a decision,
- a decision made using the information at hand, information that is relevant to the future, which should refer to a specified object, in a specified meaningful context and the resulting conclusions).

Under these conditions, risk acceptance, is risk tolerance on the basis of resource and relational discretion. The rationale for this statement stems from the fact that an integral part of the analyzed each risk (risk receiver, risk issuer), are the conditions of the decision-making process, creating a decision-making situation, which is determined, among other things, by legal conditions. Among other things, such relations may result from the assessment of decision-making freedom made at the stage of building variants for solving the decision issue in the aspect of advantageousness, completeness and sufficiency of resource wielding, as well as the selection of a variant for solving the decision issue in the aspect of wielding sufficient resources in the period of decision implementation (Walasek, Wojnarowski, 2011).

Summarizing on the basis of an analysis of theoretical research on risk in the maritime sector and a review of strategic documents, the author of the article:

- defines key concepts: risk management, critical infrastructure, maritime critical infrastructure,
- analyzes risk management models in the literature,

- classify risks in maritime infrastructure (natural, technical, cyber, terrorist, and geopolitical threats),
- identify dominant approaches and compare international perspectives.

4. Results and discussion

A recurring theme across policy and academic work is the fragmentation of responsibility and the absence of coherent, sector-specific governance frameworks. C. Bueger and T. Liebetrau (2023) emphasizes that high-profile incidents exposed gaps in assignment of roles and coordination between state actors and private operators. Similarly, practitioner reports argue for system-level coordination mechanisms and common procedures to improve situational awareness and response. Together, these analyses suggest that effective MIC risk management requires institutional designs enabling cross-jurisdictional information sharing and joint decision processes rather than ad hoc, reactive arrangements.

Based on an analysis of the literature on the subject and strategic documents, the author identified the main theoretical gaps (described in Table 3), which focus on the lack of uniform definitions and models dedicated to the maritime sector, weak interdisciplinary integration, failure to take into account complex systemic links, underrepresentation of new generation threats, and insufficient development of the concept of resilience and the international perspective.

Table 3.
Theoretical gaps in research on risk management in maritime critical infrastructure

№	Area	State of research	Theoretical gap	Directions for further research
1.	Definitions and conceptual frameworks	General definitions of critical infrastructure and risk management exist (ISO 31000, EU directives).	Lack of unified definitions and models dedicated to the maritime sector.	Development of standardized, sector-specific definitions and conceptual frameworks.
2.	Theory–practice integration	Technical and security-oriented studies dominate over managerial and organizational analyses.	Lack of interdisciplinary approaches combining technical, legal, economic, and social aspects.	Development of holistic models integrating multiple research perspectives.
3.	Systemic and cascading risks	Analyses focus on single elements (ports, terminals, cables).	Insufficient research on interdependencies and cascading effects.	Creation of systemic models considering interactions and cross-border consequences of failures.
4.	New Types of Threats	Focus on traditional threats (natural disasters, technical failures).	Low representation of cyber threats, hybrid conflicts, and the impact of climate change.	Expanding analyses to include new generations of threats and their effects on maritime infrastructure.

Cont. table 3.

5.	Resilience	Dominance of preventive approaches and risk minimization.	Weak development of resilience and adaptability concepts in maritime systems.	Research on adaptability and rapid recovery of infrastructure functions.
6.	International Perspective	Analyses mainly concentrated at the national level.	Lack of comparative studies on regulations and practices at the global scale.	Development of studies on international cooperation and regulatory harmonization.

Source: own study.

A strong strand of recent research advances the argument that this process must be treated as an interconnected network whose local failures can propagate widely. J. Liupeng, W. Guangsheng, F. Xuejun, Y. Tong and L. Zhiyi (2024) develop quantitative models of cascading failures in maritime networks, demonstrating that disruptions in a single port or chokepoint may trigger broad, nonlinear consequences for global flows. Complementary modeling work using multi-agent simulations (Qu et al., 2024) shows that even short-term port disruptions can create long-tail impacts on supply chains that persist after direct physical operations resume. These studies collectively make the case for embedding network and systems thinking - rather than single-asset risk assessment - into maritime risk frameworks.

On the other hand, work on multiple hazard analysis and flood impact mapping methodology (Arvidsson et al., 2023) highlights the vulnerability of ports and coastal infrastructure to complex hazards. Ports in low-lying areas are exposed to cumulative effects (e.g., storms and simultaneous infrastructure failure) that significantly weaken their resilience. Researchers emphasize that climate risk must be integrated into classic hazard analyses to account for both the increasing frequency of events and the degradation of infrastructure in the long term.

The risk analysis carried out in the publication takes into account the realization that nowadays, the unlearning of risk becomes a scientific problem in itself, where in this situation it will be necessary to reveal the contradictions and difficulties that exist in the interrelationships between practice and disciplines in the interdisciplinary maritime reality, which should take into account that (Falencikowski, 2008):

1. In a technologically advanced innovative economy, the production of occurring risks and hazards shows a dependence on knowledge as its product, based on standards of its own rationality.
2. The dynamics of civilizations progress means that we can no longer speak of the predictability of risks as they are:
   - produced - the problem of unpredictability is mainly due to the difference based on scientific skill between estimation and calculability,
   - contradict rational conditions of acceptability, deforming the rules of universal acceptance.

3. There is a so-called risk intelligence in the maritime safety space that:
   - has a fundamental impact on the theoretical content of risk and its relation to the proliferation of its varieties,
   - has an impact on the so-called risk content (extent, intensity, causality, damage).

Under these conditions, the risk of the effectiveness of the security management of maritime critical infrastructure dictates that we consider:

1. Operational risks, which arise from inadequate and malfunctioning internal processes, occurring, for example, in the environment of those employed at the facility.
2. Economic risks, which may be caused by changes in economic conditions - e.g. the risk of an acceptable financial contribution to the security management organization.
3. Event risk, which may be caused by the occurrence of specific events or natural disasters.
4. Model risk, or the risk of theoretical error in the real world, which includes the model of security management itself (and the risks within it).
5. Model of risk assessment adopted, which most often leads to wrong decisions being made in the face of the risks of their relationship to the social mission of the company.

In this situation, security management of maritime critical infrastructure is utilitarian in nature and is realized in an informational dimension, as a process of making effective decisions that guarantee the fulfilment of the mission of a given system under the existing conditions and constraints (Jajuga, 2018).

On the other hand, in a substantive sense, risk management in the implementation of such governance is essentially based on the appropriate management of information and its attributes of completeness, completeness, reliability, certainty, accuracy and timeliness. Therefore, in view of the subject and object relationships, IT security, which is related to the estimation and control of risks arising from the use of computers, computer networks and data transfer, assumes fundamental importance. These processes and issues should be assigned a subjective character, the components of which are: information and communication equipment, systems and networks, paper documents or content contained on another medium. Accordingly, the risk analysis should include the identification of the entities' information resources. In addition, such an analysis should also take into account the standards of security system design in information systems, which are based on general principles that include: implicit denial of access to information, control of the security system including acceptability of the security system, control of the authorization to access information, implementation of the principle of least privilege, and separation of privileges and minimization of shared protection mechanisms.

At this point, it is also worth mentioning risk intelligence in the management of maritime critical infrastructure. According to the learning experience, the basic issue in risk intelligence is to determine the difference between our degree of understanding of a given risk and that of others, which is mainly due to our awareness and our predisposition. Understanding risk requires two conditions. Firstly, in order to fully understand risk, it is necessary to identify

possible solutions to the problems created by the risks, as well as the factors that determine them. Secondly, understanding risk requires experience that allows us to recognize which of the solutions presented can be effective, which are flawed, and whether we need more options. When talking about risk intelligence, it is important to bear in mind this experience in the safety management process that we have already gained or will gain in the future. This means that the concept of risk refers precisely to the second determinant of understanding risk intelligence. Thus, risk intelligence refers to the ability to choose the right type of risk by applying the rules of risk intelligence, which we will be able to manage effectively thanks to our experience (Apgar, 2016).

In summary, given the variety of causes of the most frequently investigated hazards, we usually have no way of determining their unambiguous origin - in practice, this implies that they cannot be accurately forecast. Therefore, their assignment to system elements should introduce the concept of an elementary incident indicator. Thus, the elementary incident indicator, as a security threat and a measure of danger in a system element, can become a function in which the incident scaling index is assigned to a given number of attempts. This will help us determine the abundance of the set of identified threats as specific features in the scaling elements of the information security system. In this situation, this indicator will indicate and describe the image of the weakest for security, element of the system. On this basis, it will become possible to select security measures that will reduce the identified risks to an acceptable level. In this situation, it is essential to have the necessary knowledge, understood as the ability to understand the relationship between cognition, knowledge and reality, on the basis of which it will become possible to reasonably believe in it.

Conclusions

Critical infrastructure management is a complex process that requires coordinated action at various levels - from local to international. In the face of increasing threats, both natural and man-made, it is necessary to constantly improve management methods and introduce innovative technological solutions. Effective management of critical infrastructure ensures not only the security of citizens, but also the stability of the economy and the state. Meanwhile, the identification of risks in the process, along with the attempt to manage them, has become an integral part of the strategy of any such organization. The goal here is not just to protect against threats, but also to take advantage of opportunities that may arise as a result of the changing environment. Effective risk management requires the use of appropriate tools and techniques, as well as the ability to adapt quickly to changing conditions. However, the growing complexity of risk and uncertainty remains a challenge for organizations, requiring continuous improvement of risk management processes.

From 2022 to 2025 the field has shifted toward an appreciation of interdependence, hybrid threats and climate-driven vulnerabilities. Future theoretical work should prioritize:

- integrated frameworks that marry network science with governance analysis,
- operational resilience metrics and recovery planning tools,
- more granular studies of cyber–physical coupling in port and subsea systems,
- comparative policy analysis of coordination mechanisms.

Filling these gaps will support risk management approaches capable of both anticipating cascading failures and enabling rapid system recovery - objectives that are essential for sustaining maritime security and global trade.

In summary, the author's study and analysis based on the author's experience makes it necessary to analyze risks on an ongoing basis in order to quickly grasp the problem where the resulting risk turns into a crisis. The crisis in the transfer to the application of management decisions is the growing process of uncertainty in the process of changes and risks that occur under these conditions, which leads to the occurrence of a critical situation. The problematic issue signaled is important because a crisis, understood as a sudden or growing event, causes a threat to the basic values of the functional potential of maritime critical infrastructure. In fact, it can be a specific type of breakthrough period, in which a solstice occurs (usually manifests itself as a strong deterioration in the ability of a maritime critical infrastructure entity to perform its functions), which causes the collapse of the existing line of development, which in turn forces the search for alternative and, most often, innovative solutions.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

LIFE CYCLE ASSESSMENT OF A PULLEY MANUFACTURED FROM VARIOUS POLYMER MATERIALS USING 3D PRINTING TECHNOLOGY

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Purpose: The reason for taking up the subject was many inadequate decisions in the scope of material choice for the production process. The main aim of the carried-out analyses was comparing environmental influence of materials used for designing and manufacturing machine elements.
Design/methodology/approach: The objectives achieved using literature review and special CAD/CAM software – SOLIDWORKS 2024 with integrated sustainability module. The software was used to obtain environmental impact results. The results of analyses were presented in the form of tables and charts with wide descriptions.
Findings: In the conclusions presented and discussed the influence of the harmful factors on the environment. Additionally, authors recommended the best selection method of material in the technological process.
Research limitations/implications: The limitation of research was material base not including bio-materials – for example popular in 3D printing polylactic acid (PLA) or others.
Practical implications: The prepared analyses help in the materials selection, products assessment and prevent harmful effects on the environment. The indicators presented in the form of charts and tables help make thoughtful decisions to prepare the manufacturing process.
Social implications: The presented results pay attention on the environmental problems in the form of carbon footprint, total energy consumption, air acidification and water eutrophication.
Originality/value: The novelty is LCA analyses of specific machine elements. In the study presented pulley wheel analyses of environmental factors as material, manufacturing, transport and end-of-life.
Keywords: Life cycle assessment (LCA), polymer materials, 3D printing, sustainable design.
Category of the paper: Research paper.

1. Introduction

The 3D printing technology, also known as the additive technology, is becoming increasingly important in modern industry, bringing significant changes to the way products are manufactured (Thakar et al., 2022). Due to its flexibility and versatility, 3D printing allows for the creation of complex forms, reduction of waste and decrease of raw material consumption (Jandyal et al., 2022). The use of additive technologies to manufacture machine parts and components, such as pulleys, creates new opportunities in process optimisation in terms of both cost and production time (Krawiec et al., 2021; Wygoda, Witko, 2024). Printing in 3D is increasingly used in sectors such as automotive and aviation industries, medicine, and electronics where precision, low weight and customisation of products are of key importance (Shahrubudin et al., 2019; Pavan Kalyan, Kumar, 2022).

Along with the growing popularity of 3D printing, there appears the need for in-depth analysis of its environmental impact (Khosravani, Reinicke, 2020; Shuaib et al., 2021). Modern engineering focuses on sustainability, which requires environmental aspects to be taken into account at every stage of the product life cycle (Jachimowski, 2021). An important tool in this regard is the Life Cycle Assessment (LCA) which allows a detailed analysis of the environmental impact of a product from the acquisition of raw materials, through the production and use, to the recycling and disposal (Hendrickson et al., 2006). In the case of components manufactured using 3D printing, such as pulleys, LCA becomes a key tool to assess the benefits and challenges of using different materials, both ecologically and economically (Da Silva Barros, Zwolinski, 2016).

It should be emphasised that in the face of the global challenges of climate change and increasingly stringent environmental regulations, life cycle assessment becomes an indispensable tool for engineers and designers (Hauschild et al., 2020). Through the application of LCA, it is not only possible to improve production processes in terms of energy savings and waste reduction, but also to develop strategies to minimise negative environmental impacts (Rödger et al., 2021; Croes, Vermeulen, 2021). Therefore, research into the use of LCA for products manufactured using 3D printing is of particular importance in the context of the search for greener materials and component manufacturing technologies (Saade et al., 2020; Ulkir, 2023).

This paper focuses on the life cycle assessment of a pulley made from four different materials, i.e. Acrylonitrile Butadiene Styrene (ABS), Polypropylene Copolymer (PP-c), Polyethylene Terephthalate (PET) and Polyamide PA6. Each of these materials is characterised by different mechanical and chemical properties, which bears upon the production process and the entire product life cycle (Al-Zaidi, Al-Gawhari, 2023). The purpose of the investigation is to compare the environmental impact of the different materials taking into account factors such as greenhouse gas emissions, energy consumption and potential risks in terms of air

acidification and water eutrophication. The analysis is intended to help select the most environmentally friendly materials, which is crucial for sustainable design.

2. Literature review

In The 3D printing technology is becoming increasingly significant in the context of industrial sustainability (Gebler et al., 2014; Kim, 2018; de Mattos Nascimento et al., 2022; Dey et al., 2022; Prashar et al., 2023). Its growing importance is due to its unique properties that bring fundamental changes to manufacturing processes (Ćwikła et al., 2017; Herzberger et al., 2019). In engineering practice, there has always been a demand for low-volume production for various industries (Salobir et al., 2019). This is typically associated with the manufacture of prototypes, unavailable machine spare parts or modifications to a given design. The necessity of modification may be related to incorrect design assumptions, calculation errors, and the intention to increase the load on an object or to increase the durability of a particular component. The most common areas requiring intervention are those weakened by material discontinuities in the cross-section – known as notches. In addition to weakening the cross-section, the notch effect causes a local increase of stress – which contributes into fatigue life of the components (Romanowicz et al., 2024). In such cases it is necessary to reinforce the affected zone. One possible form of structural reinforcement is the use of an appropriately designed reinforcement – typically with a complex geometry directly related to the shape of the hole (Romanowicz et al., 2022). The problem of how to precisely form the shape of the reinforcement can be solved by additive technologies which are gaining in popularity and practicality (Gao et al., 2015).

Thus, with accurate dispensing of materials and the ability to create complex geometries without generating excess waste, 3D printing is becoming a key tool in the quest to minimise the environmental impact of industry (Ngo et al., 2018; Vanaei, Zirak, 2024). Unlike traditional manufacturing methods, which often involve large amounts of waste and high energy consumption, 3D printing allows for a more efficient use of raw materials resulting in lower resource consumption and lower emissions (De-la-Cruz-Diaz et al., 2022; Embia et al., 2023).

One of the most important aspects of the sustainability of 3D printing is the possibility to precisely adjust the manufacturing processes according to the actual demand (Xu et al., 2021). Traditional manufacturing often leads to mass production, resulting in overproduction and waste of materials. An example of this might be machining as part of the process of turning or drilling where the waste is the chips of the material being machined. Therefore, analyses should take into account the wear and tear of expensive cutting tools and their relatively short lifespan relative to the parts that are manufactured (Paprocki et al., 2021). With its ability to produce on demand, 3D printing allows for the production of only those components that are actually

needed, which significantly reduces excess waste (Driouach et al., 2023; Lakshmanan et al., 2023). This technology also reduces the energy consumption associated with the storage of redundant products helping to further reduce the environmental impact (Javaid et al., 2021).

Furthermore, the 3D printing technology also opens up new opportunities with regard to designing products with the entire life cycle in mind (Subramoniam et al., 2021). Engineers and designers can now more easily choose materials with a lower environmental impact, such as biopolymers and other green substances that can replace traditional plastics (Ncube et al., 2020). Such materials not only reduce the environmental impact, but also facilitate recycling. 3D printing also allows for flexible design modifications during the manufacturing process, which supports iterative design and allows for further product improvements towards greater material and energy efficiency (Jandyal et al., 2022; Prashar et al., 2023).

A key tool in analysing the environmental impact of 3D printing is life cycle assessment (Cerdas et al., 2017; Kumar et al., 2022; Roux et al., 2023; Tay, Tan, 2023). In the context of 3D printing, LCA is particularly useful as it allows the comparison of different materials in terms of greenhouse gas emissions, energy consumption and impacts on air acidification and water eutrophication (Caceres-Mendoza et al., 2023; Kokare et al., 2023). This type of analysis allows for more informed choices of materials and production methods that are most environmentally efficient (Pollini, Rognoli, 2021; Lunetto et al., 2021).

Another aspect of sustainability in 3D printing is the possibility of local production (Longhitano et al., 2021; Rayna, Striukova, 2021). Due to the flexibility of this technology, the manufacturing of components can take place closer to their end use, reducing the need for long-distance transport and thereby reducing the gas emissions associated with the transport of goods (Javaid et al., 2021). Locating production close to the consumers not only reduces logistics costs, but also reduces the environmental impact of the global supply chains (Attaran, 2017).

Taking this into account, a diagram (Fig. 1) was proposed to show the key aspects of sustainability in the 3D printing technology. In particular, the various factors that contribute to a green and efficient production process are shown.

It should be emphasised that when viewed in this way, the 3D printing technology has great potential to promote sustainability in many industries. By reducing the use of materials, energy and waste as well as promoting local, flexible production, additive technologies contribute to minimising negative environmental impacts (Peng et al., 2018; Godina et al., 2020; Javaid et al., 2021; Gopal et al., 2022; Nyika et al., 2022; Hegab et al., 2023). Combined with the search for even greener materials and improvements in manufacturing processes, 3D printing can play a key role in the future of industrial production, fostering a more responsible and resource-efficient response to the global environmental challenges.

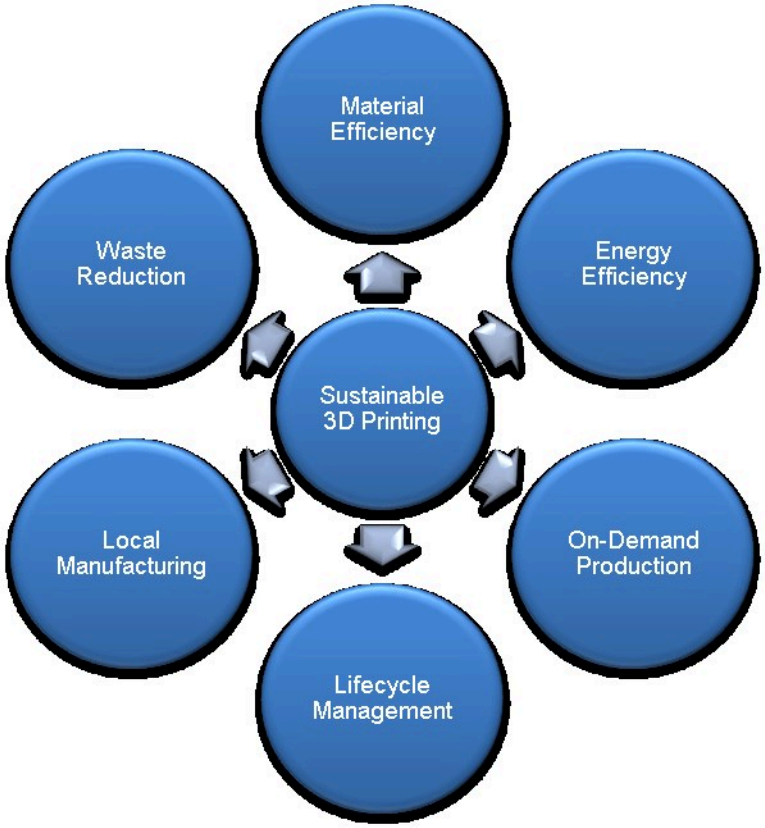

Figure 1. Aspects of the sustainability of 3D printing.
Source: author's work.

3. Methods

The present investigation uses a model of a pulley made using the SOLIDWORKS 3D CAD software. Figure 2 presents the spatial model of the object under investigation; the exact geometry together with the technical drawing was presented in the previous paper on 3D printing parameters (Wygoda, Witko, 2024).

The environmental analyses made use of the specialised SOLIDWORKS Sustainability module which allows the assessment of the environmental impact of a product by combining life cycle assessment (LCA) with engineering design (Casamayor, Su, 2021; Dudkowiak et al., 2024). The Sustainability module was implemented in 2009 and is integrated into the SOLIDWORKS CAD software. It allows the assessment of carbon dioxide emissions (in kg CO2 eq), energy consumption (in MJ), air acidification (in kg SO2 eq) and water eutrophication (in kg PO4 eq) throughout the life cycle of the product under investigation (Bałdowska-Witos et al., 2022).

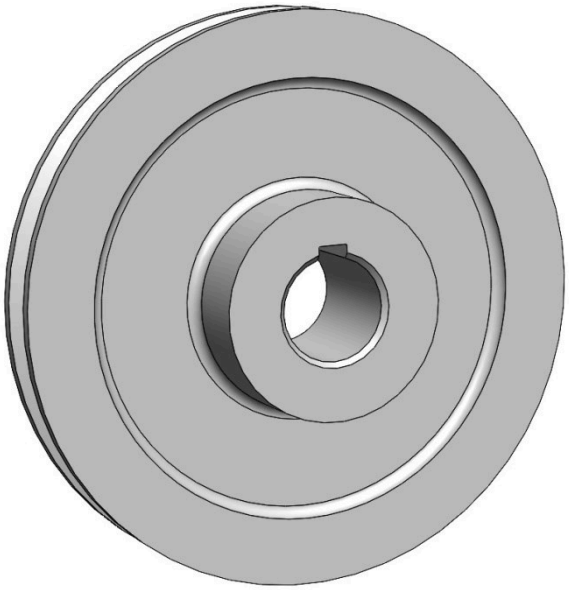

Figure 2. The 3D model of the pulley wheel.

Source: author's work.

Four types of polymeric materials were used for the environmental analyses, i.e. acrylonitrile-butadiene-styrene terpolymer (ABS), polyethylene terephthalate (PET), polypropylene block copolymer (PP-c) and PA6 (Polyamide 6). Table 1 presents a comparison of unit prices and selected physical and mechanical properties (SOLIDWORKS Software, 2024). The materials selected for the analyses are available in both the SOLIDWORKS Sustainability software and the BCN3D Stratos software used to prepare 3D prints.

Table 1.
The unit-prices, physical and mechanical properties of selected materials

Material	Unit Price	Density	Young's Modulus	Poisson's Ratio	Tensile Strength
[-]	[USD/kg]	[g/cm^3]	[GPa]	[-]	[MPa]
ABS	2.90	1.02	2.00	0.39	30.0
PET	2.20	1.42	2.96	0.37	57.3
PA-6	4.90	1.12	2.62	0.34	90.0
PP-c	2.80	0.89	0.90	0.41	27.6

Source: author's work based on (SOLIDWORKS Software, 2024).

The first step was to prepare the geometry of the pulley model in line with the engineering approach to designing structural components. The pulley was designed in accordance with the relevant standards, and a detailed description is presented in the paper (Wygoda, Witko, 2024). It should be noted that within the scope of the environmental studies carried out, the changes to the materials that were needed for the analyses can significantly affect the durability of the target component. The choice of a particular material will change the stresses acting on the pulley under operating conditions. In engineering practice to accuracy assessment of the loaded machine elements is possible by the Finite Element Method – advanced numerical computations. The obtained results in the form of stress and strains allow for the selection of reliable material.

The second step was to import the model into the BCN3D Stratos software in which manufacturing simulations were performed. The materials that were selected from the available material databases had the designation of the manufacturer BCN3D. For the purpose of the simulation, it was assumed that the constant parameters would be the pattern design (PD), the printing accuracy / layer height (LH), the printing speed (v), and the type of build plate adhesion (BPA). For further calculations, it was assumed that the power consumption (P3D) of the 3D printer available in the laboratory, i.e. BCN3D Epsilon W27, is 840W. The main and only variable was the infill density expressed as a percentage (I_D) that ranged from 10 to 100%. The input data provided information on print time (t) and print weight (w). This made it possible to determine the total energy consumption [kWh] needed to produce the model (P_C), according to formula (1):

$$P_c = (P_{3D} \cdot t)/1000 \tag{1}$$

where:
P3D – power consumption of the 3D printer [W],
t – time [h].

In order to calculate the electricity required per gram of print (EC) formula (2) was used:

$$E_c = P_c \div w \tag{2}$$

where:
P_C – power consumption of the process,
w – weight.

The simulation results, together with the calculated energy consumption parameters, are presented in Table 2.

The results obtained from the analyses (Table 2) also include an averaged value of electricity consumption (AVG. E_C) per gram of print produced. The authors decided to average the value of electricity consumption per unit mass due to the small differences in the individual results and the limitations of the environmental assessment module (SOLIDWORKS Sustainability) in terms of rounding the values entered. Therefore, further work on determining the environmental impact of the selected pulley material will be carried out for the solid component.

For the environmental analyses carried out, Europe was assumed as the region of production and use of the product. It was specified that the product was designed with a service life of 5 years and would then be decommissioned after 5 years. For each of the materials used, it was assumed that production was carried out from new raw material. In addition, with regard to the end of life, a 100 percent recyclability was assumed for all material variants. For the production process, average energy consumption per gram (AVG. E_C) of print was assumed for the selected materials as shown in Table 2. In the next step, it was assumed that transport would take place by road, with an input value of 149 km. Available analyses (Raport Transport drogowy, 2021)

show that in Poland, more than 60% of goods (by weight) are transported by land over the above-stated distance (Tseng et al., 2021; Miranda et al., 2023).

Table 2.
The results of 3D printing simulations

Material	Infill Density	Time	Weight	Power consumption of 3D Printing Process	Manufacturing Process – Electricity consumption	Average Value of Electricity Consumption
-	I_D [%]	t [h]	w [g]	P_c [kWh]	E_c [kWh/g]	AVG. Ec [kWh/g]
ABS	10	8.80	119	7.392	0.062	0.056
	25	11.07	163	9.296	0.057	
	50	14.75	237	12.390	0.052	
	75	18.42	311	15.470	0.050	
	100	26.25	385	22.050	0.057	
PET	10	11.87	178	9.968	0.056	0.051
	25	14.62	224	12.278	0.055	
	50	18.43	301	15.484	0.051	
	75	20.77	376	17.444	0.046	
	100	24.12	452	20.258	0.045	
PP-c	10	7.45	87	6.258	0.072	0.065
	25	9.70	124	8.148	0.066	
	50	13.40	186	11.256	0.061	
	75	17.07	247	14.336	0.058	
	100	24.90	309	20.916	0.068	
PA6	10	7.45	107	6.258	0.058	0.052
	25	9.70	153	8.148	0.053	
	50	13.40	230	11.256	0.049	
	75	17.07	307	14.336	0.047	
	100	24.90	383	20.916	0.055	

* The analyses are presented for constant values: Pattern design, PD: grid; Layer height, LH: 0.3 [mm]; Speed of printing, v: 45 [mm/min]; Build plate adhesion, BPA: raft; Power consumption of the 3D printer, P3D: 840 [W].

Source: author's work.

4. Results

Based on the available research results with regard to the environmental impact, a division was made into four categories, i.e. carbon footprint, energy consumption, air acidification and water eutrophication (Kruszelnicka et al., 2020). The analyses used the CML method through which it is possible to estimate environmental pollution in terms of material, manufacturing process, transport and end-of-life (Dong et al., 2021; Zegardło, 2021). Furthermore, the CML methodology is based on European regional conditions and is the most commonly used set of environmental indicators in LCA studies.

Taking the above into account, four test scenarios were carried out to analyse the life cycle of a product made from different filaments, such as ABS, PP-c, PET and PA6, in three stages: material, manufacturing and transport. The results as well as the environmental indicators are presented in Tables 3 and 4.

Table 3.
The results of Carbon Footprint and Total Energy Consumption

		Carbon Footprint [kg CO_2e]				Total Energy Consumption [MJ]			
		ABS	**PET**	**PA-6**	**PP-c**	**ABS**	**PET**	**PA-6**	**PP-c**
Influence	**Material**	1.2	1.4	3.8	0.599	30	39	70	23
	Manufacturing	12	14	11	12	230	270	220	230
	Transport	0.0024	0.0034	0.0027	0.0021	0.036	0.05	0.04	0.032
	End-Of-Life*	0	0	0	0	0	0	0	0
	SUMMARY	13	15	15	13	260	309	290	253

* End-Of-Life - the obtained results caused by the assumption of 100% recycling of materials.

Source: author's work.

Table 4.
The results of Air Acidification and Water Eutrophication

		Air Acidification [kg SO_2e]				Water Eutrophication [kg PO_4e]			
		ABS	**PET**	**PA-6**	**PP-c**	**ABS**	**PET**	**PA-6**	**PP-c**
Influence	**Material**	0.0027	0.0025	0.0057	0.0013	0.00047	0.00024	0.00067	0.00012
	Manufacturing	0.081	0.093	0.077	0.082	0.0029	0.0034	0.0028	0.003
	Transport	1.1E-05	1.6E-05	1.3E-05	9.9E-06	2.6E-06	3.6E-06	2.8E-06	2.3E-06
	End-Of-Life*	0	0	0	0	0	0	0	0
	SUMMARY	0.084	0.096	0.083	0.083	0.0034	0.0036	0.0035	0.0031

* End-Of-Life - the obtained results caused by the assumption of 100% recycling of materials.

Source: author's work.

In addition, Table 3 and Table 4 indicate the most negative (red) and the lowest (green) environmental impacts for the four stages, i.e. material, manufacturing, transport and end-of-life. Based on these results, a percentage comparison was prepared in the form of pie charts (Figs. 3-6). Due to the zero values of the end-of-life results, no further presentation was made for them.

Figure 3 shows the percentage impact on CO_2 emissions for the various plastics. It follows from the analyses that PA-6 (54%) has the largest share in material footprint while PP-c has the smallest share at only 9%. PET had the largest impact at the manufacturing stage with a result of 29% and PA-6 the smallest with 22%. In terms of transport, on the other hand, PET again has the highest result (32%) and PP-c the lowest at 20%.

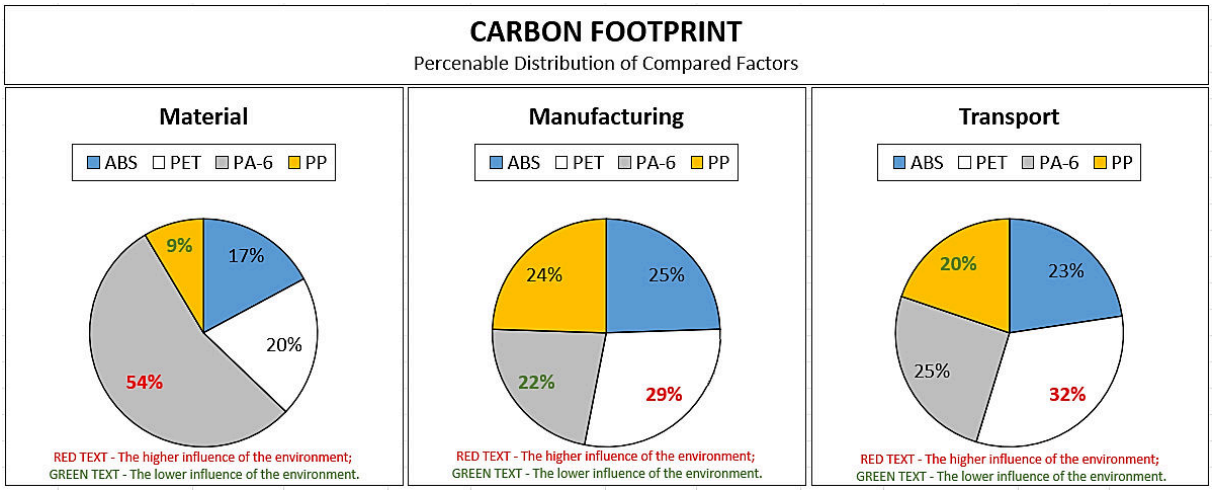

Figure 3. The results of the Carbon Footprint.

Source: author's work.

In the Figure 4 presented the analysis of the total energy consumption for the different materials. The analyses show that PA-6 has the highest contribution to energy consumption in terms of material (43%) and PP-c the lowest at 14%. PET had the highest impact at the manufacturing stage with a score of 29% and PA-6 the lowest with 23%. In terms of transport, on the other hand, PET has the highest result with 32% and PP-c the lowest with 20%.

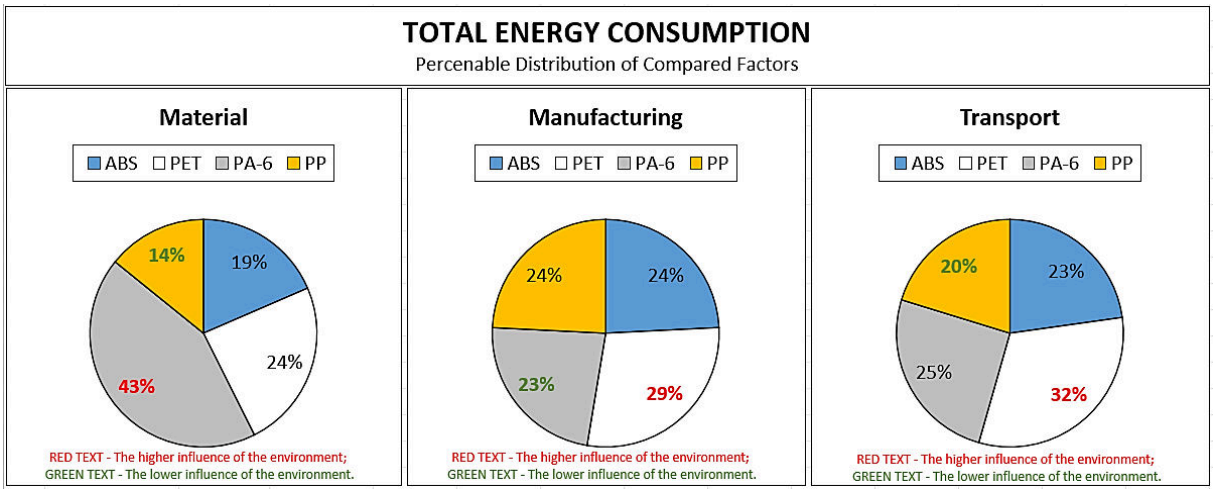

Figure 4. The results of the Total Energy Consumption.

Source: author's work.

Figure 5 shows how different materials affect air acidification at each stage of the product life cycle. The analyses show that PA-6 has the highest contribution in terms of material (43%) and PP-c the lowest at 11%. PET had the highest impact at the manufacturing stage with a score of 28%, and PA-6 the lowest with 23%. In terms of transport, on the other hand, PET has the highest score with 32% and PP-c the lowest with 20%.

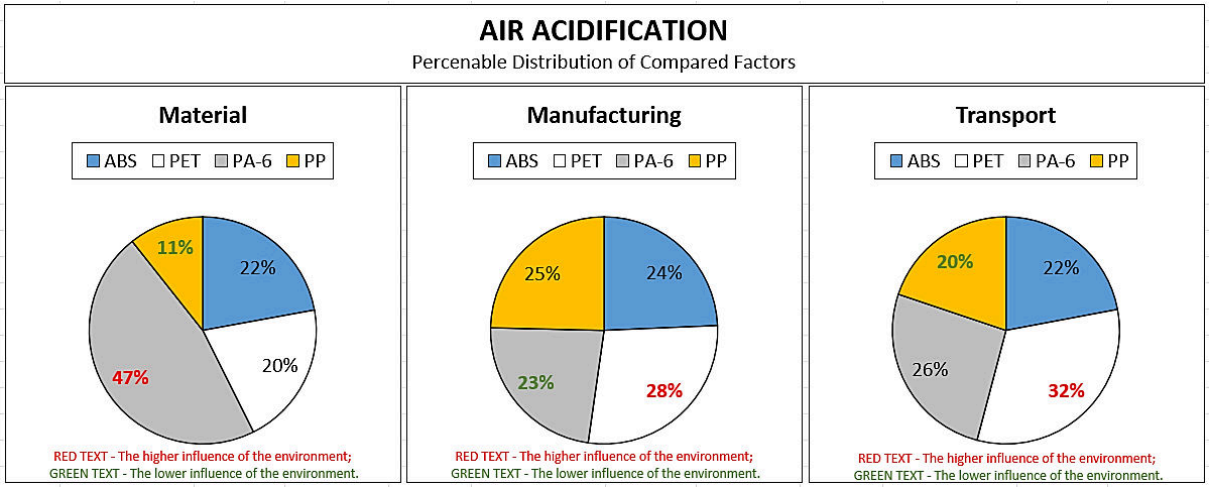

Figure 5. The results of the Air Acidification.

Source: author's work.

In the Figure 6 presented the analysis of water eutrophication in the context of different filaments. The analyses show that PA-6 has the highest impact on water eutrophication in terms of material (45%) while PP-c has the lowest impact of only 8%. PET had the highest impact at the manufacturing stage with a score of 28% while PA-6 had the lowest impact of 23%. In terms of transport, on the other hand, PET has the highest result with 32% and PP-c the lowest with 20%.

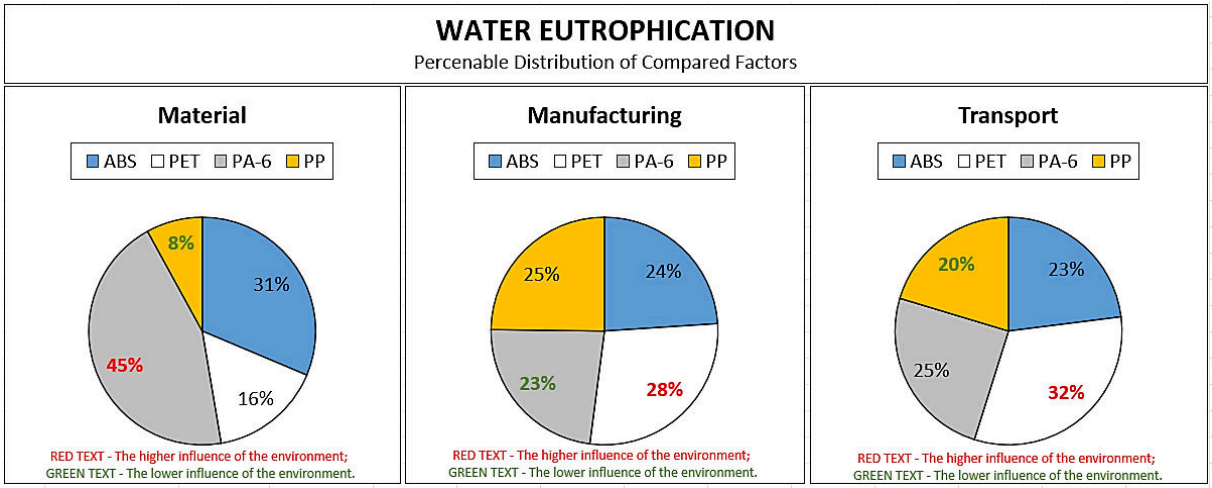

Figure 6. The results of the Water Eutrophication.

Source: author's work.

5. Discussion

When comparing the results with similar studies, it is evident that much of the literature focuses on the life cycle assessment (LCA) of polymer materials, particularly in the context of 3D printing (Faludi et al., 2015; Ma et al., 2018; Výtisk et al., 2019; Kumar et al., 2022; Ulkir 2023; Al Rashid, 2024). However, some studies explore a wider range of materials or other manufacturing technologies (Garcia et al., 2021; Chatzipanagiotou et al., 2023; Kokare et al., 2023). The results presented in this paper, which show that PP-C has the lowest environmental impact, align with trends highlighting the benefits of using low-density materials that require less energy for transportation (Fan, Njuguna, 2016; Czerwiński, 2021). At the same time, the significant impact of PA6 and PET in terms of emissions and transport confirms the need for optimization of production and transportation processes for materials with a higher environmental footprint.

The limitations of the study include focusing solely on 3D printing technology and four polymer materials, which may not fully represent the entire range of manufacturing possibilities. The results are based on data from the SOLIDWORKS Sustainability software, which may not be entirely accurate in some cases as it is limited to four environmental categories. Additionally, the material library does not contain bio-type of materials, for example (polylactic acid) PLA.

Future research should include an analysis of other materials, such as biopolymers, and consider different manufacturing methods, such as injection molding. Additionally, further studies on recycling and the end-of-life phase of products should be conducted to develop more sustainable solutions. Another important direction is the analysis of the impact of transport and production location on the product's life cycle.

6. Summary

In the analysis of the environmental impact of ABS, PP-c, PET and PA-6 filaments, covering categories such as carbon footprint, energy consumption, air acidification and water eutrophication, provides important information about their life-cycle environmental impact. The investigation carried out using the CML method allowed the assessment of the impacts at the material, manufacturing and transport stages. The main conclusions of the analysis are presented below:

- In terms of carbon footprint, PA-6 shows the highest contribution to CO_2 emissions (54%) while PP-c has the lowest emissions (9%). In transport, PET generates the most emissions (32%) while PP-c is the greenest (20%).
- With regard to energy consumption, PA-6 stands out as having the highest energy requirement at the material stage (43%) while PP-c has the lowest consumption (14%). PET requires the most energy in the manufacturing process (29%) while PA-6 requires the least (23%).
- In respect of air acidification, PA-6 has the greatest negative impact (43%) while PP-c has the least (11%). In transport, PET generates the greatest impact (32%) and PP-c the least (20%).
- As far as water eutrophication is concerned, PA-6 has the highest impact at the material stage (45%) while PP-c is again the most environmentally friendly (8%). In transport, PET has the highest impact (32%) and PP-c the lowest (20%).

In summary, the presented study with the use SOLIDWORKS Sustainability module shows that PP-c stands out as the most environmentally friendly filament, especially in terms of material and transport factors. However, the presented advantages should be treated with some caution, due the lowest tensile strength (27.6 MPa) of all studied materials. For this reason, it may be a limit of its functional applicability for some cases, from the point of view of the loading conditions of elements and their capacity. Therefore, a more responsible approach to the environmental and sustainability balance in relation to mechanical performance is required. On the other hand, it should be noted that the PA-6 - despite the highest tensile strength equals 90 MPa - has the greatest negative impact on the environment, mainly in terms of CO_2 emissions and air acidification at the material stage, while PET (tensile strength 57.3 MPa) shows the greatest negative environmental impact in the manufacturing process and transport.

Acknowledgements

The publication was financed from the subsidy granted to the Krakow University of Economics - Project nr 055/ZJE/2025/POT.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

STUDENTS' EXPECTATIONS AND THE QUALITY OF EDUCATION AT A HIGHER EDUCATION INSTITUTION – RESEARCH REPORT

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Purpose: The purpose of the conducted research was to find out students' opinions on their expectations in the context of ensuring optimal quality of education at the university.
Design/methodology/approach: The research, using the method of diagnostic survey carried out with the survey technique, was conducted at the Faculty of Management and Command (WZiD) of the War Studies University in Warsaw. The research was conducted in January 2023 among 336 students.
Findings: According to the research obtained, the main measures that the university should take to prepare students for the modern requirements of the labor market are: providing students with professional career counseling, increasing the scope of cooperation with entrepreneurs in the form of internships/internships offered by the university, and developing the offer of the career office, i.e. supporting students in the job search process.
Research limitations/implications: The research on students' expectations in the context of ensuring optimal quality of education at the university, was conducted at one university, which limits the possibility of generalizing the results to the entire population of students in Poland. The research sample was not representative.
Practical implications: Based on the results obtained from the survey, it should be concluded that in order to meet the expectations of students, it is of great importance that universities adapt their educational offerings to the needs of the labor market. The results indicate the need for regular evaluation of educational programs, taking into account the opinions of teaching staff, external stakeholders and students themselves. It is also crucial to develop students' practical skills through cooperative programs with experienced teachers and professionals. Universities should offer opportunities for personal development, access to modern resources and communication tools, and develop internship and work experience programs. Cooperation with industry and flexibility in the approach to learning are important to increase student satisfaction.
Originality/value: The article describes the results of a survey conducted in 2023, thus constituting a new empirical study of student expectations in the context of providing quality education.
Keywords: student expectations, education quality, university.
Category of the paper: Research paper.

1. Introduction

Ensuring at a high level the quality of education in a university is the most important factor determining the success of its graduates. Effective management of educational quality in a university is linked to the need to consider several important aspects. The first under consideration are accreditations from external institutions, whose regular evaluations translate into care in maintaining high standards, both didactically and academically. Another aspect is properly prepared educational programs, which must be constantly monitored and adjusted to both the needs and requirements of the modern labor market and scientific progress. A factor of great importance is also the appropriately selected and prepared, in terms of their competence, teaching staff. University managers should invest in the professional development of university teachers, e.g. through postgraduate studies, training or other initiatives that will increase their competence in new teaching or research methods. Teaching methods that take into account students' learning styles are also noteworthy. Any university wishing to achieve and maintain a competitive advantage should encourage and enable its scientific and teaching staff, as well as students, to conduct research, the results of which could ultimately improve educational programs. Given that the mission of every university is to equip the student with the right competencies to find a rewarding job, it is necessary to establish cooperation with industry in the broadest sense. Such activities help prepare the student for the realities and requirements of the modern labor market. Hence, each university should also maintain high standards of international student exchange programs, which would also enrich students with both educational experience and equip them with additional competencies, such as language. When considering the quality of education, one should also not forget about student support programs. These programs should primarily concern career development, soft skills development or psychological support.

All the above-described activities should be reviewed by students. Their evaluation of the lectures, exercises and general conditions for development and learning at the university, should be taken into account in making changes in its operation. It is indisputable that students' expectations of higher education institutions are high. The diversity of needs can be determined by the chosen field of study, individual variables, socio-cultural conditions, as well as future career plans. Students expect that quality education will enable them to acquire practical skills that they will use in the performance of their professional duties, but also allow for personal development that will contribute to professional success.

2. Ensuring the quality of education at the university

Presenting the results of the research, which focused on the issue of the quality of education at the university, it is necessary to pay attention to how quality in the strict sense is perceived. For there is no doubt that the very concept of quality is difficult to define unambiguously. It is usually understood as everything that has to do with certain characteristics that affect the customer's evaluation of a certain product or service. Thus, it can be seen that it is usually a subjective evaluation, clearly linked to the expectations of a particular customer. In many cases, quality is perceived as the high value of a product or the level of fulfillment of customer expectations. Thus presented, the concept of quality referred mainly to business activities, in which the formal expression is the fulfillment of the requirements contained in the ISO 9001 standard. The mentioned standard is treated as a set of principles (guidelines) that can help the organization to achieve high quality of both the management process and the products proposed to the customer (Mroczko, 2012).

Today, most authors define quality as meeting or exceeding customer requirements. Every organization has a set of certain values on the basis of which its quality is judged, and at the same time the quality of the products it offers. The listed values are usually divided into two groups, which should be as identical as possible (Mroczko, 2012):

- advertised values, i.e., those that show the organization in its message to external customers (recipients of the products offered) and internal customers (members of the organization),
- observed values, i.e., those that the organization realistically adheres to.

When considering the concept of quality, it is also worth touching on another aspect, which is the understanding of the concept of quality in relation to the social responsibility of the organization. Hence, managers should pay attention not only to internal quality (e.g., products, services, service), but also to the four main stakeholder groups, which are: shareholders, customers, societies and employees.

From the perspective of the considerations made, it should be noted that in order to structure the process of evaluating the quality of a service by the customer, criteria are given that play the role of a kind of template, which is used when evaluating a specific service (Stoma, 2012). The determinants of service quality, which are reflected in the evaluation of the quality of education in higher education, include:

- professionalism and qualifications of employees (members of the organization),
- behavior and attitudes of employees in relations with customers,
- flexibility and accessibility to the goods offered by the organization,
- reliability of the service offered,
- reputation and credibility of the organization, viewed through the prism of the opinions of previous customers.

The above considerations indicate that educational quality is also a relatively difficult term to define. It is often understood intuitively, it is also a relative concept by which different groups participating in the educational process understand the term "quality" differently. Therefore, it should be assumed that the quality of education is a multidimensional, heterogeneous concept. At the same time, there is no consensus on how to define it (Popek, Świda, 2011). This can be done in more than a dozen ways, as can be seen in the extensive literature on the subject.

At universities the quality of education is a fundamental factor that determines the effectiveness of the educational process, as well as the preparation of graduates to function in the dynamically changing labor market. At a time of increasing competition between universities and globalization, providing quality education is a strategic priority for academic institutions (Wilson, 2023).

The concept of educational quality in higher education is multidimensional and includes a number of interrelated elements. According to R. Thompson and K. Richardson (Thompson, Richardson, 2022), the quality of education consists of: study programs, academic staff, teaching infrastructure and the educational management system. The above definition is also supplemented by M. Anderson (Anderson, 2023) also turning back the aspects of internationalization and cooperation with the socio-economic environment.

Nowadays, education is considered as a process that is a fundamental element of the university's activity. Its quality is influenced by a whole spectrum of elements, the most important of which include the input level of skills, knowledge and competencies of students entering education and their activity in the educational process. Other factors influencing the quality of the educational process are primarily (Bakonyi, 2012):

- properly prepared study programs,
- active scientific and teaching staff with practical experience,
- developed and implemented comprehensive system of evaluation and control of educational quality,
- modern teaching infrastructure.

Evaluation of educational quality at the university is carried out externally (institutional) and internally (intra-university). In accordance with the current regulations, the following external quality assurance processes are envisaged (eurydice.eacea.ec.europa.eu/pl/, 2024):

- initial institutional assessment: assessment of applications for entry and registration of newly established non-public higher education institutions in the register,
- institutional re-assessment: assessment of applications for renewal and extension of non-public higher education institutions in the register,
- initial program evaluation: evaluation of applications for permission and issuance of permits for the establishment of first and second degree programs and single master's degree programs in all fields of study - in the case of newly established universities and existing public and non-public universities that do not meet the statutory conditions for

autonomous establishment of degree programs; and additionally evaluation of applications / accreditation for the establishment of degree programs in nursing and midwifery,

- periodic program evaluation, including: evaluation of first and second degree programs and single master's degree programs in all fields of study.

All four current processes and the evaluation of the quality of education at the doctoral school combine the supervisory (accreditation) function with the function of improving the quality of education. On the one hand, they are mandatory in nature and culminate in the issuance of a formal decision that conditions the establishment or continuation of non-public universities or the establishment or continuation of a degree program or doctoral school in public and non-public universities. On the other hand, the criteria, the analysis of the material and the reports of the teams conducting the assessment are aimed at improving quality (eurydice.eacea.ec.europa.eu/en/, 2024). Hence, universities implement their own quality assurance systems, which include, among other things, regular evaluations, hospitalizations of classes, student satisfaction surveys, as well as career tracking. S. Peterson (Peterson, 2023) notes that effective internal educational quality assurance systems are characterized by comprehensive and systematic evaluation activities.

External quality assurance is currently the responsibility of the Minister of Science and Higher Education and the Polish Accreditation Commission (PKA), as well as the Minister of Health and the National Accreditation Council for Schools of Nursing and Midwifery (KRASzPiP). Two new processes, comprehensive evaluation and evaluation of the quality of education at doctoral schools, which have not yet been introduced, will be the responsibility of PKA and the Commission for the Evaluation of Science (KEN), respectively.

In the case of internal quality control of education, on the other hand, the regulations stipulate only general rules for study programs, teacher evaluation and periodic evaluation of courses by students. Detailed solutions are regulated in the internal regulations of universities. PKA and KRASzPiP take into account internal quality assurance mechanisms in external evaluations (eurydice.eacea.ec.europa.eu/en/, 2024).

External accreditations and certifications are a very important part of verifying the quality of education in a higher education institution. P. Harrison (Harrison, 2022) points out that external educational quality assurance systems contribute to the standardization of education internationally.

Ensuring quality education in higher education requires a systemic approach, as well as the involvement of all stakeholders in the teaching process. M. Wilson and S. Taylor (Wilson, Taylor, 2023) conclude that investments in the quality of education translate directly into the competitive position of the university and the professional success of its graduates. Therefore, it is necessary for every higher education institution to systematically improve the competence of its academic staff, continuously update its educational programs, invest in modern research

and teaching infrastructure, implement innovative teaching methods, as well as constantly develop international cooperation.

In the context of the above considerations, it is also necessary to define the concept of competencies, which play a key role in shaping the quality of education. According to the general division, competences can be divided into professional competences, which are usually identified with hard competences (knowledge, specific skills related to the profession or work experience), and personal competences, which are usually referred to in the reference books as soft competences. These include self-awareness, motivation, innovation or social skills, i.e. leadership, teamwork, communication or conflict management (Kaczmarek, Kurek, Majewski, 2023).

It should be noted that in higher education, competencies—both hard and soft—may be reflected, for example, in the following ways:

- Teachers with well-developed pedagogical skills are able to effectively convey knowledge and inspire students to actively participate in classes.
- Competencies related to curriculum design enable the development of content that is current, engaging, and relevant to labor market needs.
- Teachers who possess classroom management skills can create an environment conducive to learning and collaboration.
- Competencies in assessment and the provision of constructive feedback are essential for monitoring student progress.
- The development of soft skills—such as effective communication, teamwork, and problem-solving—is just as important as the teaching of theoretical subjects.
- In the face of dynamic technological and social changes, competencies related to educational innovation and the use of modern technologies are becoming indispensable.

In summary, appropriate skills contribute to the effectiveness of educational processes and better alignment with the challenges of the contemporary labor market.

3. Results of empirical studies

3.1. Research methodology

The research, the results of which are presented in this article, was conducted in January 2023 at the Faculty of Management and Command (WZiD) of the Academy of Military Arts in Warsaw. The research was conducted by a team consisting of: A. Kaczmarek, D. Kurek and T. Majewski. The main objective of the conducted research was to find out the opinions of students regarding expectations in the context of quality assurance of education at the

university. The main research problem was formulated in the form of the question: *What factors determine the quality assurance of education at the University?*

Solving the main research problem formulated in this way required solving several specific problems, defined in the form of the questions presented below:

1. *What measures should the University take to prepare students to meet the demands of the labor market?*
2. *What is the level of students' satisfaction with studying?*
3. *Does the level of satisfaction with studying vary by gender and major?*
4. *Is there a correlation between the level of satisfaction and the year of study?*
5. *Is there a correlation between the level of satisfaction and the type of study?*
6. *Would students choose the same field of study at ASzWoj again?*
7. *Is there a correlation between re-choosing a major and the age of the students?*
8. *How do students of the Faculty of Management and Command evaluate the teaching offer and the potential of the University?*
9. *Does remote learning have an impact on the formation of students' competencies?*
10. *What is the attitude of students towards remote learning?*

For the purposes of the research conducted, the main hypothesis was formulated as follows: Ensuring the quality of education at a higher education institution is a very complex process in which many factors must interact. Hence, it is extremely important to invest in the development of staff or infrastructure, as well as to create educational programs that take into account the needs of the modern labor market. This will increase the university's chances of success, as well as prepare students for future challenges.

Due to the diagnostic nature of specific problems 1, 2, 6, 8, 9, 10, specific hypotheses were not formulated. Hypotheses were formulated for problems No. 3, 4, 5 and 7 as follows:

H3. The overall level of satisfaction with studying is different between men and women and those studying management and command, logistics and aviation.

H4. There is a relationship of at least weak strength between the level of satisfaction and the increase in the year of study.

H5. There is a relationship of at least weak strength between the level of satisfaction and the type of study.

H7. There is a relationship of at least weak strength between re-choosing a field of study and the age of students.

Students' expectations were taken as the independent variable, while the dependent variable was the quality of education at the university.

3.2. Sample structure

Diagnosing opportunities for the development of soft competences, in order to adjust educational programs to the needs of the labor market, should be carried out in each university, regardless of its nature or the courses offered. The research analyzed the competences of

students of the Faculty of Management and Command at the War Studies University, which was due to the place of work of the authors of the article, as well as was related to the first stage of the research carried out, during which the research tool – a survey questionnaire – was analyzed in detail, which, after validation, will be used in subsequent stages of the research. The authors of the article would like to carry out the research of students' competences periodically, which will allow to reveal the impact of changes in educational programs on students' competences.

The structure of the research sample is shown in Table 1. The research sample was characterized by six basic criteria, such as gender, age, level and type of study, field and year of study, and place of residence.

Table 1.
Sample structure

Criterion	Responses	N	%
Gender of the respondents	Female	139	41.37
	Male:	197	58.63
Age of respondents	Up to 22 years old	206	61.31
	23-25 years	89	26.49
	More than 25 years	41	12.20
Level and type of study	Full-time undergraduate studies	177	52.68
	Full-time graduate studies	40	11.90
	Part-time bachelor's degree program	73	21.73
	Part-time graduate studies	46	13.69
Field of study*	Command and Management	123	36.72
	Logistics	153	45.67
	Aviation	59	17.61
Year of study*	I	159	47.46
	II	120	35.82
	III	56	16.72
Place of residence	village	73	21.73
	city with up to 19 999 inhabitants	29	8.63
	city with 20,000 to 99 999 inhabitants	79	23.51
	city with 100,000 to 499 999 inhabitants	17	5.06
	city with 100,000 to 499 999 inhabitants	138	41.07

*For field of study and year of study, 335, and not 336 students, responded to the survey.

Source: Own research results.

A total of 336 students were surveyed, so 59.79% of the total number of students studying at the Faculty of Management and Command participated in the survey. This included 41.37% of women and 58.63% of men. The survey included undergraduate students, with a total of 250, and graduate students, with a total of 86. The survey questionnaire was completed by 159 first-year students, 120 second-year students and 56 third-year students. The largest group was made up of students from the field of logistics (45.67%). The remaining students studied management and command – 36.72% and aviation – 17.61%. Most of the students surveyed were residents of cities with a population of 20 000 to 99 999 (23.51%) and cities with a population of more than 500 000 (41.07%).

3.3. Results and conclusions of the study

The first question that was analyzed was the students' expectations regarding the measures that the university should take to prepare students to meet the demands of the labor market. The results are presented in Table 2.

Table 2.
Actions, which the university should undertake in order to prepare students to meet the requirements of the labor market

Responses	%
provide students with professional career counseling	64.07
increase the scope of cooperation with entrepreneurs in the form of training/internships offered by the university	56.29
develop the offer of the career office - support for students in the process of looking for a job	45.51
pay more attention to the formation of language competencies	41.14
pay more attention to the formation of soft competencies	30.84
pay more attention to the formation of hard competencies of students	30.84
increase the employment of practitioners as lecturers	27.84
pay more attention to digital competencies	26.65
increase the number of hours of practical classes	21.56
increase the competence of the university teaching staff	18.86
increase the number of hours of compulsory trainings/internships	7.78
other	2.40

Source: results of own research.

Analyzing the answers given by students, we can see, that the most important aspects for them are those that will enable them to find an interesting and rewarding job in the future. Students indicated the importance of providing professional career counseling (64.07% of indications), increasing the scope of cooperation with entrepreneurs in the form of trainings/internships offered by the university (56.29% of indications), and developing the offer of the career office, i.e. supporting students in the job search process (45.51% of responses). Therefore, it is worth organizing meetings that would allow students to establish contact with representatives of companies, which at the Faculty is provided in the form of organizing job fairs or Practical Management Workshops. Other measures that students believe should be taken at the university are the acquisition of language skills (41.14%) and the formation of competencies, both soft (30.84%) and hard competencies (30.84%). Students also indicated that there should be more hiring of practitioners as lecturers (27.84%), more attention to digital competencies (26.65%), and more hours of practical classes (21.56%).

All of the above-mentioned expectations of students affect their perception of the university. A university that can meet these expectations can gain a competitive advantage, as well as build a positive image, which is an extremely important aspect for future student recruitment.

Taking the above into account, therefore, the level of student satisfaction with studying at the university was checked. The results obtained are included in Table 3.

Table 3.
Level of student satisfaction with studying

Responses	%
Definitely high	7.19
Rather high	41.02
At medium level	39.52
Rather low	8.08
Definitely low	4.19

Source: results of own research.

Definitely and rather high level of satisfaction with studying was indicated by almost 48% of respondents. A medium level was indicated by 39.82% of respondents, while dissatisfaction was indicated by 12.27% of students.

In order to identify potential differences in the level of satisfaction between the surveyed groups, distinguished by gender and field of study, the U-Mann-Whitney and Kruskall-Wallis tests were used. During the conducted research in terms of satisfaction among men and women, the differentiation of satisfaction levels was not confirmed (p-value>0.05). Differences in satisfaction were identified by considering the opinions of students of each field of study, as illustrated in Table 4.

Table 4.
Kruskkalla-Wallis test results - satisfaction vs. field of study

	Management and command (n = 122)	**Logistics (n = 153)**	**Aviation (n = 58)**		
	average rank	average rank	average rank	*H*	*p*
Satisfaction with studying	152.95	166.68	199.71	10.74	**0.0046**

n - number of observations; *H* - result of Kruskall-Wallis test; *p* – significance.

Source: results of own research.

There is a difference in the level of satisfaction with studying between two groups of students - those studying management and command and aviation. The study shows that higher levels of satisfaction with studying are manifested by students majoring in aviation (64.41% indicated levels 4 and 5), while lower levels are manifested by students majoring in management and command (40.98% indicated levels 4 and 5).

It was also indicated (weak strength of relationship) that the level of satisfaction decreases as the year of study at the university increases (Spearman's Rho -.17, p = 0.001).

In turn, using Cramer's V coefficient, the relationship between the level of study and the type of study was identified (weak strength of relationship V Cramer 0.17, p = 0.004). Indeed, it turned out that a higher level of satisfaction was manifested by full-time BA students.

From the point of view of the research conducted, it was also important to check whether WZID students would choose their current field of study again. The collected responses are included in Table 5.

Table 5.
Re-choosing the same field of study

Responses	%
Definitely yes	22.75
Rather yes	40.72
Difficult to say	21.86
Rather no	8.38
Definitely no	6.29

Source: results of own research.

The analysis of the obtained results allows us to conclude that the vast majority of WZID students - 64%, would again choose the field of study in which they are currently studying. For 22% of respondents it was difficult to answer this question, while 15% of respondents would not choose their major again.

Therefore, it was checked whether there was a correlation between the re-choice of the field of study and the age of the students. It turned out that younger students were more likely to declare a re-choice of their current major (Cramer's V 0.16, p = 0.02).

A correlation was also detected between the year of study and re-choice of the field of study - re-choice was declared more often by first-year students (V Cramer 0.15, p = 0.04), which confirms the correctness of the calculation of the correlation indicated in the previous paragraph.

The quality of education at a university is a key aspect that affects the reputation of the institution, as well as the future of students - the possibility of finding an interesting and rewarding job. Hence, from the point of view of the research conducted, it was extremely important to find out the opinion of students regarding the evaluation of the teaching offer and potential of the University. The results are presented in Table 6.

Table 6.
Assessment of the teaching offer and potential of the University

Responses	Definitely no	Rather no	I have no opinion	Rather yes	Definitely yes
Students have access to valuable library resources and reading rooms	2.68%	3.28%	23.28%	42.68%	28%
The University has an extensive teaching infrastructure (lecture halls, high-quality laboratories)	8.05%	18%	32.53%	30.14%	11.34%
Teaching staff is easily accessible (by email, on-call, etc.).	2.99%	11.67%	25.44%	45.80%	14.07%
Teachers support students in the development of talents	9.58%	26.43%	36.82%	20.65%	6.58%
Students have the opportunity to participate in foreign exchange programs, internships, internships	1.20%	4.20%	29.12%	41.44%	24.02%
Students have access to high quality computer equipment	21.55%	24.25%	26.04%	24.25%	3.89%
The level of teaching at the University is high	4.20%	15.91%	34.23%	37.83%	7.80%
The University has a high level of requirements for exams/assessments	0.89%	7.46%	20.29%	46.26%	25.07%

Cont. table 6.

Exams are conducted reliably	2.38%	4.76%	22.02%	48.80%	22.02%
Teachers are always reliably prepared for classes	1.49%	7.16%	14.32%	48.35%	28.65%
The quality of teaching materials recommended/provided by lecturers is very high	2.39%	8.08%	25.14%	46.40%	17.96%
As part of the course, students learn practical problem solving	8.03%	27.08%	31.25%	23.80%	9.82%
The study program is adapted to the needs of the labor market	8.63%	21.42%	40.47%	24.40%	5.05%
The career office cooperates with many employers offering a wide range of internships and placements	8.35%	16.11%	60.29%	11.34%	3.88%
As part of the course of study, students have the opportunity to learn software programs computer programs necessary to work in the profession	15.61%	23.42%	27.32%	27.02%	6.60%
The university offers assistance in career planning and entering the labor market	11.64%	25.07%	45.07%	13.13%	5.07%
The university has good sports infrastructure	6.56%	13.43%	32.23%	36.71%	11.04%
Students have a real impact on didactics and university management through members of the student government	9.85%	21.19%	40.59%	21.49%	6.86%
The quality of internships offered by the career office is high (one can gain interesting and useful experience)	7.25%	10.57%	67.97%	10.57%	3.62%
Participation in student internships increases the possibility of students to find an attractive job	4.50%	10.21%	36.93%	35.43%	12.91%
Students have ample opportunities to choose thesis supervisors	10.21%	8.70%	36.33%	33.53%	11.11%
The University is fully prepared to provide online classes	5.07%	14.02%	15.82%	40.89%	24.17%
Students are free to choose faculties	11.78%	12.99%	26.58%	32.93%	15.70%
At the University, during foreign language classes, students learn industry vocabulary necessary for professional work	9%	13.81%	33.63%	29.42%	14.11

Source: results of own research.

In order to better illustrate the results obtained, all the factors listed in the table were divided into four categories, which included: infrastructure and resources, teaching staff, as well as educational methods, curriculum and student support. According to the author, there are key areas, the provision of which, as well as their continuous development, contributes to increasing the quality of education and the competitiveness of graduates in the labor market.

The first category mentioned is the **infrastructure and resources** owned by the university. In a university, investments in infrastructure, such as modern lecture halls, laboratories or access to various databases, as well as scientific literature, are essential for effective education. Students rated very highly the access to valuable library resources and the reading room operating at the university (71% of indications). The quality of teaching infrastructure, such as lecture halls, laboratories, was rated slightly lower (42% of positive indications). Students were divided in their opinions regarding the assessment of the availability of high-quality computer equipment - answers definitely no and rather no were given by almost half of the respondents

(46%), while answers definitely yes and rather yes were selected by 28% of students. The rest did not express an opinion in this regard, choosing the answer I have no opinion. Another important factor from the point of view of the research conducted, was the students' assessment of whether the university has good sports infrastructure. Almost 48% of students gave a positive assessment of this factor. The university should also provide access to technologies that support learning, so students were asked for their opinion on whether the university is fully prepared to teach online - almost 64% of students gave a positive opinion on this aspect. Nowadays, the use of online teaching tools plays an increasingly important role in modern education because it improves communication between the teacher and the student, improves the teaching and learning process, thereby determining the achievement of learning objectives.

Further, WZID students expressed their opinion on the **teaching staff** employed at the university, as well as **teaching methods**. Academic teachers not only impart knowledge to students, but also play an important role in terms of inspiring students to learn independently, as well as to think critically, the use of various teaching methods by teachers, such as case studies, learning by doing or interactive lectures, can significantly increase student involvement, as well as enhance their analytical skills. It is also worthwhile to introduce various elements of project work that help develop practical skills, as well as stimulate creativity. The results from the survey indicate that the students very highly rated the reliability of the lecturers' preparation (77% of indications) and the quality of the teaching materials recommended/provided by the lecturers (64% of indications). Only 27% of surveyed students believe that teachers support students in the development of talents, and 37% of respondents had no opinion in this aspect. In the context of the research conducted, it is also worth noting the availability of teachers, both in and out of class. Therefore, respondents were asked to assess whether teaching staff are easily accessible (by email, on-call, etc.) - 60% of students positively assessed this aspect. The last factor that students were asked about was the ability to choose thesis supervisors. 45% of students positively assessed this aspect. Choosing a supervisor who will adequately guide students as they conduct their research, as part of their thesis development, is extremely important. 36% of students were unable to assess this aspect - however, these were mainly students who were in their first year of undergraduate studies.

The next category assessed by WZID students, which has its own not inconsiderable impact on the quality of education at the university, is the **curriculum**. It should be emphasized that curricula should be flexible and adapted to the changing requirements of the modern labor market, as well as technological advances. The factor regarding the high level of teaching at the university was positively assessed by 46% of students. The answer I have no opinion was given by as many as 34% of all respondents. Aspects that were rated very highly by students were the high level of requirements for exams/assessments (71% of indications), the reliability of the exams conducted (71% of indications), the freedom to choose faculties (49% of responses) and the teaching during foreign language classes of industry vocabulary necessary for professional

work (44% of indications). The least positive evaluations of students were recorded in the areas of opportunities to learn computer programs necessary for professional work (34%), learning practical problem-solving in class (34%), matching the curriculum to the needs of the labor market (29%), and the reality of student influence on didactics and university management through members of the student government (28%). It should also be noted that when evaluating these aspects, 30-40% of respondents did not know how to evaluate these factors, choosing to select the answer I have no opinion. Nevertheless, new subjects should be introduced to reflect current trends, as well as to increase the attractiveness of majors. It is also important to take into account soft skills, such as communication, teamwork and resistance to stress.

The final category assessed was student support. Nowadays, more and more attention should be paid to taking care of students' well-being by introducing various programs for professional support, personal development or psychological support. These programs can significantly affect student satisfaction and comfort. Among the aspects students rated best were the opportunity to participate in foreign exchange programs, internships, apprenticeships (65% of indications) and participation in student internships that increase the possibility of finding an attractive job (48%). Other aspects students were not able to assess, due to lack of knowledge in this area because the students surveyed did not use the programs available at the university. The difficulty of assessment was related to the following variables: the career office cooperates with many employers offering a wide range of internships and placements; the university offers assistance in career planning and entry into the labor market, the quality of internships offered by the Career Office is high (one can gain interesting and useful experience).

In the context of the research conducted, another important aspect was to find out students' opinions on the impact of remote learning on the formation of competencies. The results are presented in Table 7.

Table 7.
Influence of remote teaching on the formation of students' competencies

Responses	%
Yes, it influenced definitely positively	24.48
Yes, it influenced rather positively	38.21
Yes, it influenced rather negatively	14.33
Yes, it influenced definitely negatively	3.88
Difficult to say	14.33
It did not	4.77

Source: results of own research.

The analysis of the results from the conducted surveys shows that for 63% of WZID students, remote teaching has a positive influence on their competence development. No variation in students' responses (statistically significant correlations) was revealed in terms of socio-demographic variables.

Some of the competencies that can be shaped through remote learning include: creativity in teaching (innovation in creating educational materials), development of technological skills (use of e-learning platforms or communication and collaboration tools and applications), self-directed learning, networking (students can connect with other students from all over the world) or development of digital competencies.

Taking the above into account, during the research attention was also paid to the attitude of students towards remote learning. The results obtained are shown in Table 8.

Table 8.
Students' attitudes towards remote learning

Responses	%
All classes should be conducted remotely	20.60
All lectures should be conducted remotely	56.72
Only subjects that develop soft competencies should be conducted remotely	12.54
Remote learning allows the development of competencies at the same level as on-site learning	21.19
Remote learning does not allow for the development of competencies at the same level as on-site learning	18.51
The implementation of classes in a remote mode allows for the development of skills in the organization of own work	31.34
The implementation of classes in a remote mode allows for the development of skills necessary for teamwork	9.55

Source: results of own research.

According to nearly 57% of WZID students, all lectures should be implemented in a remote mode. According to students, the implementation of remote learning allows the development of skills in the field of organization of own work - 31% of indications. 21% of students pointed out that remote learning allows the development of competencies at the same level as on-site learning. However, a similar percentage of students (18%) believe that remote learning does not allow the development of competencies at the same level as on-site learning. Thus, it can be concluded that remote learning has great potential for the development of students' competencies, but the implementation of this solution requires constant adaptation or innovative actions on the part of both universities and teachers. The introduction of hybrid activities - combining stationary and remote learning, is a good solution for students with different expectations. This is because there is a possibility of choosing the hours of classes or recording lectures by teaching staff, so that students can listen to them at a time convenient for them.

Although remote learning has recently gained prominence, the results of conducted research (See: Pituła, Grzyb, 2021, pp. 88-116; Franczyk, Rajchel, 2024; ksztalceniezdalne.psrp.org.pl, 2024) indicate that the effectiveness of remote learning depends on a number of factors to which universities should pay special attention, which include, for example, the quality of educational programs, adaptation of infrastructure, availability of resources or, finally, the ability of students to learn independently.

Research conclusions

As a result of the conducted research, the most important key aspects affecting the quality of education in the opinion of students were identified. This article formulates the main research problem in the form of a question: What factors determine the provision of quality education at the University? Providing answers to the main research problem was preceded by providing answers to specific problems.

The main activities that the university should undertake in order to prepare students for the modern requirements of the labor market are: providing students with professional career counseling (64.07% of indications), increasing the scope of cooperation with entrepreneurs in the form of internships/internships offered by the university (56.29% of indications), and developing the offer of the career office, i.e. supporting students in the job search process.

WZID students mostly (48%) feel a high level of satisfaction with their studies. The survey shows that higher levels of satisfaction with studying are manifested by aviation students (64.41% indicated levels 4 and 5), while lower levels are manifested by management and command students (40.98% indicated levels 4 and 5). Higher levels of satisfaction were manifested by full-time undergraduate students. What's more, the vast majority of WZID students - 64%, would again choose the major they are currently studying.

From the point of view of the research conducted, it was extremely important to find out the opinion of students regarding the evaluation of the University's teaching offer and potential. The factors that students evaluated were divided into four categories, which included infrastructure and resources, teaching staff as well as educational methods, curriculum and student support. From the point of view of the infrastructure and resources available at the university, students rated very highly the access to valuable library resources and reading room operating at the university (71% of indications). The university has extensive, high-quality teaching infrastructure, such as lecture halls, laboratories (42% of positive indications). Students also felt that the university is fully prepared for online classes - almost 64% of students expressed a positive opinion in this aspect.

Further on, WZID students expressed an opinion about the teaching staff employed at the university, as well as teaching methods. The results of the survey indicate that students rated very highly two extremely important aspects - the reliable preparation of instructors for classes (77% of indications) and the quality of teaching materials recommended/provided by lecturers (64% of indications).

The next category that WZID students rated was the curriculum. The factor regarding the high level of teaching at the university was positively assessed by 46% of students. Students noted that the university has a high level of requirements for exams/assessments (71% of indications), exams are conducted reliably (71% of indications), and students are free to choose faculties (49% of responses).

The last criterion was student support. Among the aspects best rated by students were, first of all, the opportunity to participate in foreign exchange programs, internships, apprenticeships (65% of indications) and participation in student internships increasing the possibility of finding an attractive job (48%).

In the context of the research conducted, another important aspect was to find out students' opinions on the impact of remote teaching on the formation of students' competencies. For 63% of WZID students, remote teaching has a positive impact on the development of student competencies. Some of the competencies that can be shaped through remote learning include: creativity in learning, development of technological skills, independent learning, development of digital competencies, among others.

In the context of the ongoing discussion, it is also worthwhile to provide a brief overview of research conducted at other academic institutions in Poland and abroad. Studies carried out at institutions such as the Vistula University of Finance and Business, WSB Merito University, and the University of Technology and Economics (UTH) indicate that students prefer programs tailored to labor market needs, offering individualized, innovative, and practical learning paths. Therefore, it is essential for universities to integrate student expectations into decision-making processes, which will enhance the competitiveness and attractiveness of their educational offerings. These findings highlight the need for a dynamic approach to curriculum design that responds to the evolving expectations of students and the demands of the labor market (Kocot, Kwasek, 2024).

Meanwhile, research conducted in the context of higher education in Turkey suggests, among other things, that quality assurance systems should incorporate advanced technologies such as AI and big data analytics; strengthen partnerships with industry to better align curricula with labor market needs; pursue international accreditations and develop global partnerships; adopt evaluation frameworks that reflect the unique characteristics of new-generation universities; and actively involve students, faculty, and external stakeholders in quality assurance processes (Nurgül Durmuş Şenyapar, 2024).

In summary, the research findings point to several important trends that may influence the quality of education in the coming years, including:

- the growing importance of the practical dimension of education,
- the need for greater flexibility in study programs,
- the necessity of integrating technology into the teaching process,
- the increasing relevance of intercultural competencies,
- the expectation of personalized educational pathways.

These trends reflect the dynamic development of higher education aimed at enhancing educational quality and better preparing students for the challenges of the modern labor market.

4. Summary

Meeting the expectations of students in the context of ensuring the quality of education requires the university's commitment in the form of continuous monitoring and, above all, adapting the educational offer to the needs of the labor market. Hence, universities should rely on regular evaluations of educational programs, both using the opinions of teaching staff, external stakeholders and students. Another important factor shaping quality education in universities is that students can develop practical skills. That's why it's very important to introduce various programs through which experienced academics or professionals from various industries will support students in better understanding the labor market, for example. Universities should also focus on opportunities for students' personal development, such as through various courses or workshops, in the course of which young people could develop their talents, passions or interests. To this end, it is also worth ensuring that students have access to modern resources such as laboratories, libraries or e-learning platforms. Universities, in order to ensure high quality education, should use modern communication tools, such as mobile applications, thanks to which students would have easy access to information. One should not forget to constantly develop internship or work experience programs, which would help young people to get in touch with people from a particular industry and, as a result, to gain experience.

Attention to ensuring the quality of education, cooperation with industry, as well as flexibility in the approach to learning are key elements that significantly affect the fulfillment of students' expectations and increase their satisfaction with studying.

Acknowledgment

The article was financed from the research task "Psychological aspects of management in the context of ensuring business continuity in modern organizations" of scientific activity specified in the "Financial plan of ASzWoj scientific activity for 2024", code II.2.7.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

THE IMPACT OF SHIFT WORK ON THE HEALTH AND WELL-BEING OF EMPLOYEES IN SELECTED MANUFACTURING COMPANIES IN POLAND

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Purpose: The aim of this article is to analyse the impact of shift work on the health and well-being of employees in manufacturing enterprises, with particular consideration given to occupational health and safety (hereafter referred to as "OHS"). OHS issues represent an important component of the action plan for implementing the European Pillar of Social Rights.
Design/methodology/approach: The empirical part of the study employed a diagnostic survey method based on a proprietary questionnaire distributed to a group of 170 individuals working in a shift system. The research tool included questions concerning, among other things, the occurrence of symptoms and consequences of shift work, as well as employees' subjective evaluation of their working conditions.
Findings: The findings indicate that shift work significantly contributes to the deterioration of both physical and mental health, leading to a general decline in employee well-being. Particularly concerning are reports of chronic fatigue, sleep disturbances, and reduced concentration, all of which may substantially increase the risk of workplace accidents.
Research limitations/implications: The study was conducted on a limited sample of 170 employees from manufacturing enterprises, which restricts the generalisation of the findings to other sectors of the economy. The use of a self-report questionnaire may also involve a degree of subjectivity. Future research could include larger and more diverse groups of employees and adopt longitudinal approaches to provide a broader perspective on the long-term effects of shift work.
Practical implications: Based on the analysis, a series of recommendations were formulated for both employers and employees to help mitigate the negative effects of shift work. The proposed measures include, among others, the implementation of preventive programs,

educational initiatives, and organisational solutions aimed at promoting health and improving working conditions.
Social implications: The results draw attention to the wider social consequences of shift work, particularly its impact on employees' quality of life and family relations. They also highlight the importance of integrating occupational health and safety considerations into broader health promotion and labour policies in order to reduce the negative outcomes of non-standard working hours.
Originality/value: This article contributes to the body of knowledge on the effects of shift work on the health and well-being of employees in the manufacturing sector. It also outlines potential directions for intervention in the areas of OHS, health promotion policies, and work organisation.
Keywords: shiftwork, well-being, health, OHS.
Category of the paper: Research paper.

1. Introduction

Regulations concerning shift work in the Polish legal framework are included in the Labour Code, which constitutes the primary normative act governing issues such as conditions of employment, work schedules and systems, remuneration principles, occupational health and safety (OHS), as well as the mutual rights and obligations of employees and employers. The Labour Code defines shift work as the performance of duties according to a work schedule that involves a change in working hours for individual employees after a specified number of hours, days, or weeks (Act of 26 June 1974 – Labour Code. Journal of Laws). Issues related to shift work are also regulated by European Union legislation (Directive 2003/88/EC of the European Parliament and of the Council of 4 November 2003 on certain aspects of the organization of working time).

The introduction of shift work systems in manufacturing enterprises is primarily driven by economic considerations, such as the need to ensure continuity of technological processes, maximise the use of production resources, and enhance operational efficiency. However, this form of work organisation affects the human body in complex ways, triggering a range of physiological and psychological changes. The literature describes numerous disruptions to the human biological rhythms caused by working irregular or atypical hours (Caruso, 2014; Kuleta, 2016; Boersma, 2023), the impact of shift work on the prevalence of health problems among employees (Costa, 2000), and its influence on the risk of cardiovascular diseases (Bitner, 2013; Salska, 2015), and gastrointestinal disorders (Stranks, 2005; Łokieć, 2020). Night work, in particular, is associated with an increased risk of cardiovascular incidents, with estimates suggesting a rise of up to 3.1% (Wei et al., 2022).

Additionally, employees engaged in shift work tend to exhibit more frequent health-risk behaviors, such as excessive alcohol consumption and increased tobacco use (Ogeil, 2021). Recently, there has also been a noticeable trend of increased use of psychoactive substances among this group (https://poradniauzaleznienia.pl/, 20.06.2025).

The literature highlights that shift work is often accompanied by heightened fatigue and both acute and chronic stress (Łuczak, 2002), leading to decreased mental and psychophysical performance. Working night shifts especially contributes to reduced sleep quality and duration, resulting in exhaustion, mood disorders, and chronic fatigue (Matheson, 2014). Studies have shown that permanent night shifts significantly increase the risk of excessive sleepiness, which in turn directly correlates with higher accident rates (Ohayon et al., 2010). Shift work may also contribute to psychosomatic disorders, elevated stress levels, and impaired cognitive function, all of which reflect the negative effects of sleep deprivation (Vogel et al., 2012, Kecklund et al., 2016). More-over, a significant link has been established between shift work and the occurrence of headaches – the risk increases by as much as 44% (Wang, 2014).

The negative impact of shift work on mental health, particularly in terms of increased risk of depressive symptoms and anxiety disorders, has been confirmed in numerous studies (Xu, 2023; Liu, 2023). Analyses by Liu and Jia further indicate that women working in shift systems are significantly more susceptible to depressive symptoms than men (Liu, 2023). Supporting this, Park (2020) examined the relationship between work systems and suicidal ideation, taking into account gender differences. While no statistically significant differences were found among women between day and shift workers, men employed in shift work exhibited a markedly higher risk of suicidal thoughts.

Another important health-related aspect of shift work is its potential association with an increased risk of cancer. A meta-analysis by Wei et al. revealed that shift work is linked to a 2.9% increase in the overall risk of developing breast cancer. Among individuals working shifts for more than 10 years, this risk rose to 8.6% (Wei et al., 2022). Similar findings were observed concerning prostate cancer incidence (Rao et al., 2015). Research by Rao et al. (2015) indicates that night work over a period of at least five years is associated with a 2.8% increase in prostate cancer risk. These findings suggest that long-term disruption of circadian rhythms may have serious oncological consequences.

The main objective of the study conducted for this article was to identify the impact of shift work on employees' physical and mental health, as well as their overall well-being. To support this main aim, specific objectives were formulated, including:

1. Identification of the most common health-related symptoms among shift workers and their subjective assessment by respondents.
2. Recognition of consumption preferences regarding the use of psychoactive substances and stimulants among shift workers.
3. Evaluation and comparison of employees' well-being levels, taking into account both the positive and negative effects of working in a shift system.

Employee well-being can be understood in both positive and negative terms (Danna, Griffin, 1999; Warr, 1999; Bautista, Khan, 2023). Although there is no single, universally accepted definition of well-being, it is often described in the literature as a combination of health, happiness, and mental and physical wellness. It is also defined as "the presence of positive emotions and mood, absence of negative emotions, life satisfaction, fulfilment, and positive functioning" (Karademas, 2007; Bautista, Khan, 2023).

Negative well-being can be defined as deficits in these areas – not merely momentary emotions, but persistent disturbances in psychological functioning that affect day-to-day experiences, life satisfaction, and the ability to cope with stress and challenges (Scannell et al., 2002; Karademas, 2007; Karaś, 2019).

2. Methods

As part of the conducted research on the impact of shift work on the health and well-being of employees in the context of occupational health and safety (OHS) within manufacturing enterprises, three research questions were formulated:

1. How does shift work affect the physical and mental health of employees in manufacturing companies in Poland?
2. How does shift work influence the preferences of manufacturing employees regarding the use of various stimulants and psychoactive substances?
3. What actions and recommendations can help minimise the negative effects of shift work from an OHS perspective?

A quantitative research method was applied using an original, anonymous questionnaire survey. The above research questions formed the basis for structuring the questionnaire. The survey consisted of 13 questions, including 11 mandatory closed-ended questions (single- and multiple-choice) and 2 optional open-ended questions. The closed section included questions regarding the type of shift work performed, demographic variables (gender, age, education level), job position, length of service, as well as the occurrence of symptoms such as sleep disturbances, use of psychoactive substances and stimulants, and subjectively perceived effects of shift work.

Question 11 used a five-point Likert scale to assess the degree of agreement or disagreement with the presented statements. The open-ended questions (12 and 13) addressed, respectively, the positive and negative effects of shift work, and were non-mandatory. The research was conducted between 9 March and 17 March 2024 in two formats: paper-based and electronic (via an online form). Participation in the study was entirely anonymous and voluntary (Appendix).

The sampling method was purposive; the survey was addressed exclusively to employees of manufacturing companies who perform shift work. The data analysis involved several stages: preliminary data cleaning (excluding responses from individuals not employed in shift work), the development of descriptive statistics using Microsoft Excel tools (percentage distributions and graphical visualisation through charts), and the formulation of recommendations based on the obtained results.

3. Results

The research sample comprised a total of 173 respondents, of whom 3 declared that they were not employed in a shift work system and were therefore excluded from further analysis. As a result, 170 fully completed questionnaires submitted by employees working in shift-based systems were qualified for detailed analysis. The study included 117 women (69%) and 53 men (31%) from various age groups, job positions, lengths of service at their current workplace, and levels of education. The vast majority of surveyed employees (149 individuals, 88%) were under the age of 44. A total of 142 respondents (84%) held either secondary or higher education qualifications.

The questionnaire was conducted primarily in large manufacturing enterprises, which explains the high proportion of respondents working in manual labour positions (130 respondents, 77%). Managerial positions were held by 27 employees (16%), while 9 individuals (5%) worked in administrative or office-based roles. Engineering and technical staff accounted for 2% of the sample (4 respondents). The largest group of respondents had between 3 and 5 years of service at their current workplace (56 individuals, 33%). A total of 12 employees (7%) had worked in the same place for over 10 years.

Among the respondents, 68 individuals (40%) worked in a 12-hour shift system, 56 (33%) in a two-shift system, 30 (18%) in a three-shift system, and 2 (1%) in a four-shift system. An irregular or flexible working time system applied to 14 respondents (8%).

Employees working in shift-based systems frequently reported disruptions in their daily functioning, both physically and mentally. Figure 1 presents the most commonly reported negative consequences of shift work. The most frequently cited effects included: sleep disturbances, poor eating habits, general malaise, nervousness, and irritability. Less frequently reported consequences included: depression, anxiety, mood swings, reduced sex drive, lowered self-esteem, digestive issues, increased blood pressure (hypertension), and the use of stimulants or substances.

As many as 133 respondents (78.24%) reported experiencing sleep problems, either frequently or occasionally, after night shifts. Only 37 individuals (21.76%) did not experience this issue. Tied for second place in terms of frequency were eating disorders and poor well-being, each reported by 71.76% of respondents. Slightly fewer, 70% of employees, re-ported

nervousness, and 64.12% reported irritability. Approximately half of the respondents struggled with problems such as headaches, abdominal pain, muscle pain, concentration difficulties, weakness and reduced immunity, and increased susceptibility to stress, which were reported by 56.47%, 53.53%, 52.94%, and 51.76% of respondents, respectively. Changes in mental behaviour were noticed by 27.65% of respondents, decreased sexual drive by 27.06%, lowered self-esteem by 25.88%, and digestive problems (nausea, vomiting, and diarrhoea) by 20.59%. The least reported issues were substance use and high blood pressure, experienced by 15.88% and 10% of respondents, respectively.

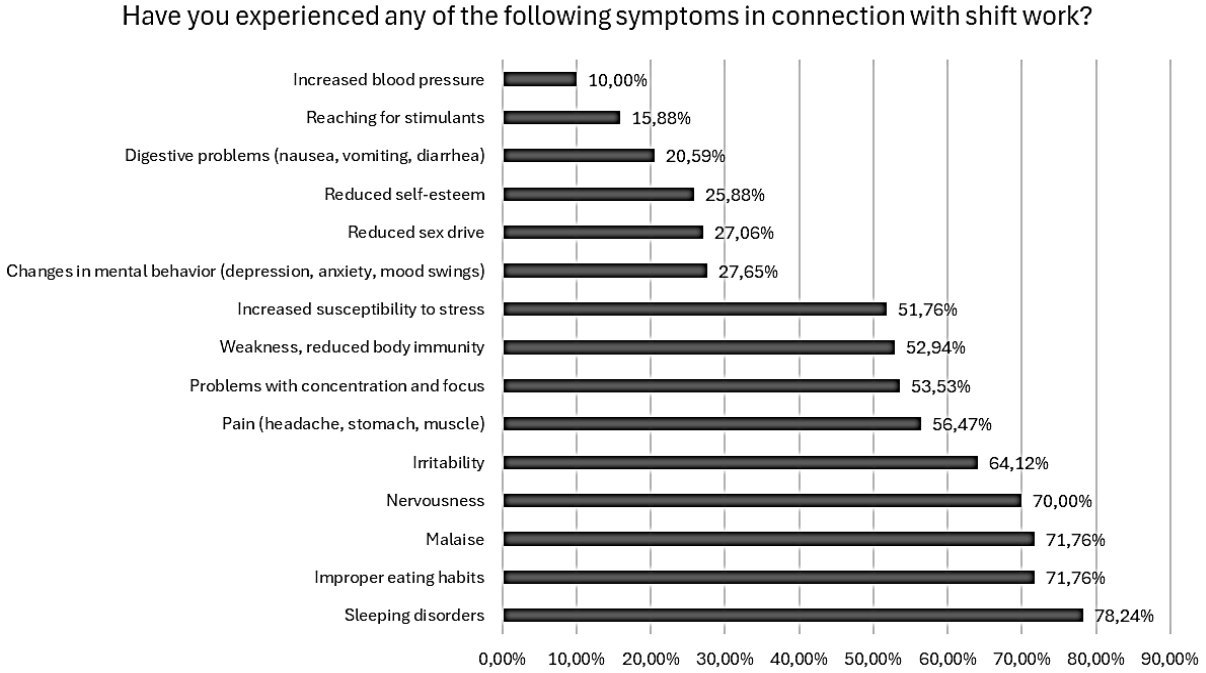

Figure 1. Prevalence of health issues associated with shift work (% of respondents per symptom).

According to the Pareto principle (which helps identify 20% of problems/symptoms responsible for 80% of reports/effects), the top 20% of the 15 health problems/symptoms consist of three main categories accounting for the majority of reports: sleep disorders – 133 mentions, poor eating habits and poor well-being – 122 mentions each. These represent key areas on which preventive or supportive health actions should focus.

Shift work often leads to increased consumption of substances such as cigarettes, alcohol, and psychoactive drugs, as illustrated in Figure 2. Employees most commonly used cigarettes, medication, and alcohol. According to the results, these three main preferences (cigarettes, medication, alcohol) account for over 90% of all mentions. These should therefore be the focus of preventive or educational activities for this study group.

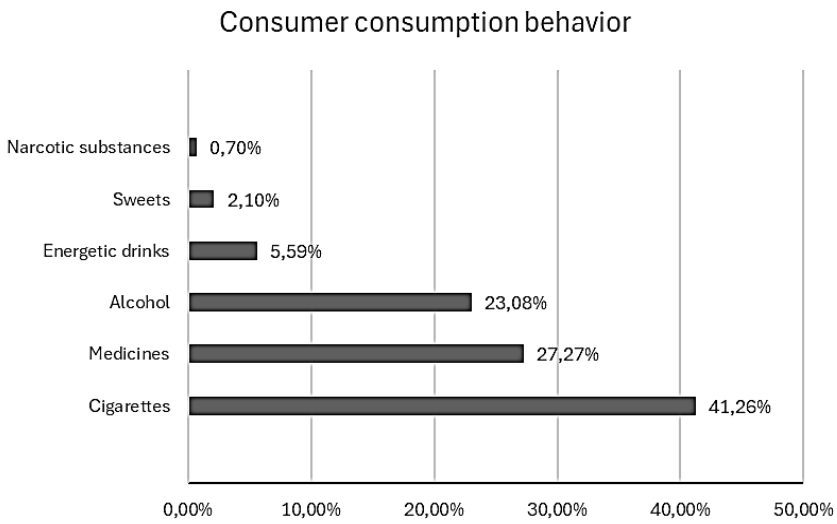

Figure 2. Shift work – respondents' consumption behaviours.

The most frequently chosen substance was cigarettes (41.26% of responses), indicating a strong connection to habits, addictions, or stress (van Amelsvoort, 2006; Costa, 2010). Medications (27.27%) and alcohol (23.08%) also represent significant consumption preferences among respondents and may reflect health issues, stress (Dorrian et al., 2017; Richter et al., 2021), and similar factors. Energy drinks (5.59%) and sweets (2.10%) were less important to the studied group but may indicate a need to obtain energy from sources other than sleep (Jay et al., 2006; Heath et al., 2012; Farinetti et al., 2024). Psychoactive substances were marginally present among respondents, accounting for only 0.70%.

Figures 3 and 4 present respondents' attitudes towards the positive (Figure 3) and negative (Figure 4) aspects of shift work.

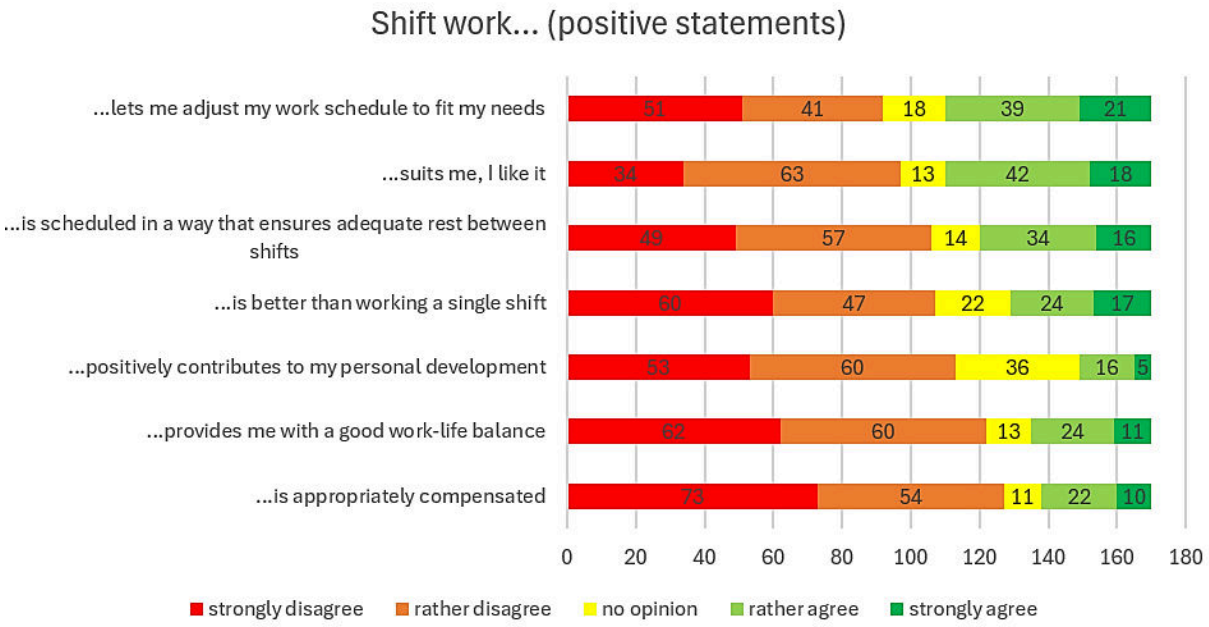

Figure 3. Responders' opinions on shift work (positive statements).

The vast majority of employees (73%) believed that shift work was not adequately compensated. For 72% of respondents, such work did not provide a balance between private and professional life; 66% felt it did not positively influence their personal development, and 62% reported insufficient rest between shifts. At the same time, 35% of respondents declared that they liked shift work. Similarly, 35% had the opportunity to adjust their work schedule to their individual needs (Figure 3).

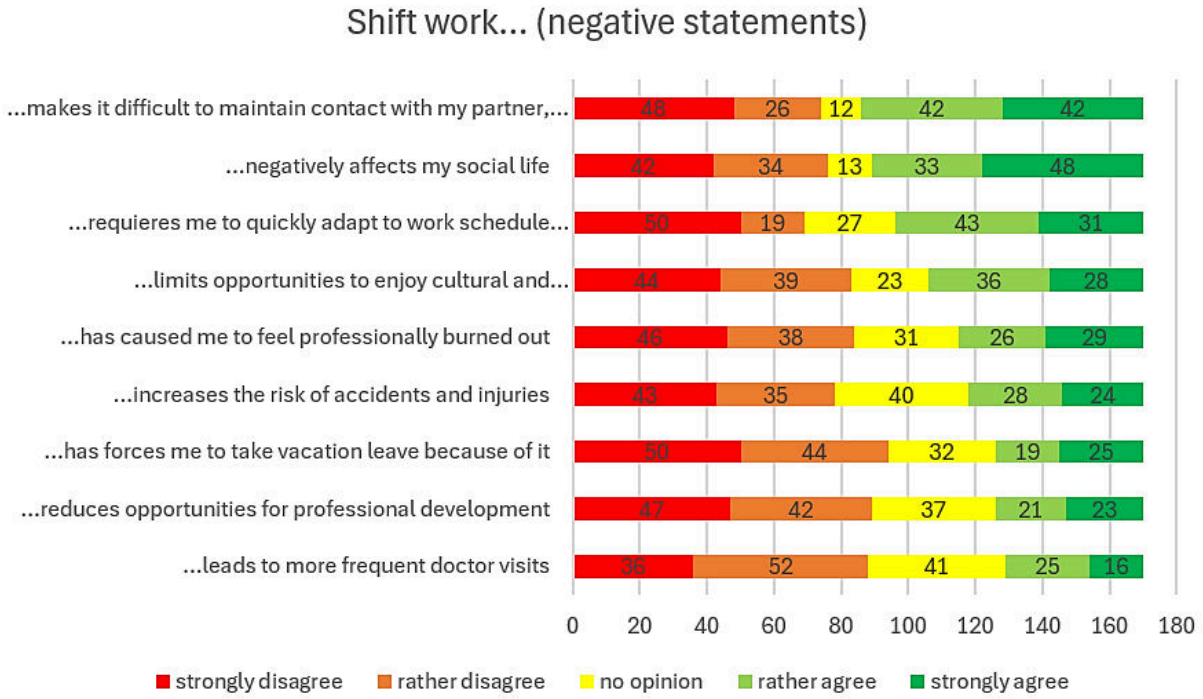

Figure 4. Responders' opinions on shift work (negative statements).

Among the negative aspects of shift work, respondents considered the greatest burden to be the difficulty in maintaining contact with family and close ones (49%) and the adverse impact on social life (48%). A relatively large portion also felt that shift work hindered their ability to enjoy cultural and entertainment activities (38%) and led to occupational burnout (32%). About 26% thought the shift system limited their development opportunities, and 24% reported increased medical visits (Figure 4).

Opinions on various aspects of shift work were divided. Analysis of Figure 4 shows that a considerable number of respondents did not find that shift work hindered contact with loved ones or affected their social life (44% and 45%, respectively). As many as 52% did not agree with the view that shift work reduced their opportunities for development.

Among the positive aspects of shift work, respondents mentioned the following:

- more free time,
- the ability to take care of matters (e.g., administrative tasks) from Monday to Friday.

The most frequently indicated negative effects were:

- sleep problems,
- physical fatigue,
- lack of balance between private and professional life.

Shift work poses significant challenges for many employees, both in terms of maintaining a balance between professional and private life and preserving good physical and mental health. The literature highlights a range of preventive measures that can effectively minimize or even completely eliminate the negative effects of shift work. However, it is important to remember that the effectiveness of these measures may vary; not every preventive action will be equally suitable or effective for every worker. Therefore, the approach to prevention should be flexible and tailored to individual needs as well as the specific conditions of the work environment.

One key element of a preventive strategy may be the optimization of work time organization, for example, by modifying shift schedules to take into account employees' individual chronotypes and their preferences regarding circadian rhythms (including sleep and activity).

Actions that help maintain the health and well-being of employees working in shift systems include maintaining proper sleep hygiene, adopting healthy eating habits, engaging in regular physical activity, and implementing techniques for stress management and psychophysical recovery.

Preventive measures can also be initiated and supported by the employer. These include, among others: introducing flexible work schedules, organizing regular and free preventive health check-ups, conducting training on stress management, and coping with the adverse aspects of shift work, and promoting health awareness in the workplace. Equally important is providing ergonomic workstations and optimal environmental conditions (adequate lighting, microclimate, noise reduction), which directly affect employee comfort and occupational health and safety.

4. Summary and discussion

The shift work system is an integral component of many sectors of the economy, enabling continuous operations and uninterrupted service provision by businesses, institutions, and organisations. Despite the numerous advantages this work model offers – including increased flexibility in working hours and the ability to better align schedules with diverse organisational and production needs – it also presents a number of serious challenges. Therefore, it is essential to conduct an in-depth analysis of the effects of shift work and to implement appropriate strategies to minimise its undesirable consequences.

The results of the survey indicate that employees working in shift-based systems often experience significant disruptions to their daily rhythms. Since shift work includes night shifts, the normal sleep-wake cycle is disturbed, which may have potential consequences for both physical and mental health (Torquati et al., 2019). Based on the study, the most commonly reported complaints among shift workers include sleep disturbances, general discomfort,

and unhealthy eating habits. These workers also more frequently resort to alcohol, medication, and cigarettes as a way to cope with stress and tension associated with this system of work. As noted by Richter (2020), alcohol is sometimes used by shift workers as a sleep aid, which further increases the risk of addiction and sleep disorders.

A work system based on variable hours and times of day not only disrupts the body's biological rhythm but also negatively affects social functioning – reducing time for family life, interpersonal relationships, and access to cultural and recreational activities. The literature highlights that shift work conflicts with the human circadian rhythm, leading to numerous psychological and physiological issues (Srivastava, 2010).

It is important to note that despite the many difficulties associated with shift work, some employees may still perceive certain benefits. The flexibility of working hours allows them to attend to administrative matters, schedule medical appointments at convenient times, and manage their free time more effectively.

Therefore, the evaluation of shift work should not be one-sided. Its impact on employee well-being largely depends on individual factors such as lifestyle, adaptability, health condition, and personal preferences.

In order to minimise the negative effects of shift work, it is crucial for both employees and employers to take preventive action. From the employee's perspective, helpful practices include adopting healthy eating habits, maintaining regular physical activity, proper sleep hygiene, and using supportive supplements such as melatonin. Employers, on the other hand, should aim to provide ergonomic working conditions, introduce flexible scheduling, and ensure regular preventive health screenings. It is worth emphasising that the effectiveness of these measures depends on how well they are tailored to the specific needs of the employees and the organisational conditions of the given production enterprise.

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Appendix

1. **Is your work organized in a shift system?**
   a) Yes, I work in a shift system
   b) No, I do not work in a shift system
   c) I am not professionally active, I do not work at all

2. **Gender**
   a) Female
   b) Male

3. **Age**
   a) Under 18
   a) 19–34 years old
   b) 35–44 years old
   c) 45–54 years old
   d) 55–64 years old
   e) Over 65

4. **Education**
   a) Primary
   b) Secondary
   c) Vocational
   d) Higher

5. **Job position**
   a) Manual labor / physical work
   b) Managerial
   c) Administrative / office work
   d) Engineering / technical
   e) Other (respondent could enter their own answer)

6. **Length of service at your current workplace**
   a) Less than 1 year
   b) 1–2 years
   c) 3–5 years
   d) 6–10 years
   e) 11–15 years
   f) Over 15 years

7. **What type of working time system is used at your workplace?**
   a) Two-shift work
   b) Three-shift work
   c) Four-shift work

d) 12-hour shift work
e) Irregular or flexible work schedule
f) Other (respondent could enter their own answer)

8. Do you experience sleep problems after night shifts?
a) Yes, frequently
b) Yes, occasionally
c) No
d) Not applicable

9. Shift work makes me reach for...
(*multiple answers possible*)
a) Cigarettes
b) Medicines
c) Alcohol
d) Narcotic substances
e) Other (respondent could enter their own answer)

10. Have you experienced any of the following symptoms related to shift work?
(*multiple answers possible*)
a) Increased blood pressure
b) Reaching for stimulants
c) Digestive problems (nausea, vomiting, diarrhea)
d) Reduced self-esteem
e) Reduced sex drive
f) Changes in mental behavior (depression, anxiety, mood swings)
g) Increased susceptibility to stress
h) Weakness, reduced body immunity
i) Problems with concentration and focus
j) Pain (headache, stomach, muscle)
k) Irritability
l) Nervousness
m) Malaise
n) Improper eating habits
o) Sleeping disorders
p) Other (respondent could enter their own answer)

11. Shift work…

Shift work…	**Answers**				
	Strongly disagree	***Disagree***	***No opinion***	***Agree***	***Strongly agree***
• ... suits me, I enjoy it					
• ... is appropriately compensated					
• ... has a positive impact on my personal development					
• ... is better than working a single (day) shift					
• ... provides a proper work-life balance					
• ... allows me to adjust my schedule to my needs					
• ... is organized in a way that ensures proper rest between shifts					
• ... requires me to quickly adapt to schedule changes (e.g. shift plan updates)					
• ... makes it harder to maintain contact with my partner, family, or loved ones					
• ... negatively affects my social life					
• ... limits my access to cultural and leisure activities					
• ... has led to professional burnout					
• ... increases the risk of accidents and injuries					
• ... results in more frequent visits to the doctor					
• ... caused me to take vacation leave because of it					
• ... reduces opportunities for professional development					

12. The beneficial effects of shift work are…

13. The adverse effects of shift work are…

SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

CMS WORDPRESS AS A TOOL FOR SHAPING THE DIGITAL SKILLS DEVELOPMENT OF BUSINESS STUDENTS

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Purpose: Investigate the possibility of using a tool CMS WordPress to develop the digital competences (in technological terms) of university students of economics.
Design/methodology/approach: A survey questionnaire (a total of 563 surveyed)/ explores the potential for practical e-business learning and the development of digital competencies, particularly in designing websites with integrated e-commerce functionalities.
Findings: Familiarity CMS WordPress is not difficult to master and allows the development of digital competencies/ CMS can successfully support the improvement of students' technical skills, even in business majors (not related to IT)/ literature highlights the inadequacies in expanding students' digital competences and underscores the need for increased attention to their development. The proposed model of program have been effectively implemented and validated/ it teaches problem-solving skills, effective communication and collaboration with real-world companies, information management, content creation, and sharing. In professional practice, these competencies translate into the ability to search for digital information, effectively present it on websites, and proficiently use CMS systems - integral elements of modern e-business operations.
Research limitations/implications: In the coming years systems (like Sigma or AI) may gradually replace the current popular CMS platforms. The author plans to continue researching, monitoring developments in technology and assessing their impact on digital competence acquisition. The author aims to contribute to the ongoing evolution of digital education and prepare students for the changing landscape of e-business.
Practical implications: Research has shown that it is worthwhile to teach digital competences as early as the university stage and to pay more attention to them because of the surrounding digital world. The research confirmed that the use of a popular tool (CMS) opens up opportunities to enter new professions, connects potential employees with employers. The impact of the article has a practical and economic dimension.
Social implications: changing approaches to competence formation in the information society, changes in approaches to university education.
Originality/value: The article shows the possibilities of using the CMS tool to develop digital competences. It provides a contribution to their development. It addresses universities and the wider business community.
Keywords: CMS WordPress, digital competences, Content Management System, university students.
Category of the paper: Research paper.

1. Introduction

The digitalization of the economy within the state significantly impacts the demand for specific skills in the job market, commonly referred to as digital competences. These competences are not only vital for navigating the information society but also essential for organizational leaders and decision-makers who must adapt their practices to thrive in the digital era (Berghaus, Back, 2016). As stated in (Gałan, 2022), digital competences have become one of the pivotal skills of the twenty-first century, gaining increasing importance across various educational domains amidst the ongoing digital revolution. Among the five core pillars of digital competence development—information processing, communication, security, problem-solving—content creation stands out. This pillar encompasses the development and integration of digital content, as well as the management of copyright, licensing, and software content (Vuorikari et al., 2016).

One approach to educating individuals in this domain involves teaching website creation, along with e-commerce integration, utilizing tools like Content Management Systems (CMS). For years, WordPress has stood out as the most widely used software globally for constructing websites and applications (Ciorici, 2024). Compared to other CMS - WordPress has already been the most used CMS in the world for many years (for comparison - WordPress used by 87.75 % of websites in category CMS, followed by Drupal - used by 4.95 % of websites in category CMS), which is why it was the system chosen for the classes (Stackcrawler, 2025). Additionally, literature highlights the application of CMS in production engineering, such as implementing an Open Source CMS system in product maintenance and service applications to facilitate information and knowledge management throughout operational processes (Wan et al., 2016).

However, there remain significant gaps in the development of digital competences among both students and educators. Many universities have yet to fully integrate these competences as fundamental skills, including proficiency in technology. Moreover, it's evident that new models for introducing digital competences are rapidly evolving, thereby exacerbating the existing digital divide. Available, free but highly developed tools such as CMS should therefore be used to support not only the learning process, but also the expansion of business, economic, social and many other skills.

The primary research question addressed in this article is: Is testing students' actual proficiency in specific WordPress functions, rather than just self-reported competence, a good way to concretely measure digital skills development?

The research hypothesis is that an innovative teaching approach using tools such as the CMS WordPress positively influences students' digital competences and can be one way to measure the level of these skills.

The subsequent section synthesizes the overarching findings drawn from the literature review, encapsulating previous experiences related to digital competence, e-business, and the utilization of CMS. Additionally, it examines students' attitudes and approaches towards learning these subjects. Following this, the subsequent sections delineate the objectives, methodology, and findings of the two empirical studies conducted. Finally, the paper concludes with overarching insights derived from the studies.

2. Literature review and reasons for choosing the course model

The author leveraged the resources of the Bydgoszcz University of Science and Technology Library, accessing a multi-search engine that scoured various bibliographic databases. These included Academic Search Ultimate, Business Source Ultimate, Springer Nature Journals, IEEE Xplore Digital Library, Social Sciences Citation Index, Scopus, and Directory of Open Access Journals. The search aimed to identify articles pertinent to the study's focus, employing search phrases such as 'digital competences' or 'digital skills' alongside 'students' or 'university,' as well as 'CMS' or 'content management system' or 'WordPress' in conjunction with "e-business course." The search was restricted to peer-reviewed scientific articles accessible in full within the academic fields of Economics, Business and Management, Information and Technology, as well as Social Sciences and Humanities. The ensuing section presents the most salient search outcomes, particularly those most aligned with the article's title and objectives.

2.1. Development and relevance of digital competence in student learning

In 2020, the European Commission noted that: ‘The current COVID-19 crisis has greatly accelerated the need for modernisation and digital transformation of education and training systems across Europe. The goal is to reinforce the ability of education and training institutions to provide high quality, inclusive digital education’ (European Commission, 2020). Digital competence, therefore, is a topic whose role has also been recognised in higher education, especially at a time when the COVID-19 pandemic has forced teachers and students to use ICT in the teaching and learning process (Gómez-Fernández, Mediavilla, 2021). While there are many definitions of the term, one of the most pertinent has been proposed by the European Commission as one of the eight key life skills and is defined as ‘the confident, critical and responsible use of digital technologies and a commitment to using them for learning, work and social participation’ (European Commission, 2019). It has also been noted that ‘digital competence seems to support research competence and may even support inclusion’ (Mieg et al., 2024).

Transforming higher education due to digitalization is a critical challenge to ensure adequate capabilities for a more entrepreneurial economy (Canal et al., 2024). In a survey conducted among Spanish university students (Esteve-Mon et al., 2020), it was found that the majority perceive themselves to possess a moderate to high level of digital competence, particularly emphasizing their proficiency in multimedia and communication aspects rather than the technical dimensions. This observation aligns with the findings of recurring research on digital competence issues, as highlighted by (Zhao et al., 2021). Researchers emphasize the importance for higher education institutions to prioritize the development of both students' and teachers' digital competences, advocating for the creation of relevant learning strategies and the utilization of appropriate tools to enhance the quality of education.

Conclusions drawn from various studies (Zhao et al., 2021) underscore the necessity of promoting the development of key competency areas for digital competence, including digital content creation, while also assisting students in acquiring knowledge to address everyday technological challenges. Furthermore, there is a clear demand for training initiatives focused on ICT usage and digital competencies.

Numerous studies from the last few years, e.g. (Martzoukou et al., 2020; Gazca et al., 2019; Dias-Trindade, Albuquerque 2022; Guillén-Gámez et al., 2023; Masias-Fernandez et al., 2023) indicate gaps in the development of students' and teachers' digital competence. It is noted that (González-Mujico, 2023, p. 15) "self-assessment tools have garnered significant attention in the interest of measuring the skillset required by educators and students to function productively and ethically in digitally mediated environments". The argument posits that higher education has yet to fully integrate digital competence as a fundamental skill, encompassing proficiency in technology. The rapid evolution of new models for introducing digital competencies risks widening the existing digital divide. To mitigate this trend, there's a pressing need to incorporate new methods and models into curricula that comprehensively develop digital competences, including the technical aspect. Furthermore, the literature suggests standardizing educational systems for teaching digital competences, which currently exhibit significant divergence (Morales et al., 2021). This article therefore emphasises technical competence within a specific tool - a content management system (CMS). Mastery of the CMS includes learning, use, implementation and operation - all integral elements of digital competence.

2.2. CMS as a tool to support the development of digital competence in the light of the literature

“Plenty of information and communication technologies are frequently employed in educational activities to improve the opportunities for students to gain knowledge and experience” (Vejačka, 2024, pp. 681-691). As content management systems are powerful, flexible and extensible - they have become the subject of much research in the last few years, and are even considered one of the most important information and communication technologies (ICTs) for managing an organisation's information and knowledge (Clair, 2012).

In particular, open-source CMS platforms like WordPress have attracted considerable research interest for their capabilities in managing knowledge and processes, particularly unstructured information and knowledge (Clair, 2012; Yen C.C. et al., 2008). Universities and colleges are increasingly adopting innovative curricula or courses that incorporate practical e-business learning facilitated by IT tools, with CMS playing a central role. Web Content Management (WCM), a specific type of CMS, is predominantly utilized for this purpose (Barker, 2016).

Notable research in this domain has been conducted in Croatia, where an e-business course was implemented at the Zagreb School of Economics and Management - Faculty of Higher Education Economics - between 2012 and 2015, with 20-25 students enrolled annually (Jerkovic et al., 2016). Similarly, in Poland, research has been conducted at Bydgoszcz University of Science and Technology (formerly UTP) between 2019 and 2024 (Krupcała, 2021; Krupcała, Kurek, 2020), from which it follows that digital competences need not, and should not, be a strictly IT domain, but should primarily concern future managers who, with the skills already acquired at university, will be better prepared for their work in the new, sought-after professions. According to this research, business students are keen to take on challenges such as building a CMS-based website, and their results are so good that those running organisations want to use their services and do. The students themselves also find such a course extremely useful in their field of study and provide them with opportunities that previously seemed unattainable to them due to their field of study or lack of familiarity with IT tools.

The reason for choosing the WordPress CMS is its universality - 810 million websites utilizing it, representing 43% of all websites on the internet. Moreover, WordPress commands a dominant 63,1% share of the CMS market, surpassing its closest competitor by more than tenfold. Notably, WooCommerce, an e-commerce platform built on WordPress, holds the distinction of being the most widely used e-commerce platform globally, boasting a market share of over 29% (Silkalns, 2024). Given these statistics, the selection of WordPress as the preferred CMS appears almost inevitable. Furthermore, the accessibility of CMS platforms like WordPress, which do not necessitate intricate programming skills or extensive IT expertise, presents significant opportunities for students from various academic backgrounds, including management.

The author has already conducted research for many years on the development of digital competences of university students through practical learning of website building and e-commerce based on CMS WordPress (Krupcała, 2021, 2023; Krupcała, Kurek, 2020).

The literature shows a disparity in attention towards studying the attitudes of economics students regarding the teaching of subjects like e-business and the associated applications used in these classes (Ahrens, Zaščerinska, 2014). While this aspect is not extensively explored, it is a recurring theme indirectly addressed in literature focused on CMS learning experiences (Jerkovic et al., 2016). However, some studies do delve into the general attitudes of students

towards learning e-business. For instance, Ahrens, Zaščerinska (2014) highlights that students' negative attitudes towards e-business applications hinder the enhancement of their knowledge and skills in this domain. Conversely, positive attitudes towards e-business applications contribute to enriching students' competence in e-business. Moreover, (Lichtenstein et al., 2015) presents intriguing findings indicating that students are tasked with creating new electronic businesses and developing prototypes of their electronic web fronts, reflecting a hands-on approach to learning. The authors also observe that "more than half of the students were enthusiastic about the new approach: they felt satisfied and even proud of their projects". This finding resonates with the research conducted by (Krupcała, 2021, 2023), which consistently indicates positive student attitudes towards building websites using the CMS WordPress. Moreover, these activities have been shown to enhance digital competences and uncover new job opportunities in fields that students had not previously considered, such as digital management or marketing and website management specialist roles, which are in demand in the labor market.

3. Research Methodology

The main objective of the empirical study was to investigate the possibility of using a tool such as CMS WordPress to develop the digital competences (in technological terms) of university students of economics (building a comprehensive website for an actual company operating in the market and an e-commerce site). The achievement of the main objective was to ensure the following specific objectives:

1) To learn about the possibilities of CMS as a tool for developing digital competences.
2) To learn about the validity of developing digital competences in economics faculties from the technological side, which could contribute to their enhancement.

Through this investigation, the article explores the potential for practical e-business learning and the development of digital competencies, particularly in designing websites with integrated e-commerce functionalities.

This study adopted a quantitative survey approach to gather evidence within the research domain, employing both digital and analog methodologies. The study's context draws from prior knowledge regarding the utilization of ICT tools in higher education (Gueldenzoph, 2006). Additionally, insights from an intriguing study reported by (Draganac el al., 2022) were considered. This study highlighted an average level of digital competence among students and identified disparities between self-reported digital competence levels and actual survey results, underscoring the necessity to enhance the educational process to elevate digital competence levels among students and secondary school students. Notably, programming emerged as the most deficient skill across all observed groups. Drawing from the literature review and practical

experience garnered during the initial project year, a survey questionnaire was developed. The questionnaire covered topics such as the skills acquired, the innovation of the programme, knowledge of the various elements of CMS WordPress, the future use of the knowledge acquired and the prospects of entering high-demand jobs in the labour market (Top 100 careers, 2024). More information about the questionnaire is included in Chapter 4. The survey was conducted among students of management and management and production engineering at the Faculty of Management at the Bydgoszcz University of Science and Technology (Poland), starting in the 2019/2020 academic year, and students of economics at the Merito (WSB) University (Poland), in the 2020/2021 academic year. A total of 563 students were surveyed – February 2020 – 94 students, June 2020 – 39 students (this was a sample of 100% of students - a very small yearbook size), February 2021 – 203 students, February 2022 – 70 students, February 2023 – 85 students, February 2024 – 72 students. There are no other digitization-related classes at these universities and their economics majors. The scope of the study therefore included all students of each academic year of the majors: Management and Production Management and Engineering (100%), participating in a project based on CMS WordPress. A limitation of the survey is that it was conducted at two business schools in Poland, which is a rather small study area.

4. Research Results

An earlier study (Lichtenstein et al., 2015) revealed that the Bydgoszcz University of Science and Technology stands out as the sole public university in Poland that emphasizes the development of specific technical facets of digital competence through instruction in building websites with e-commerce functionality using CMS WordPress. The course concept was formulated by the author in 2019, drawing upon her firsthand experience in the labor market, which highlighted the demand for individuals proficient in website and e-store operation. Additionally, the course design was informed by research examining existing e-business curricula at economic universities across Poland. The business acumen acquired by students during their studies serves as an advantageous foundation for effectively presenting content and products to target audiences. The concept is implemented through thematic labs conducted throughout the academic semester (on computers with online CMS access). Each student (men and women, full-time and part-time studies) is tasked with independently creating a comprehensive website that includes an online store, and each lab session introduces a new skill to enhance the site's functionality. At the onset of the course, the author demonstrates tasks such as creating and integrating a contact form into the site, after which students replicate the process on their own computers, customizing the form to suit the needs of a chosen company. In the academic year 2019/2020, students developed websites for hypothetical companies.

However, starting from 2020/2021, the focus shifted to creating websites for real organizations that applied to participate in the "Free Website" project at Bydgoszcz University of Science and Technology. Consequently, the class involves constructing a website from scratch for a participating company, encompassing components like a homepage, a slider, a contact form, a company blog with multiple posts, widget adjustments, and a complete e-store featuring services or products. Given the constraints of the publication size, only the responses to the three questions most relevant to the article's topic are included in the survey questionnaire, despite the questionnaire containing a total of 12 questions. Other questions included whether the respondents thought the skill would be useful in their future work, how much they enjoyed the classes (most vs. least), how much time they spent building the site and whether they were satisfied with the outcome and their involvement in the classes, and whether the occupations involved are in their opinion in demand on the job market.

First, students were asked about their familiarity with the various elements of the CMS system with which they created a comprehensive website and e-shop. It should be added that each element of the website was discussed very thoroughly and extensively, from the necessary plug-ins to, for example, building an e-commerce site, which was based on the woocommerce plug-in and included learning how to add simple products, complex products (with variants), setting up payment, shipping, taxes and a plug-in to enrich the order fields (such as an additional field for entering the VAT number). The results from each year are shown in Table 1.

Table 1.
Knowledge of the various WordPress elements (tools) and the ability to use them (1 - I know it and will use it; 2 - I know it, but I will not use it; 3 - I do not know it) (in percentage)

Tool/element of CMS WordPress	**February 2020**			**June 2020**			**February 2021**			**February 2022**			**February 2023**			**February 2024**		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Building the sites from scratch	84	14	2	90	10	0	88	11	1	94	6	0	90	9	1	79	15	6
Creating a contact form	84	16	0	85	15	0	87	13	0	96	4	0	95	5	0	88	11	1
Subscription to the newsletter (pop-up)	67	30	3	82	18	0	80	19	1	80	19	1	80	18	2	69	28	3
Building an on-line store	89	9	2	85	15	0	86	13	1	89	11	0	80	19	1	81	18	1
Building and editing menus	92	8	0	95	5	0	94	6	0	94	6	0	95	5	0	88	11	1
Creating links under the words in the text	81	16	2	90	10	0	85	14	1	94	6	0	91	9	0	83	14	3
Editing the shop's shipping settings	79	17	3	87	13	0	80	18	2	83	14	3	70	21	9	65	32	3

Cont. table 1.

Creating a slider	75	17	8	85	13	3	83	13	4	96	3	1	96	4	0	83	13	4
Sidebar modification (side panel)	43	40	16	85	13	3	63	29	8	70	24	6	73	20	7	57	32	1
Creating a blog and posts on it	63	29	8	92	5	3	80	16	4	93	7	0	95	5	0	86	13	1

Source: own research.

The results from Table 1 indicate that the most familiar elements of CMS WordPress that students know are: "building the sites from scratch". - can up to a total of 88% of all respondents, "creating a contact form" - can 89% of all those surveyed, "building and editing menus" - 93% of all students, "creating links under the words in the text". - 87% of all respondents. In two cases, there was no person who did not know and did not know how to perform "building and editing menus" and "creating a contact form". The biggest problems students have with "sidebar modification (side panel)". - 9% overall do not know and do not know how to modify it, 26% know but do not know how to edit it, and only 65% of respondents know and can edit the side panel. Overall, all CMS elements know and can do as much as 83% of the surveyed students, which is a very satisfactory result from the Author's point of view as a teacher.

Then students were asked whether classes of this type should be held at economic universities at all. The results from each year are presented in Table 2.

Table 2.
Opinions on the relevance of e-business classes for economics majors (in percentage)

Digital CMS classes should take place at economics faculties	**February 2020**	**June 2020**	**February 2021**	**February 2022**	**February 2023**	**February 2024**
Yes	78.5	87.2	77.3	94.2	87,1	87,5
No	6.5	7.7	9.9	2.9	4,7	5,6
I don’t know	15	5.1	12.8	2.9	8,2	6,9

Source: own research.

Familiarity with the tools and the ease of their use may have an impact on the very fact that, thanks to this, the vast majority of students believe that classes using CMS should be held at economic universities (a total of 467 people). 85% of respondents from all years of study who are studying business majors are convinced of the usefulness of CMS in their course of study.

The results presented in Table 3 demonstrate that the overwhelming majority of students either enjoyed or greatly enjoyed the classes, indicating a high level of satisfaction with the teaching approach and the skills acquired through it.

Table 3.
Students' perceptions of the e-business course (in percentage)

Did you like the class?	February 2020	June 2020	February 2021	February 2022	February 2023	February 2024
1. I did not like them at all	0	0	0	0	1,2	1,4
2. I rather did not like them	3.3	0	0.5	0	0	1,4
3. I liked them a bit	25.5	2.5	8.9	2.9	23,5	18,1
4. I liked them	38.2	15.4	33	22.8	29,4	37,5
5. I liked them a lot	33	82.1	57.6	74.3	45,9	41,7

Source: own research.

Importantly, there were virtually no respondents who expressed dissatisfaction with this mode of teaching or the skills they had gained through it (except for two people out of all respondents). This positive feedback is valuable as it enhances both the course content and the learning experience, making them more appealing to students. It underscores that the digitization of competencies and the acquisition of these skills through tools like CMS WordPress do not pose any challenges for students. As evidenced by the literature discussed earlier, job satisfaction plays a crucial role in the expansion of digital competencies and the motivation to further develop them.

Indeed, one of the key advantages of a CMS is its standardized structure across different platforms. Familiarity with one CMS, such as WordPress, provides a solid foundation for navigating other CMS platforms like Drupal or Joomla! This similarity in functionality means that students can leverage their knowledge of one system when required to work with a different CMS. Consequently, acquiring digital competencies not only enhances technical skills but also broadens the opportunities for their practical application.

Evidence of this can be seen in another survey that was conducted among course graduates in the 2022/2023 and 2024/2025 academic years. The questionnaire of the survey was completed by 84 graduates of the faculty who attended the academic year 2020/2021 (36 people) and 2021/2022 (14 people), academic year 2022/2023 (19 people), academic year 2023/2024 (14 people) and contained 12 questions. Below are the two most important from the point of view of this article.

Table 4.
Responses to the question of whether the skills/knowledge from web building have ever been applied

Successfully applied skills/knowledge from website building	Number of people (in percentage)
1. Yes	25
2. No	65
3. I don't know	10

Source: own research.

Table 4 shows that several people were able to use the knowledge gained in the classes in such a short period of time. These people (21 people) were also asked under what circumstances/situations this took place. The answers are as follows: "Internet sales; Privately, a front-end course; Helping a colleague, while at another university; While talking to friends,

at the university; I created a website for a company where a person close to me works; At a job interview at my current job, I'm supposed to run our company's website in the future; Designing my own website for academic purposes; Updating the current website; Noticing how other websites are badly done, such as not adjusted to be opened on a phone; At work; I've been to a training course on editing the website of the project where I work. It made it easier for me to understand how to edit that page; Working at a programming school - learning how to create pages; Working on a company website; Helping friends create a page for their business; An additional asset at a job interview; I got orders to make pages; In conversation with friends; When making a page for my own use; Studying and while using the site". As can be seen from the responses - many graduates found the course useful at work, while the classes interested the students so much that some of them decided to take other paid related courses, such as the front-end developer course.

Table 5.
Responses to the question of whether the student has already undertaken the construction of a website or dealt with professional website building themselves after completing the course

After the class was over, I undertook to build the site from scratch	Number of people (in percentage)
Yes, and I still do it today	1
Yes, but it is more of an occasional activity	15
Yes, but it came out poorly/not well	6
No	76
I don't remember	2

Source: own research.

In Table 5, it can be seen that 1 person undertook CMS-related work and is still working today. 12 people (15%) indicated that they had attempted to create a website, but not in a professional manner, but rather as an occasional activity. Considering the not too distant time since the topic was completed, the above results can be considered optimistic. Overall, about 22% of respondents have used their competencies formed during e-business classes and working with CMS.

5. Conclusion

Research over the past five years shows that familiarity with a tool like CMS WordPress is not difficult to master and allows the development of digital competencies, including the ability to build websites. The easiest way for students is to create and edit menus, create a contact form, and in general - to build sites from scratch.

Moreover, CMS can successfully support the improvement of students' technical skills, even in business majors (not strictly related to IT). Business students find the skills they have acquired very useful, and some of them (as shown in another part of the survey, which is not

presented in this article) are even considering their future work in the area of creating e-business solutions.

Recent literature highlights the inadequacies in expanding students' digital competences and underscores the need for increased attention to their development. The proposed model of e-business classes and the developed program have been effectively implemented and validated, as evidenced by the highly positive evaluation from students at Bydgoszcz University of Science and Technology. Students benefit from a high degree of autonomy in the course, which fosters motivation and facilitates a flow experience. The course not only imparts broad theoretical knowledge through lectures but also equips students with practical skills essential for effectively, correctly, and ethically performing tasks related to website construction and management. Furthermore, it teaches problem-solving skills, effective communication and collaboration with real-world companies, information management, content creation, and sharing. In professional practice, these competencies translate into the ability to search for digital information, effectively present it on websites, and proficiently use CMS systems - integral elements of modern e-business operations, as evidenced by surveys of graduates who, in such a short interval from classes, have already managed to apply the knowledge at work or even take up the topic professionally and earn money from it.

Recommendations for teachers or curriculum developers may be as follows: always assume that students' digital competencies are not highly developed (although logic might suggest that young people should be proficient with computers and internet use. However, this is not equal and does not translate to digital competencies). Therefore, popular IT tools that support the didactic process and develop skills in this area should be used for teaching. It should also not be assumed that topics related to digital competencies will be too difficult for students of non-IT-related fields. Having curricular blocks of classes, e.g., 30 teaching hours (laboratory) dedicated to what might seem like one topic, but which provides the future employee entering the job market with a comprehensive skill that they can utilize, understand deeply, and sustain themselves with. It is therefore worth cooperating with the business environment to meet the market's needs in developing digital competencies, activating not only students but also employers - companies with specific demands. And this demand for digital competencies, as evidenced by the current e-commerce market (which records an annual growth rate of about 10%) (The National Chamber of Commerce, 2024), is constantly increasing.

Indeed, the CMS-based application system continues to evolve rapidly and is expected to remain the basis for websites and web applications for the foreseeable future. However, the continued development of artificial intelligence and the trend to simplify technology for users is leading to the emergence of blockchain-based systems such as Figma (Figma, 2024). It is conceivable that these systems could gradually replace the current popular CMS platforms in the coming years, just as CMS replaced HTML-based websites in the past. AI is already being used in CMS for machine learning, natural language processing, computer vision, and knowledge graphs (Kandepu, Harry, 2023). Some blogs available on the internet even

suggest that it is a matter of time before CMS is completely replaced by AI (Tricension, 2024). This topic is much more extensive and could be the subject of a separate publication.

The author plans to continue researching this dynamic area, monitoring the development of technologies and assessing their impact on digital competence acquisition and educational approaches. By staying abreast of emerging trends and technological changes, the author aims to contribute to the ongoing evolution of digital education and prepare students for the changing landscape of web development and e-business.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

MISUNDERSTOOD MARKETING

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Purpose: The aim of the study was to present and attempt to understand the common misconceptions about marketing among researchers, practitioners, and consumers. Additionally, the study aimed to examine whether each element of the 4P and 4C marketing mix is criticized by consumers, or if the criticism is limited to promotion and advertising.
Design/methodology/approach: Based on an analysis of scientific and business literature (desk research), the study identifies misconceptions about marketing among researchers and practitioners. Content analysis is conducted on social media, blogs, and online forums to determine the narratives on this topic and confirm that for each element of the marketing mix (4P and 4C), it is possible to identify critical consumer narratives that highlight the perceived ineffectiveness or low credibility of a given tool.
Findings: The article identifies the differences between the common perception and the true meaning of marketing within business strategy. The research confirms that for each element of the marketing mix (4P and 4C), it is possible to identify critical consumer narratives that highlight the perceived ineffectiveness or low credibility of a given tool.
Research limitations/implications: The review is limited by the transient nature of social media content, reliance on external sources, and its focus on the 4P and 4C models, excluding more advanced frameworks such as the 7P. Future studies should examine whether negative consumer perceptions of these tools shape broader views of marketing as manipulative, opaque, and misaligned with consumer values.
Practical implications: Academics, practitioners, and consumers all contribute to shaping the perception of marketing, often not fully leveraging over a century of accumulated knowledge and experience in the field. As a result, marketing is frequently misunderstood and reduced to short-term sales tactics, limiting its recognition as a strategic tool for long-term business success. This limited understanding leads to significant consequences, including reduced trust in marketing, ineffective business strategies, and missed opportunities to build lasting relationships with customers, ultimately affecting both business sustainability and public perception. The article serves as a foundation for further research and educational initiatives aimed at redefining marketing as a tool for long-term business value creation.
Originality/value: This article highlights common misconceptions about marketing and offers a basis for redefining it as a strategic, ethical tool for long-term business success. It shows how consumer criticism affects the perception of marketing in business and society and sets the stage for further research on its redefinition as both a science and a tool.
Keywords: Marketing Misunderstanding, Consumer Perception, Marketing Mix (4P, 4C), Criticism of marketing.
Category of the paper: General review, Case study.

1. Introduction

The shift from handmade to factory production during the 18th-century industrial revolution led to mass production and sales challenges. According to Al-Noorachi, "marketing emerged as a separate field to address the sales problems caused by mass production" (Al-Noorachi, 2014). Practitioners often associate marketing only with sales techniques, while consumers see it as a manipulative tool used by companies to push purchases.

Many students starting marketing studies view it as "a set of tools used by businesses to sell products" (Al-Noorachi, 2014). Lambin (2001) points out that marketing is often misunderstood by both critics and supporters, which leads to its devaluation. Marketing is frequently seen as a way to pressure consumers into accepting products, but this approach ignores buyers' true needs and focuses on the seller's interests. Critics argue that this view is disproven by the frequent failure of new products, which shows consumers' ability to resist manipulation and reject unsuitable products (Lambin, 2001).

2. Criticism and Misunderstanding of Marketing – Literature Review

Criticism of marketing has a long history, dating back to the early days of its academic existence. Between 1913 and 1915, when the first theoretical foundations of marketing were developed by scholars like P. Cherington, L. Weld, and A. Shaw, critics raised concerns about its effectiveness. E.D. Jones, from 1911 to 1914, highlighted the waste of resources in marketing, noting that in retail, marketing costs account for about 50% of the product price, with most of this spent on advertising and store displays, which he considered inefficient (Kozielski, 2013).

The lack of a clear definition of marketing leads to diverse interpretations, causing misunderstandings and controversies among researchers and practitioners. Al-Noorachi (2014) argues that such discrepancies can result in the devaluation of marketing, as inconsistent definitions hinder constructive discussion. Moreover, the ambiguity of definitions may lead to the marginalization of marketing, as it obstructs the development of the field (Krycia-Chomińska, 2025).

Marketing has developed from a traditional, transactional approach into a more modern, customer-focused concept, driven by changes in the capitalist economy. Classical definitions, as outlined by Szulce (2007), focus on company activities related to market planning and control, while modern definitions, such as Kotler's (2005), emphasize satisfying customer needs for profit. However, since the 1980s, these perspectives have faced criticism for being overly simplistic, production-oriented, and neglecting the active role of consumers (Otto, 2004;

Seliga, Woźniak, 2014). In response, newer approaches like relationship and partnership marketing have emerged, highlighting the importance of long-term customer relationships and value creation.

In the literature on management, sociology, and ethics, marketing is presented as a practice that, through PR, CSR, and branding, manipulates consumer awareness and collective identity to serve corporate interests. The ideology of marketing is also criticized for supporting the maintenance of power and the existing social order. However, proposals for ethical marketing, based on social responsibility and sustainable development, have also emerged (Sułkowski, Lenart-Gansiniec, 2021).

Numerous studies have shown that unethical marketing practices are not profitable for businesses. One example is unethical word-of-mouth marketing, such as paying individuals to post positive reviews without disclosing this information, which leads to a loss of consumer trust. Barton and Haghirian (2016) demonstrated that consumers are sensitive to manipulations on social media, resulting in negative reactions and weakened brand image. Companies can also face financial losses and penalties for such practices. In 2023, the Polish Office of Competition and Consumer Protection (UOKiK) imposed a fine of over 5 million PLN on Olimp Laboratories for improperly labeling advertising materials on social media. The company used influencers who did not disclose the commercial nature of their posts, misleading consumers. Advertising manipulations, such as exaggerating product benefits, lead to a decline in consumer loyalty. Eisenbeiss, Van Herpen, and Schifferstein (2012) showed that consumers who feel deceived lose trust in the brand, which lowers their loyalty and sales. Price manipulation, such as artificially inflating prices only to later offer discounts, also results in a loss of trust and boycotts. Chandon, Wansink, and Laurent (2000) noted that while such manipulations may temporarily boost sales, in the long term, they lead to negative outcomes because consumers feel deceived. Narver and Slater (1990) found that customer-oriented companies, which focus on understanding customer needs rather than manipulation, achieve better financial results in the long term.

Marketing, while typically aligned with companies' profit-maximization goals, can sometimes generate unintended negative consequences—even when addressing social needs. Overemphasis on certain strategies may contribute to excessive consumerism and reinforce social inequalities. For instance, campaigns promoting fast fashion encourage frequent purchases of low-quality clothing, fostering unsustainable consumption patterns and environmental harm (Assadourian, 2010). Similarly, the aggressive marketing of ultra-processed foods by global corporations has been linked to increased consumption of unhealthy products, particularly among lower-income populations (Hastings, 2012). Selective targeting strategies may also exclude certain groups, reinforcing social divisions and inequalities (Cova, Cova, 2002). Moreover, some companies adopt socially engaged narratives—such as advocating for women's rights or environmental causes—not as a genuine commitment, but primarily to improve their public image (Vredenburg et al., 2020). Marketing can also shape

social identities by promoting lifestyles and values that differentiate between "desirable" and "undesirable" consumers, leading to marginalization and social pressure (Baudrillard, 1998; Kamiński, 2014).

The impact of marketing on professionals' perception is often shaped by their initial contact with marketing concepts at the beginning of their education. The future evaluation of marketing is determined by the teaching methods that lead to acquiring knowledge and skills. Oczachowski (2016) points out the weaknesses of marketing literature used in education, highlighting its biased style, which merges various threads and objectives, often leading to misleading messages that influence future practitioners. One popular approach is presenting marketing as a set of tools – the 4P marketing mix (McCarthy, 1964), which includes a collection of tactical marketing instruments that a company combines to provoke a desired market response. This framework, developed in 1964, is criticized for its outdatedness, producer-centric perspective, lack of consideration for customer relationships, limited scope for different markets, and absence of strong theoretical foundations, yet it remains present in textbooks used in academic programs.

Expectations formed during studies regarding marketing can lead to its perception as morally questionable methods of influencing customer decisions, using information asymmetry, manipulation, deception, or small lies to achieve "miraculous" sales increases. Rogowski (2008) provides examples of criticisms directed at the most scrutinized elements of the 4P – advertising and promotion: selling defective or dangerous products, flashy packaging providing exaggerated information about the product, and deceptive pricing and delivery practices. However, the criticism and complaints may apply to all marketing tools.

Marketing is often misunderstood and used in ways that can lead to ethical and social abuses. Business leaders frequently view it solely as a tool for quick sales increases, neglecting its long-term, strategic role in building customer relationships and creating lasting brand value. As Kamiński (2016) notes, "marketing is still often limited to sales or promotional functions, rather than being seen as a process of creating value for the customer and developing long-term relationships." This reductionist view leads to an instrumental approach to marketing, focusing managers only on financial results, thereby marginalizing its broader social, cultural, and economic impacts. Furthermore, such managerial perceptions undermine the academic status of marketing, overlooking its interdisciplinary nature. Levitt (1960) already described a focus on product maintenance or sales effectiveness over customer satisfaction, a short-sighted marketing approach that can result in loss of market position and growth potential. Examples of companies that made this mistake include Kodak, which failed to adapt to the digital revolution, and Nokia, which could not adjust to technological changes in the smartphone industry. Both companies prioritized the protection and development of traditional products rather than aligning with evolving customer needs and preferences.

A common criticism of marketing is its inability to clearly demonstrate the benefits it brings to organizations, particularly in terms of measuring the impact of marketing expenditures on the growth of company value. The difficulty in precisely determining how specific marketing activities contribute to the final outcome undermines the effectiveness of marketing performance analysis, which is a significant issue from an economic perspective (Oczachowski, 2016).

According to Rust and colleagues (2004), organizations face challenges in measuring the long-term effects of marketing due to the time lag of results and the difficulty of isolating the impact of marketing actions from other market factors. The dominance of short-term financial metrics in company reporting systems, coupled with the pressure to show results in quarterly cycles, naturally favors tactics that yield immediate outcomes. The lack of widely accepted standards for measuring long-term marketing values, such as brand equity or customer loyalty, further complicates companies' ability to consistently assess and appreciate the strategic dimension of marketing.

Expectations regarding marketing tools often overlook contextual factors, resulting in overgeneralization, reliance on outdated research, and misuse of marketing principles. Managers frequently apply tools to solve specific issues without considering that marketing research, like other social sciences, must be interpreted within particular temporal and spatial contexts (Woleński, 2022). For instance, Coca-Cola's "Share a Coke" campaign, successful in some regions, struggled in markets like China and Taiwan due to cultural mismatches. Similarly, Tropicana's packaging redesign—intended to appeal to younger consumers—backfired, causing a 20% sales decline and necessitating a return to the original design (Sharp, 2010). These examples highlight the importance of adapting marketing strategies to specific cultural and market conditions rather than relying on universal assumptions.

Another mistake is applying mature marketing principles to markets that are still underdeveloped. Examples of such errors include products that consumers are not ready for, such as Vidal Sassoon's Wash & Go shampoo, introduced to the Polish market in the 1990s as a 2-in-1 shampoo and conditioner. It failed to gain expected popularity because Polish consumers, unfamiliar with using conditioners, preferred traditional shampoos, and the 2-in-1 concept was not widely accepted. Another example is pricing not adjusted to local income levels, as seen with Apple's initial failure in markets like India, where the high prices of iPhones were unaffordable for local consumers.

Also expectations placed on marketing tools that do not consider the situational context of the results lead to a loss of credibility for marketing as a discipline, as the ineffectiveness of one tool is generalized to marketing. These types of errors, in addition to the lack of effectiveness perceived by marketing managers, can also result in a loss of consumer trust, reduced effectiveness of marketing activities, and a weakened market position for the company.

A common criticism of marketing, shared by consumers and organizations alike, is its paradoxical effectiveness—while it successfully influences behavior, it also contributes to overconsumption, resource depletion, and negative effects on well-being and the environment. Consumers often perceive marketing narrowly, viewing it as manipulative sales tactics rather than as a value-creating, educational, and needs-driven process. Although marketers have access to powerful tools, they frequently fail to consider their ethical and social responsibilities, which can result in harm to individuals and society (Sudoł, 2016). Interestingly, consumers' assessments of marketing tools are inconsistent – they claim ads don't influence them (Davison, 1983), yet simultaneously blame marketers for persuading them into unnecessary purchases (Pollay, Mittal, 1993).

In the context of the widespread presence of brands on social media and the ease of direct communication between consumers and brands—as well as among consumers themselves—content analysis in these platforms offers a valuable tool for understanding how marketing activities are perceived. Even when based on commonly criticized, yet widely taught models such as the 4P marketing mix (McCarthy, 1960) and the 4C framework (Lauterborn, 1990), social media content analysis can yield meaningful insights into consumer responses to specific marketing instruments. These include product, price, place, and promotion (4P), as well as communication, convenience, cost, and customer value (4C).

This leads to the hypothesis that for each element of the marketing mix (4P and 4C), it is possible to identify critical consumer narratives that highlight the perceived ineffectiveness or low credibility of a given tool. This reflects an extension of the objections to advertising and promotion discussed by Rogowski (2008).

3. Methodology

To test the hypothesis, a review was conducted of consumer reactions to marketing tools used by companies and institutions, as expressed in social media. The goal was to examine whether each element of the 4P and 4C marketing mix is criticized by consumers, or if the criticism is limited to promotion and advertising. Additionally, the study aimed to identify the existence and nature of negative narratives regarding how marketing and its instruments (4P and 4C marketing mix models) are perceived and evaluated by consumers, rather than their statistical representativeness or prevalence. This review, which includes both Polish and international examples, also aims to outline the boundaries of socially acceptable marketing practices in digital spaces and the potential consequences of crossing them. Furthermore, this serves as an introduction to further analysis of how the use of marketing tools—when negatively evaluated by consumers—may affect the overall perception of marketing as a scientific discipline.

The review was conducted between March and April 2025 using the desk research method. Due to the temporary nature of social media content and the difficulty of archiving it, as well as the aim to identify the consequences of consumer reactions, examples were primarily sourced from external outlets such as online news media. This approach ensured that despite the ephemeral nature of social media posts, their description in more permanent external media not only preserved these reactions but also amplified and highlighted consumer sentiment regarding the described situations, making their impact more evident for analysis. The review covered content related to the following social media platforms: TikTok, YouTube, X (formerly Twitter), Facebook, Instagram, Snapchat, and Reddit. All cases presented later in the paper are illustrative in nature and serve to highlight the identified critical narratives regarding individual elements of the marketing mix (4P and 4C), rather than to statistically generalize their frequency.

One effective tool used in this review for analyzing consumer reactions on social media is the hashtag, a word or phrase preceded by the hash symbol (#). Hashtags help categorize content and increase its visibility, while their ability to group posts by topic makes them valuable for analyzing consumer reactions and enabling two-way marketing communication, allowing both promotion and public feedback.

4. Results

The examples of consumer reactions to marketing activities on social media presented below are illustrative in nature. Their purpose is to identify the existence and nature of the critical narratives regarding each element of the marketing mix (4P and 4C) [previous conversation, 75]. It should be emphasized that they do not constitute a statistically representative sample nor are they intended to determine the prevalence or frequency of these narratives. They were selected to highlight the types of perceived dissatisfaction and the consequences of exceeding socially acceptable marketing practices. A summary of examples of consumer reactions to marketing activities on social media is presented below:

1. Product

   Since 2020, a series of videos titled "#AmazonBasicsFails" have appeared on TikTok and YouTube, highlighting the poor quality of Amazon's private-label products, which has influenced the perception of the entire product line.

   A Twitter user ZabX@zabikozord noted in 2017 that Isana and Alterra products in Poland had fewer ingredients and were more expensive than their counterparts in Germany, prompting her to file a complaint with the Office of Competition and Consumer Protection (UOKiK). For example, a 500ml Isana liquid soap costs PLN 3.49

in Poland and an equivalent of PLN 2.35 in Germany, even though the Polish one has 16 ingredients and the German one has 19.

2. Price

   TikTok users began posting videos showing that prices in the McDonald's app were higher than in the restaurant, leading to the hashtag #McDonaldsScam and official company explanations.

   On TikTok, users created a trend under the hashtag #RyanairReality, where they shared experiences related to additional fees charged by the airline. Videos under this hashtag showcased how an initially low ticket price significantly increases when mandatory charges for baggage, seat selection, and other services are added, aiming to highlight the airline's pricing practices. For example, TikTok user Gleza Elena Serrano posted a video titled "Challenges of Flying with Ryanair: A Reality Check," in which she discusses typical issues encountered when flying with Ryanair, including extra fees and other difficulties related to budget airlines.

3. Place (Distribution)

   During the Black Friday sale, Zara's website crashed, triggering a wave of complaints on Instagram and Twitter under the brand's promotional posts, exposing weaknesses in its e-commerce infrastructure.

   On Facebook, posts from Polish Lidl regularly attract comments about the unavailability of promoted products on the first day of the promotion, leading to the introduction of sales restrictions in some stores, such as limiting the number of Wittchen bags to two per customer, despite earlier assurances that there would be no product rationing.

4. Promotion

   Snapchat's "Would You Rather" ad, which asked users whether they would "rather hit Rihanna or Chris Brown" (referencing the history of domestic violence), triggered a strong backlash on Twitter and led to a $800 million drop in Snapchat's stock value.

   An Instagram ad for micellar water, featuring a photograph of the product placed on a grave during All Saints' Day, faced criticism from users who deemed it inappropriate and disrespectful in the context of the solemnity of the holiday and the location.

5. Customer

   The removal of popular TV shows and movies from Netflix sparked the #CancelNetflix campaign on Twitter, where subscribers questioned the value of the service as its catalog shrank and prices increased.

   Rossmann in Poland introduced changes to its loyalty program, shifting from a simple discount system to a more complex points-based system. This led to a wave of negative comments on Rossmann's Instagram, with customers highlighting the reduced real value of the loyalty program.

6. Communication

   Starbucks' "Race Together" campaign, which encouraged baristas to engage customers in conversations about racism, sparked a wave of criticism on Twitter under the hashtag #RaceTogether. Users pointed out the inappropriateness of such communication in the context of ordering coffee.

   The humorous tone of communications from mBank in Poland about app outages provoked mixed reactions on Twitter. While some customers appreciated the humor, others criticized the lack of seriousness in communication from a financial institution. For example, in 2020, mBank accidentally sent push notifications with the text "ęśąćż" and "test wiadomości push," causing confusion and server overload. mBank's deputy spokesperson, Piotr Rutkowski, apologized for the incident, explaining it was a mistake caused by the app.

7. Convenience

   On TikTok, videos from delivery drivers became popular, showing how the Uber Eats app directs them to incorrect addresses under the hashtag #UberEatsAddressConfusion. This sparked a discussion about the inconveniences related to incorrect locations and the frustrations of both drivers and customers.

   On X, the hashtag #PKPIntercity has been used by travelers in Poland to regularly document issues with the PKP Intercity mobile app, especially during peak travel times. They highlighted problems with seat reservations and the app's lack of functionality, which can lead to misunderstandings with conductors. One example is Jerzy Gozdek, who had trouble showing his ticket due to a lack of network coverage and the app failing to save tickets in its memory.

8. Cost

   The price increase of Amazon Prime sparked discussions on Reddit in the r/AmazonPrime group, where users analyzed whether the rising costs of the service were still justified by the benefits it offered. They compared price changes across various countries, highlighting differences and trying to assess whether the service's value aligned with the new costs.

   The introduction of higher subscription fees and charges for account sharing by Netflix in Poland led to discussions in Facebook groups, where users organized to share accounts within allowed households or switched to competing platforms. Since May 2023, Netflix in Poland limited account sharing to users within the same household, tweeted "Your Netflix account is for you and your household". Customers negatively commented on this decision, arguing that it contradicted Netflix's earlier stance in 2017, when the company supported sharing login information, tweeted "Love is sharing a password". Following the policy change, users felt deceived and expressed their dissatisfaction, citing Netflix's previous approach, leading to a surge of negative comments and considerations of switching to rival platforms.

5. Discussion

External sources, such as press articles, user comments on social media, and discussions on forums, serve as a lasting base of information that can shape the long-term image of a company. These sources remain accessible on the internet and influence how consumers perceive a brand.

The review of social media examples reveals a critical narrative towards corporate marketing actions, highlighting the growing awareness and demands of consumers. Users often question the authenticity and transparency of brand actions, pointing out discrepancies in pricing, unethical campaigns, or poor service and product quality. Negative reactions also arise from poor communication or misleading loyalty strategies, undermining the effectiveness of traditional marketing tools.

The review of consumer opinions confirms that for each element of the marketing mix (4P and 4C), critical narratives can be identified, indicating the ineffectiveness or low credibility of certain tools, which supports the hypothesis that for each element of the marketing mix (4P and 4C), it is possible to identify critical consumer narratives that highlight the perceived ineffectiveness or low credibility of a given tool.

6. Conclusions

The above review, due to its qualitative and exploratory nature, focused on identifying the existence and type of negative consumer narratives in social media discourse, provides a basis for further analysis. Future research can examine whether negative perceptions of specific marketing tools—such as pricing, distribution, and communication—contribute to viewing marketing as manipulative and unresponsive to consumer needs. It may also explore how critical narratives regarding tools from the 4P and 4C models shape the broader perception of marketing as disconnected from consumer values.

It should be emphasized that the presented cases (e.g., #McDonaldsScam, #CancelNetflix, or #AmazonBasicsFails) lack statistical grounding and do not indicate the representativeness of their prevalence, which is a conscious limitation of qualitative research.

Negative reactions on social media can damage brand image, reduce trust, and force corrective actions like public apologies, pricing changes, or product revisions. Over time, such responses may promote greater transparency and integrate customer feedback more deeply into value creation and communication.

These trends influence marketing's overall image, reinforcing perceptions of it as manipulative or disconnected from real needs, which weakens its credibility and ability to build long-term relationships.

While this analysis focused on the 4P and 4C frameworks, it does not reflect the full complexity of marketing models, including the extended 7P mix for services (Booms, Bitner, 1981). Future analysis can investigate how dynamic aspects of social media, such as algorithmic filtering, virality, and online polarization, might distort or amplify negative perceptions.

Marketing is often misunderstood by academics, practitioners, and consumers. In both academic literature and public opinion, it is sometimes seen as a tool for manipulation, used by companies to influence consumer awareness, support corporate interests, and reinforce social inequalities. Critics argue that marketing can promote excessive consumerism, marginalize certain social groups, and focus on short-term profits rather than long-term value.

Researchers have frequently pointed out the lack of consensus regarding the definition of this discipline (Al-Noorachi, 2014; Krycia-Chomińska, 2025), which results in confusion and undermines its position. Instead of viewing emerging concepts as logically connected stages of evolution responding to social and economic changes, they are often seen as mutually exclusive. Practitioners, on the other hand, reduce marketing to a set of sales techniques, ignoring its strategic, ethical, and social dimensions. Marketing also faces similar criticism from consumers – social media regularly feature voices questioning the authenticity of brand actions, pointing out the poor quality of products, unethical campaigns, or manipulative loyalty strategies. As a result, marketing is reinforced as a superficial, manipulative discipline that does not align with the real expectations of consumers, undermining its social usefulness and long-term effectiveness of used tools, like marketing mix 4P and 4C.

The consequences of such an approach are significant – marketing is often seen as an unnecessary addition to "real" business, leading to the marginalization of its academic contributions and a decrease in the position of marketers within organizations. Their activities are reduced to operational functions, ignoring the strategic dimension of marketing and reducing it to superficial, short-term goals.

As a result, marketing becomes a victim of instrumental business thinking. The key issue is its narrow understanding by organizational leaders, who reduce marketing to a tool solely for profit maximization. This approach ignores its potential as a holistic process for building long-term, sustainable relationships with customers, employees, partners, and local communities. As Wojciechowski (2014) points out, in this context, "marketing missteps" occur—situations where marketing activities, although effective in the short term, cause long-term damage to brand reputation or social relationships. Kamiński (2016) adds that the instrumental treatment of marketing leads to the formation of a generation of specialists who view their role solely through the lens of corporate interest, losing sight of the broader social and environmental context of their actions.

Marketing loses its identity as a discipline focused on strategically creating value and building authentic relationships, becoming perceived as a tool of manipulation subordinated to the logic of short-term profit. This not only diminishes its potential but also undermines social trust and harms the reputation of marketing as a science—both as a field of knowledge and as a practice.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

EVOLUTION OF BUSINESS MODELS IN THE GAMING INDUSTRY IN THE CONTEXT OF SOCIAL MEDIA DEVELOPMENT

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Purpose: The purpose of this publication is to analyze the relationship between the evolution of business models in the gaming industry and the popularity of various social media platforms. The study aims to identify key trends in both areas and explore their mutual influences.
Design/methodology/approach: In the theoretical part, a critical literature analysis was conducted, including international and Polish sources. The research methodology involved analyzing data on active users of selected social media platforms and rankings of the most popular games from 2015 to 2024. Particular attention was paid to changes in game business models and their correlation with social media trends.
Findings: The research revealed a significant shift towards free-to-play models with microtransactions in the gaming industry, closely tied to the growing role of social media in game promotion and community building. The study identified key platforms like YouTube, Twitch, and TikTok as crucial for the gaming ecosystem, influencing both game popularity and longevity.
Research limitations/implications: The study primarily focused on global trends and popular titles. Future research could expand on regional differences and niche gaming markets.
Practical implications: The findings provide valuable insights for game developers and marketers on leveraging social media platforms effectively and adapting business models to current trends.
Social implications: Social media makes gaming a virtual space for socializing and collaboration, expanding players' social interactions worldwide. While increased access democratizes gaming, it also raises issues of ethics and consumer protection. Content creators shape public attitudes and promote a participatory culture. These shifts call for responsible industry practices and policies to ensure positive social impact and quality of life.
Originality/value: The article offers a comprehensive analysis of the interplay between gaming business models and social media trends over a decade, presenting an original perspective on their co-evolution.
Keywords: business models, gaming industry, social media, free-to-play, subscriptions, buy-to-play, microtransactions.
Category of the paper: Research paper.

1. Introduction

The concept of business models is becoming an increasingly dominant subject of research in the field of management sciences. Over the last decade, there has been a significant increase in the number of academic studies focusing on this topic (Osterwalder et al., 2012). Table 1 provides an overview of selected definitions of a business model.

Table 1.
Selected Definitions of Business Models

Authors	Definition
Afuah, Tucci (2003)	A strategy for enhancing and utilizing a company's resources to deliver an offering to customers that surpasses the competition while ensuring the profitability of the enterprise.
Amit, Zott (2001)	An integrated set of interrelated activities that defines how business operations are conducted in relation to customers, partners, and suppliers. This system extends beyond the firm's boundaries and includes activities aimed at satisfying identified market needs, specifying who performs these activities and how they are interrelated.
Falencikowski (2013)	A complex conceptual structure that describes business operations by explaining the logic behind value creation for the customer and the mechanism for capturing part of this value by the company.
Jabłoński (2013)	A business model is a specific combination of tangible assets and intellectual capital used to implement a strategy for increasing value in a given market situation. The attractiveness of a business model enhances a company's value. Business models are dynamic and continuously active, influencing company valuation and value creation in conjunction with a changing market environment.
Obłój (2002)	A holistic approach encompassing various elements that constitute a company's competitive advantage, key resources, competencies, and value chain structure.

Source: own elaboration based on: (Afuah, Tucci, 2003; Amit, Zott, 2001; Falencikowski, 2013; Jabłoński, 2013; Obłój, 2002).

The analysis of the evolution of business model definitions reveals interesting trends in the development of this concept within management sciences. All definitions treat the business model as an integrated system where both its internal components and market environment are important.

Early definitions focused on key elements within a company that enable it to achieve a competitive advantage. Over time, subsequent researchers expanded the conceptual scope of the business model by including relationships with external partners and dynamic market changes. Notably, newer definitions associate the business model with processes of value creation and capture. This trend emphasizes not only creating value for customers but also how organizations can leverage this value for their benefit.

Despite its evolution, certain consistent elements remain in business model definitions. They consistently highlight the role of the business model in achieving market advantage. A systematic approach to the business model persists, along with its customer orientation and strategic importance.

The concept of a business model and its components has been extensively analyzed in the literature (Osterwalder, 2005). According to this approach, a business model is "a conceptual tool encompassing components and their relationships aimed at presenting the logic behind how

a company operates. It describes how an enterprise creates value and derives profits from it". Developing a complete business model requires consideration of nine key elements (Table 2).

Table 2.
Elements of the business model

Main areas of the model	Key elements of the business model	Simplified description of the elements
Product	Value proposition	Specific benefits the company offers to its customers.
Customer	Target groups	Defining who the firm's offer is aimed at.
	Customer channels	Methods the company uses to reach customers and sell its products/services.
	Customer relationships	How the company builds and maintains relationships with its customers.
Organization of Activities	Key activities	The most important activities the company must perform to deliver value.
	Key resources	The main assets and skills needed to implement the business model.
	Business partners	A network of collaborators and suppliers supporting the company's operations.
Finance	Cost structure	The main costs associated with running the business.
	Revenue streams	Ways in which the company generates income.

Source: own elaboration based on (Osterwalder et al., 2005; Osterwalder, Pigneur, 2013).

The presented overview shows that definitions of business models have evolved from emphasizing internal resources and competitive advantage (Afuah, Tucci, 2003; Obłój, 2002) toward a broader perspective that integrates value creation and dynamic interactions with the environment (Amit, Zott, 2001; Falencikowski, 2013; Jabłoński, 2013). Osterwalder's framework, with its nine building blocks, provides a comprehensive lens for analyzing these shifts (Osterwalder et al., 2005; Osterwalder, Pigneur, 2013). It highlights not only how organizations create and deliver value, but also how they maintain customer relationships, organize key activities, and structure revenue streams. This theoretical foundation creates a solid basis for examining the specific case of the gaming industry, where rapid technological and social changes strongly influence business model design.

2. Selected business models in the gaming industry

The video game industry is one of the most demanding sectors for business operations, mainly due to the limited time for adaptation (Sotamaa, Karppi, 2010) and constant changes in consumer preferences (De Prato et al., 2014). To stay competitive in the market, companies must achieve high performance and have a business model that ensures customer retention. Over the past two decades, this industry has experienced impressive growth, largely due to increasing consumer interest in products from this field (Carpenter et al., 2014). Today, it is one of the most profitable areas of the media industry.

The free-to-play model in the online gaming sector is based on providing online games without charge, both on mobile devices and desktop computers. The source of revenue becomes virtual items that users can purchase during the game. Research has shown that players decide to make such purchases for various reasons, including ensuring an uninterrupted gaming experience, establishing connections with other players, participating in competition, and for economic considerations (Brasseur et al., 2017). This model derives directly from the business concept known as freemium. A characteristic feature of this model is offering a product or service free of charge, with a set of basic functions. (Teece, 2010; Hamari et al., 2017).

From the perspective of Osterwalder's framework, the free-to-play model redefines several key building blocks of the business model. Most visibly, it alters the revenue streams, shifting the focus from direct sales to continuous monetization through microtransactions. At the same time, the value proposition expands beyond the core gameplay to include personalization, social prestige, and uninterrupted access to the game. The role of customer relationships also changes, as developers rely on constant interaction, community engagement, and timely updates to sustain players' willingness to pay. Finally, social media platforms themselves become critical channels, serving as the primary means of reaching customers and stimulating viral growth (Osterwalder et al., 2005; Osterwalder, Pigneur, 2013).

In the subscription model, most commonly used in MMORPG (Massively Multiplayer Online Role Playing Game) games, players pay regular monthly fees, which provide a steady income for developers. The best example is "World of Warcraft" with a $14 monthly fee, although the games themselves often require huge investments (Makuch, 2012). This model is popular due to the long life cycle of the game and developed end-game content, which increases players' willingness to pay. However, due to growing competition, many games are switching to a free-to-play model with microtransactions. Even the creators of "World of Warcraft" have adapted their models, offering partially free gameplay for new players (Blizzard, 2025).

The subscription model emphasizes long-term customer relationships by offering continuous access to content and regular updates, thereby strengthening player loyalty. Its value proposition is based on stability and extended content, while predictable revenue streams provide developers with financial security and the possibility to invest in large-scale projects (Osterwalder et al., 2005; Osterwalder, Pigneur, 2013).

Since the creation of the first MMORPG games, players have created a virtual market within the game. This genre is not only associated with subscriptions but also with the pay-to-earn model. Virtual currency, earned through in-game achievements, was exchanged between players. The creators of World of Warcraft introduced auction houses where players could trade items such as resources (so-called mats), which were most often desired. Players discovered the possibility of earning money on this virtual currency and began selling it on auction platforms like eBay or Allegro. In response, game creators began to prohibit this practice, threatening punishment in the form of account blocking (Rapp, 2020). However, this is not the only game genre where such trade took place. Another example of trade exchange between players are the

so-called skins in the game CS GO (Yuan, 2024), which gained enormous popularity thanks to the activity of streamers from various parts of the world in 2015-2018.

3. Social media in the gaming industry

Social media are contemporary platforms for horizontal communication, whose effectiveness depends on the active engagement of users (Kaznowski, 2010). Users create original messages, and information processes are grassroots and uncoordinated. Time is not relevant to the importance of information - virtual events can generate new discourses even years later. The aim of this process is to create and strengthen social bonds, but it can lead to the creation of information bubbles, limiting access to information through content personalization and algorithms. In this way, social media can both enable communication and fragment society, limiting access to diverse perspectives. Table 3 presents an overview of definitions of this concept.

Table 3.
Selected definitions of social media

Author	Definition
Bauer (2009)	New media are characterized by a hypertext structure of transmission and reception, programmability (asynchrony of transmission and reception), interactivity, cumulativeness, global reach, and individual access.
Bielawski, Ziółkowska (2018)	Social media are characterized by scalability, universal access, unlimited possibilities for content modification, freedom of creation and reception, and direct community influence on the content and value of information.
Gręboszz, Siuda, Szymański (2016)	Social media are internet platforms where users create communities and transmit information through websites or applications.
Kaplan, Haenlein (2010)	Social media is a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of User Generated Content.
Kaznowski (2016)	Social media are means of communication subject to social control, used on any scale, containing both the content of the message and various points of view relating to the information.

Source: own elaboration based on: (Bauer, 2009; Bielawski, Ziółkowska, 2018; Gręboszz et al., 2016; Kaplan, Haenlein, 2010; Kaznowski, 2016).

The definition of social media has evolved over the years, reflecting changes in technology and the way these communication tools are used. In early interpretations, emphasis was placed primarily on the technical aspects of new media, such as hypertext structure and global reach. Over time, definitions began to focus more on social and interactive aspects. The concept of internet platforms as places where users create content and engage in online communities was introduced. This trend has continued in more contemporary definitions, which emphasize the freedom to create and modify content, as well as the community's influence on the value of information.

Despite these changes, certain elements have remained constant in definitions over the years. Interactivity has consistently been emphasized as a two-way nature of communication that enables active user engagement. Similarly, global reach has always been an important component, including the ability to reach a wide audience. User-generated content, although initially less emphasized, has over time become a key element of the definitions.

The classification of social media by function includes the following types (Kaznowski, 2016):

- Social media for publishing opinions and views - This category enables open expression of thoughts by users. Examples include blogs and citizen journalism platforms.
- Social media for resource sharing - Based on the idea of Web 2.0, these involve sharing resources online, such as videos, photos, or presentations. Examples include YouTube, Flickr, and Slideshare.
- Social media focused on co-creation and collaboration - These are relatively rare and focus on achieving specific goals through collaboration. Examples include tools like Google Docs or MMO (Massive Multiplayer Online) games.
- Social media aimed at building and maintaining relationships - The most popular form of social media, examples being social networking sites and virtual worlds.

The presented classification illustrates that social media are not homogeneous but encompass diverse functions, ranging from opinion sharing to collaborative content creation. Despite their variety, all categories share two fundamental features: interactivity and the ability to shape community relationships (Kaplan, Haenlein, 2010; Kaznowski, 2016). These characteristics make social media particularly relevant for the gaming industry, where platforms simultaneously act as channels of communication, arenas of value co-creation, and spaces for sustaining long-term customer relationships. This multidimensional nature positions social media as a critical factor influencing the design and evolution of contemporary business models.

4. Research overview

To identify social media platforms most closely associated with the gaming industry, it's worth examining relevant research. Gandolfi (2016) study aimed to understand the motivations and behaviors of Twitch users. Gandolfi's research model encompassed three key dimensions: Information, Entertainment, and Socialization. The study results showed that the main motivation for using Twitch is entertainment, with an average rating of 4.56 on a five-point Likert scale. Other significant reasons include observing gaming events (3.95) and using the platform as an alternative to television (3.74). Regarding information, the highest-rated aspect was the ability to acquire new strategies and techniques (3.46). Socialization, though less

important, received the highest average of 2.23 for communication between users. The analysis also showed that users spending more time on the platform are inclined to spend more. It was also noted that the importance of socialization in platform usage increases over time.

Mastiņš (2024) aimed to investigate TikTok's impact on streamers' popularity. The study involved interviews and a survey with experienced streamers. TikTok was identified as the most promising promotional tool for streamers due to its reach and short-form video format. Funny gaming moments, memes, and trends are popular. Networking and collaboration with other creators proved important for increasing visibility. The study results show that many streamers regret not starting to promote their content on media outside streaming platforms earlier or not publishing enough of it.

Sjöblom and Hamari (2021) conducted a study aimed at analyzing viewers' motivations and forms of engagement during live video game broadcasts on Twitch and YouTube platforms. The authors developed a research model based on the "Uses and Gratifications" theory, which included five main motivation dimensions: Affective, Cognitive, Personal Integrative, Social Integrative, and Tension Release. Data was collected through an online questionnaire with 1097 respondents. The main motivation for watching live game broadcasts is the emotional aspect. Other important motivations are tension reduction and cognitive aspects. The analysis showed that these motivations are strongly related to various forms of viewer engagement, such as subscriptions or donations. Different types of games attract viewers with different motivations. For example, strategy games are more associated with cognitive aspects, while RPGs are associated with emotional tension release.

5. Research methodology

For the purpose of this article, an analysis was conducted on the number of active users of selected social media platforms that allow creators to conduct live broadcasts, and a list of the most popular games from 2015-2024. Particular attention was paid to the growing number of visitors to individual sites and changes in game business models (with emphasis on key resources and ways of reaching customers). Several cases indicating strong dependencies were identified.

Most of the data on active user lists comes from DataReportal reports, pertaining to the entire world and largely based on information published by the companies mentioned below. Where this was unavailable, services such as Statista were used, which provide many statistical reports depending on user requirements.

The game ranking was divided into best-selling games in given years (buy-to-play) and highest-earning games (free-to-play). Both models in most titles included microtransactions. Where this was not the case, it is marked in Table 5. The compilation was based on industry

reports from companies such as Sensor Tower, SuperData Research, gaming websites such as Eurogamer, Gamespot, or Pocket Gamer, and directly from publishers including Activision Blizzard, Electronic Arts, and Rockstar Games.

6. Popularity of selected social media and the most popular games in 2015-2024

Table 4 presents data on the number of active users (in millions) of five popular social media platforms that enable video game streaming from 2015 to 2024. The first column contains the names of social media platforms, such as Facebook, YouTube, Instagram, TikTok, and Twitch. In the subsequent columns, data for selected years from 2015 to 2024 is presented. These selected periods allow for tracking significant changes in the usage of these platforms at key points in time, which facilitates the analysis of long-term trends.

Table 4.
Number of active users (in millions) using social media platforms enabling video game streaming from 2015-2024

Platform	2015	2016	2017	2018	2019	2020	2022	2023	2024
Facebook	1,366	1,550	1,871	2,167	2,271	2,449	2,910	2,958	3,065
YouTube	1,200	1,400	1,500	1,800	2,000	2,300	2,600	2,680	2,700
Instagram	300	400	600	800	1,000	1,000	1,478	2,000	2,000
TikTok						347	500	800	1,000
Twitch	0.53	0.61	0.77	1.07	1.26	2.12	2.78	2.58	2.38

Source: own elaboration based on: (DataReportal, Demandsage, Statista, Business of apps, Oberlo, Twitch Tracker).

The presented data indicates an increase in popularity for all mentioned platforms, with Facebook and YouTube still holding leading positions. Meanwhile, Instagram and TikTok have seen significant growth in user numbers, and Twitch, despite a smaller base, has recorded a substantial increase in users, especially between 2019-2022.

Table number 5 includes two main sections: "Most profitable games" and "Best-selling games (buy-to-play)" for the years 2015-2024. For each year, three titles are presented in both categories, allowing for analysis of trends in the gaming industry over a decade. The profitable games section contains information about the title and business model, while the sales section focuses on games in the traditional buy-to-play model.

Table 5.
Most profitable and best-selling games from 2015-2024

Most profitable games		Best-selling games (buy-to-play)
2015		
Title	**Business model**	**Title**
League of Legends	Free-to-play (PC)	Grand Theft Auto V
Monster Strike	Free-to-play (mobile game)	Fallout 4
Clash of Clans	Free-to-play (mobile game)	Ark: Survival Evolved
2016		
Title	**Business model**	**Title**
League of Legends	Free-to-play (PC)	CS GO
Honor of Kings / Arena of Valor	Free-to-play (mobile game)	DOTA 2
Monster Strike	Free-to-play (mobile game)	No Man's Sky
2017		
Title	**Business model**	**Title**
Honor of Kings / Arena of Valor	Free-to-play (mobile game)	PlayerUnknown's Battlegrounds
League of Legends	Free-to-play (PC)	Call of Duty: WWII
Dungeon Fighter Online	Free-to-play (PC)	Grand Theft Auto V / Online
2018		
Title	**Business model**	**Title**
Fortnite	Free-to-play (PC)	Red Dead Redemption 2
Honor of Kings / Arena of Valor	Free-to-play (mobile game)	Call of Duty: Black Ops 4
League of Legends	Free-to-play (PC)	NBA 2K19
2019		
Title	**Business model**	**Title**
Fortnite	Free-to-play (PC)	Grand Theft Auto V
PlayerUnknown's Battlegrounds	Free-to-play (mobile game)	Pokémon Sword and Shield*
Dungeon Fighter Online	Free-to-play (mobile game/PC)	Call of Duty: Modern Warfare
*game is the only one among those listed that does not include microtransactions		
2020		
Title	**Business model**	**Title**
PlayerUnknown's Battlegrounds	Free-to-play (mobile game)	Animal Crossing: New Horizons
Honor of Kings / Arena of Valor	Free-to-play (mobile game)	Call of Duty: Modern Warfare
Roblox	Free-to-play (PC)	FIFA 20
*game is the only one among those listed that does not include microtransactions		
2021		
Title	**Business model**	**Title**
PlayerUnknown's Battlegrounds	Free-to-play (mobile game)	Minecraft
Honor of Kings / Arena of Valor	Free-to-play (mobile game)	Pokémon Brilliant Diamond / Shining Pearl
Dungeon Fighter Online (DFO)	Free-to-play (mobile game/PC)	New World
2022		
Title	**Business model**	**Title**
Honor of Kings / Arena of Valor	Free-to-play (mobile game)	Pokémon Scarlet / Violet*
PlayerUnknown's Battlegrounds	Free-to-play (mobile game)	Elden Ring
Dungeon Fighter Online (DFO)	Free-to-play (mobile game/PC)	Call of Duty: Modern Warfare II
*game is the only one among those listed that does not include microtransactions		
2023		
Title	**Business model**	**Title**
Honor of Kings / Arena of Valor	Free-to-play (mobile game)	Hogwarts Legacy
PlayerUnknown's Battlegrounds	Free-to-play (mobile game)	Call of Duty: Modern Warfare III
Candy Crush Saga	Free-to-play (mobile game)	The Legend of Zelda: Tears of the Kingdom*
*game is the only one among those listed that does not include microtransactions		

Cont. table 5.

2024		
Title	**Business model**	**Title**
Honor of Kings / Arena of Valor	Free-to-play (mobile game)	Call of Duty: Black Ops 6
Monopoly Go	Free-to-play (mobile game)	EA Sports College Football 25
Royal Match	Free-to-play (mobile game)	Helldivers 2

source: own elaboration based on: (Activision, 2020; App2Top, 2024; Business of Apps, 2022; China Film Insider, 2017; CNBC, 2016; Epic Games, 2021; Eurogamer, 2016; GameRant, 2024; Games Industry, 2016, 2020; GameSpot, 2017, 2022; Gilmore Jon, 2024; KRAFTON, 2022; League of Betting, 2017; NDTV, 2017; Newzoo, 2020; Niko Partners, 2019; Nintendo, 2020, 2022, 2023; PocketGamer.biz, 2024; Pocket Gamer, 2016; Sensor Tower, 2021, 2022; SuperData, 2017, 2018, 2020, 2021; The Jakarta Post, 2017; The Sage News, 2024; Variety, 2018; VentureBeat, 2019).

Over the years, there is a visible dominance of the free-to-play model among the most profitable titles, although initially, buy-to-play games were more popular. This trend continues throughout the analyzed period, indicating the effectiveness of the free-to-play model in generating revenue.

With the development of mobility, we observe an increasing presence of mobile games among the most profitable titles. In later years, mobile games often dominate this category, which demonstrates a change in player preferences and the development of the mobile market. The popularity of particular genres is also changing - while in the initial years MOBA games dominated (e.g., League of Legends), later on, battle royale games (e.g., Fortnite, PUBG) and open-world games gained importance.

Some games, like Grand Theft Auto V or League of Legends, remain on the lists for many years, which indicates a change in approach to the game life cycle - from a one-time sale model to a long-term support and update model. Throughout the analyzed period, it's evident that well-known franchises (e.g., Call of Duty, Pokémon) regularly appear among the best-selling games, confirming the strength of recognizable brands.

Microtransactions also remain a constant element, with exceptions to this trend clearly marked in the table. All segments of the gaming market - PC, consoles, and mobile devices - are consistently included, indicating their sustained importance. The seasonality of releases is also visible, with a tendency to publish big titles during the pre-holiday period, which is reflected in the annual lists of best-selling games.

7. Summary

One of the most significant impacts of social media on the gaming industry is the transformation of business models. The traditional buy-to-play model has, in many cases, been replaced by the free-to-play model, which relies on microtransactions and the sale of virtual items. This shift is directly tied to the growing role of social media in promoting games and building gaming communities.

7.1. YouTube - long-form content as a channel for knowledge and promotion

The revolution in the industry began with Fortnite's success in 2017-2018, which, thanks to its free model with microtransactions, displaced a paid competitor - PlayerUnknown's Battlegrounds (PUBG). The key was integration with streaming platforms like Twitch and YouTube Gaming. Fortnite, designed with spectacular gameplay in mind, became ideal content for creators (Gexe, 2025). Unlike PUBG, which was available for purchase on PC, Fortnite's free access increased availability, enabling broader promotion through user-generated content. Games that combine ease of streaming with a free-to-play model gained a competitive advantage, even against long-standing titles like League of Legends (LoL), which, despite having a massive monthly active player base, saw flattened growth in favor of newer productions. YouTube, which had 1.2 billion users in 2015 and reached 2.7 billion in 2024, remains a key platform for the gaming industry. According to research, 74% of teenagers regularly watch gameplay videos on YouTube. This platform is especially important for RPG and strategy games, which require longer sessions and more detailed tutorials (Bleeding Edge, 2024).

7.2. TikTok and Discord - virality and social spaces

Lockdowns highlighted the demand for games as virtual social spaces. Roblox became a platform for hosting virtual birthday parties and social gatherings (Wirtualne Media, 2023), offering tools for creating private worlds and chat integration. Similarly, Minecraft leveraged the trend of creative collaboration, allowing players to work together on building projects. The social value of these titles was enhanced by platforms like Discord (an internet communicator enabling voice chat via microphone (Semcore, 2024)) and TikTok.

7.3. Twitch - live streaming and community engagement

Content creators have become crucial both for sudden surges in popularity (e.g., Fall Guys in 2020 due to Twitch streamers (Twitch Tracker, 2025)) and for extending the lifespan of older titles. Minecraft, which has existed since 2011, is experiencing a renaissance thanks to "Survival Multiplayer" series on YouTube, where influencers create new narratives around the game. Streamers such as Ninja (Fortnite) or Disguised Toast (Among Us) not only popularize strategies but also influence developers' decisions - for instance, introducing timed events to enhance the FOMO ("fear of missing out") effect (Inneo, 2020).

7.4. Ethical and regulatory challenges

Alongside new opportunities, gaming business models also face ethical and regulatory challenges. Investigations by the Belgian Gaming Commission into titles such as FIFA 18, Overwatch, and Counter-Strike: Global Offensive showed that loot boxes often meet the legal criteria of gambling, exposing even underage players to risks (Gaming Commission, 2018).

Similar concerns have been raised by regulators in Poland, France, and the Netherlands, underlining the need for stricter consumer protection measures.

Another important concern relates to gaming disorder, which has been recognized as a behavioral addiction. While Internet Gaming Disorder was included in Section 3 of the DSM-5 as a condition requiring further study (American Psychiatric Association, 2013), the WHO officially classified gaming disorder in the ICD-11 as an addictive behavior alongside gambling (World Health Organization, 2019). Research highlights its impact on young people, whose excessive gaming can impair personal, educational, and social functioning (Grzegorzewska, Cierpiałkowska, 2018; Gaebel, Zielasek, Reed, 2017). These findings emphasize that, beyond innovative value propositions and new revenue streams, the industry must also confront public health challenges.

7.5. Integrated perspective - convergence of business models and social media

The evolution of business models in games is tightly connected to the development of microtransaction systems and player-to-player trading, which represents another point of intersection with social media trends.

Future research could focus on analyzing the impact of social media on the evolution of business models in gaming, such as the expansion of microtransactions and player trading. Another interesting direction is the role of content creators in ensuring the longevity of games and their influence on developers' design decisions. Additionally, it is worth exploring social spaces in games and how platforms like Discord or TikTok strengthen social interactions.

When viewed through the lens of Osterwalder's model, these transformations illustrate how different business logics converge. Value propositions increasingly rely on free access combined with exclusive digital goods, while channels such as YouTube or TikTok amplify reach and visibility. Customer relationships are strengthened by the participatory nature of platforms like Discord, where developers and players co-create game experiences. Finally, revenue streams diversify, ranging from subscriptions and premium passes to donations and in-game purchases, making the social media-gaming nexus not only a cultural but also a financial ecosystem (Osterwalder et al., 2005; Osterwalder, Pigneur, 2013).

Acknowledgements

The publication is financed from the subsidy granted to the Krakow University of Economics within the Support for Conference Activities 2025 (Wsparcie Aktywności Konferencyjnej 2025) programme.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

CREATIVE THINKING ATTITUDES AS DETERMINANTS OF INNOVATION – ORIENTED INFORMATION SYSTEM DESIGNES IN THE CREATIVE SECTOR

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Purpose: The study examines how creative thinking attitudes among employees and managers in the creative sector influence the development and use of innovation-oriented information systems (IS). It addresses a gap in the literature by exploring how attitudinal factors shape IS features that support creativity and innovation.
Design/methodology/approach: A quantitative approach was used, employing the Attitudes and Preferences Questionnaire (KPP) by Nęcka, adapted from Basadur and Hausdorf's scale. Data were collected via an online CAWI survey of 126 respondents from 89 Polish creative enterprises. Exploratory factor analysis identified underlying dimensions, and independent t-tests assessed differences across gender and organizational roles.
Findings: Two factors emerged: (1) "Creative thinking is important and pleasant" and (2) "No time for creative thinking at work." Both groups expressed positive attitudes toward creativity, with no significant differences between them. However, time pressure was widely perceived as a barrier. Creativity appears to be a shared organizational value, though constrained by structural limitations.
Research limitations/implications: The study is limited to one national context and relies on self-reported data. Future research should apply cross-cultural and longitudinal designs, as well as qualitative methods.
Practical implications: Findings offer guidance for designing user-centered IS that support creativity, optimize workflows, and incorporate adaptive and feedback features to foster innovation.
Social implications: Such systems may enhance employee satisfaction, support creative industry growth, and contribute to regional development.
Originality/value: This is among the first studies to empirically link creative thinking attitudes with IS design in the creative sector.
Keywords: Creative thinking attitudes; Innovation-oriented information systems; Creative sector; Digital innovation; User-centered design.
Category of the paper: Research paper.

1. Introduction

In an era of accelerating digital transformation, creativity has become a critical asset for organizations aiming to maintain competitiveness and foster innovation. This is particularly true in the creative sector, where ideation, experimentation, and collaboration are deeply embedded in everyday practices. Despite the increasing reliance on information systems (IS) to support such activities, the attitudinal and cognitive dimensions of system users remain underexplored in IS design research. This article investigates how employees' and managers' attitudes toward creative thinking influence the development and functionality of innovation-oriented IS. By combining empirical findings with a socio-technical perspective, the study offers both theoretical insights and practical guidelines for aligning IS design with creative organizational cultures. The article begins with a theoretical background, followed by a description of the methodology, presentation of results, discussion, and final conclusions.

2. Literature review

Creativity is widely recognized as a fundamental competence in contemporary organizations, particularly those operating under conditions of rapid technological and market change (Adebowale, 1991). In the creative sector, where innovation constitutes the primary driver of competitiveness and growth, the ability to understand and nurture employees' creative thinking attitudes is essential for sustaining long-term success (Dyduch, 2020). Creative attitudes determine not only how individuals generate ideas but also how they engage in collaborative innovation processes, making them a crucial element of organizational culture (Amabile, 1983).

With the increasing reliance on digital technologies, creativity has become both a source of novel ideas (Gregory et al., 2023) and a key capability shaping innovation strategies, digital transformation, and organizational adaptability (Strojek-Filus, 2014). In this context, recent studies emphasize that the development of digital solutions, including information systems, increasingly relies on approaches that integrate both technological and human-centered perspectives. Design Science Research (DSR) provides a valuable framework for linking theory and practice in the design of digital innovation, ensuring that systems are not only efficient but also aligned with user creativity and organizational needs (Hevner et al., 2020).

Information systems (IS), which serve as the backbone of digital operations, must therefore evolve beyond traditional efficiency-oriented solutions. Modern IS are expected to actively support cognitive flexibility, ideation, and experimentation—qualities fundamental to creative work.

The creative sector provides a particularly compelling context for studying these dynamics. Employees and managers in creative enterprises—spanning industries such as design, advertising, IT, media, and cultural production—work in environments where technology, knowledge, and creativity intersect. They rely on IS not only for operational tasks but also for project coordination, content creation, and the generation of innovative solutions. Their creative thinking attitudes directly influence how IS are perceived, adopted, and used in everyday practice, affecting the overall capacity of organizations to innovate.

Furthermore, the socio-technical perspective on IS development emphasizes that technological tools should be aligned with human cognitive capabilities, organizational values, and cultural norms (Patmore, 2025). Creativity in IS design is no longer confined to isolated phases of system development but is embedded in iterative, collaborative, and cross-functional innovation efforts (Strohman et al., 2023). This integration is becoming even more pronounced with the advent of AI-driven solutions, which require systems to adapt dynamically to users' needs while fostering creativity rather than constraining it.

Despite the growing recognition of these interdependencies, the role of employees' creative attitudes—especially within the creative sector—remains underexplored in relation to the design of IS that support innovation. Existing research has primarily focused on technological or managerial aspects of innovation, often overlooking the cognitive and attitudinal dimensions that underpin user interactions with technology (Ciriello et al., 2024).

The present study addresses this gap by examining how creative thinking attitudes among employees and managers influence the development and utilization of innovation oriented IS in creative enterprises. By identifying the dominant dimensions of these attitudes and their implications for IS design, this research contributes to both the theoretical understanding of creativity in digital environments and the practical development of user-centered systems that enhance innovation capabilities.

Recent research in human-computer interaction (HCI) and user experience (UX) design highlights the importance of integrating users' emotional, cognitive, and social needs into system design, especially in creative environments (Qi et al., 2025). Positive user experience depends not only on system usability but also on the fulfillment of psychological needs such as autonomy, competence, and relatedness—factors that are also crucial for supporting creative engagement (Hassenzahl, 2010). The need for systems that enable meaningful interaction, co-creation, and serendipity is increasingly emphasized in innovation-oriented settings (Gustomo et al., 2022).

Digital tools in creative contexts should be evaluated not only for efficiency but also for their ability to stimulate insight, reflection, and emotional resonance (Sas et al., 2009). These considerations are increasingly relevant in the creative sector, where IS are expected to inspire ideation and adapt to diverse work styles. Incorporating these insights into system design aligns with the socio-technical approach and extends the theoretical foundation for understanding how IS can support creativity in practice (Samper et al., 2025).

Accordingly, the aim of this study is threefold. First, it seeks to identify the dominant dimensions of creative thinking attitudes among employees and managers working in the creative sector. Second, it aims to examine whether these attitudes differ depending on respondents' gender or organizational role, thus providing insight into potential segmentation of user needs in the design of innovation-oriented information systems. Third, the study explores how these attitudinal patterns can inform the development of user centered IS solutions that foster creativity and support digital innovation within creative enterprises.

3. Methodology

The study employed a quantitative research approach using the Attitudes and Preferences Questionnaire (KPP) developed by Edward Nęcka, adapted from the scale by Basadur and Hausdorf (Nęcka, 1999). This tool is widely applied in research on organizational creativity, enabling the diagnosis of factors shaping employees' attitudes toward creative processes at work. The questionnaire consists of statements assessed on a Likert scale (from 1 – "strongly disagree" to 5 – "strongly agree") and measures the perceived value of creativity, motivation for creative actions, and perceived organizational barriers. For the purpose of this research, special emphasis was placed on identifying dimensions of creative thinking attitudes that may serve as a basis for designing innovation-oriented information systems.

The research sample included 126 respondents employed in 89 creative sector enterprises located in the West Pomeranian region of Poland. Companies were selected based on the PKD 2007 classification relevant to creative industries, including trade in creative goods (Section G), media and IT (Section J), architecture and advertising (Section M), and cultural institutions (Section R). The participants comprised both employees and managers, allowing for a comparison of attitudes across organizational levels. The sample consisted of 53 women (42%) and 73 men (58%), with 62 employees (49%) and 64 managers (51%). The detailed sample structure is presented in Table 1.

This study adopted the assumption that geographical location does not significantly differentiate attitudes toward creative thinking within the creative sector. The author relied on the premise that the mechanisms fostering creativity, as well as the challenges associated with its implementation, are largely universal across this sector, regardless of administrative region. Due to its specific characteristics, the creative sector tends to exhibit a high degree of homogeneity in terms of values, processes, and organizational culture—particularly within digital and project-based contexts. Therefore, it was assumed that enterprises from the West Pomeranian Voivodeship could constitute a representative sample, allowing for the formulation of broader conclusions applicable to the functioning of the creative sector in other regions as well.

The survey was conducted using the CAWI (Computer-Assisted Web Interview) method, which enabled reaching respondents from various locations while minimizing data collection costs and time. The questionnaire was distributed electronically via industry networks and direct contact with companies. Participants were informed about the purpose of the study and assured of full anonymity. The collected data were statistically analyzed using SPSS software.

Data analysis involved two main stages. First, exploratory factor analysis (EFA) was performed to identify the underlying dimensions of creative thinking attitudes. Both two-factor and three-factor models were evaluated based on eigenvalues greater than 1 and the scree plot criterion. Model fit was supplemented by reliability assessment using Cronbach's alpha. In the second stage, independent samples t-tests were applied to explore potential differences in creative attitudes depending on gender and organizational role (employee vs. managerial staff). These analyses allowed for a deeper understanding of how demographic and organizational factors may influence attitudes toward creativity.

Table 1.
Sample characteristics based on PKD classification and demographics

Category	Number of respondents	Percentage (%)
Gender: Women	53	42%
Gender: Men	73	58%
Position: Employees	62	49%
Position: Management staff	64	51%
Type of business: Section G (Trade)	7	8%
Type of business: Section J (Media, IT)	39	44%
Type of business: Section M (Architecture, Advertising)	34	38%
Type of business: Section R (Culture, Arts)	9	10%

Source: Own elaboration.

4. Results

The results of the statistical analysis revealed clear patterns regarding employees' and managers' attitudes toward creative thinking in the creative sector. Exploratory factor analysis (EFA) confirmed the presence of two distinct dimensions. The first factor, labeled "Creative thinking is important and pleasant", captured positive perceptions of creativity, including enjoyment of idea generation, belief in the importance of innovation, and intrinsic motivation to engage in creative problem-solving. The second factor, "No time for creative thinking at work", reflected perceived organizational constraints, time pressure, and negative attitudes that may inhibit creative engagement. Both factors demonstrated satisfactory reliability, with Cronbach's alpha coefficients exceeding the 0.7 threshold.

Factor loadings for each item are presented in Table 2. Items loading strongly on the first factor included statements such as "Ideas are fundamental in decision-making" (loading 0.763) and "I feel genuine excitement when I come up with a new idea" (0.731), emphasizing the value

and positive emotions associated with creativity. In contrast, items strongly loading on the second factor, such as "Talking about new ideas increases workload and confusion" (0.754) and "I am too busy to think of extraordinary ideas" (0.728), revealed that time constraints and organizational norms may create barriers to creative thinking.

Table 2.
Factor loadings for extracted factors (two-factor solution)

Item	Factor 1: Creative thinking is important and pleasant	Factor 2: No time for creative thinking at work
3. Ideas are fundamental in decision-making.	0.763	–
15. I feel genuine excitement when I come up with a new idea.	0.731	–
7. Management should encourage the generation of ideas.	0.719	–
21. Constructive changes are important in the workplace.	0.703	–
19. Crazy ideas can sometimes lead to innovations.	0.691	–
9. I enjoy the challenge of finding alternative solutions.	0.676	–
13. Most innovations arise from needs or problems.	0.634	–
14. Talking about new ideas increases workload and confusion.	–	0.754
12. I am too busy to think of extraordinary ideas.	–	0.728
10. Truly creative people are disorganized.	–	0.697
16. Only ideas related to important projects matter.	–	0.675
8. I often feel ashamed to propose unusual ideas.	–	0.639
22. If everyone generates ideas, no one works.	–	0.609
4. New ideas rarely work out. (R)	–	0.604
20. Listening to others' ideas is a waste of time. (R)	–	0.576
18. The boss's idea is usually the best one. (R)	–	0.553

Source: Own elaboration based on Nęcka, 1999.

Independent t-tests were conducted to examine potential differences in creative thinking attitudes across gender and organizational roles. The results indicated no statistically significant differences between women and men or between employees and managers in both factors. For example, the comparison of the factor "Creative thinking is important and pleasant" between women (M = ...) and men (M = ...) yielded a $t(124) = -1.89$, $p = 0.061$, suggesting only a marginal, non-significant trend toward differences. Similarly, the factor "No time for creative thinking at work" did not show significant variation across groups. Effect sizes (Cohen's d) for all comparisons were small, confirming the homogeneity of attitudes across demographics and roles.

Table 3 summarizes the outcomes of t-tests, demonstrating that the positive perception of creativity is consistently shared across groups, while perceived time-related barriers remain similar regardless of gender or managerial position. These results suggest that creativity is a culturally embedded value in creative enterprises, not limited to specific roles or demographics.

Table 3.
T-test results for gender and role comparisons

Comparison	Group 1 (n)	Group 2 (n)	t-value	df	p-value	Cohen's d
Creative thinking is important and pleasant – Women vs. Men	Women (n = 53)	Men (n = 73)	–1.89	124	0.061	0.34
No time for creative thinking at work – Women vs. Men	Women (n = 53)	Men (n = 73)	0.38	124	0.706	0.07
Creative thinking is important and pleasant – Employees vs. Managers	Employees (n = 62)	Managers (n = 64)	–0.93	124	0.352	0.17
No time for creative thinking at work – Employees vs. Managers	Employees (n = 62)	Managers (n = 64)	–1.64	124	0.104	0.29

Source: Own elaboration based on Nęcka, 1999.

Figures 1 and 2 visualize mean standardized scores for both factors by gender and organizational role. The visual representation confirms that while mean differences exist, they are not large enough to reach statistical significance. This homogeneity implies that both employees and managers value creativity equally and face similar challenges related to time pressure.

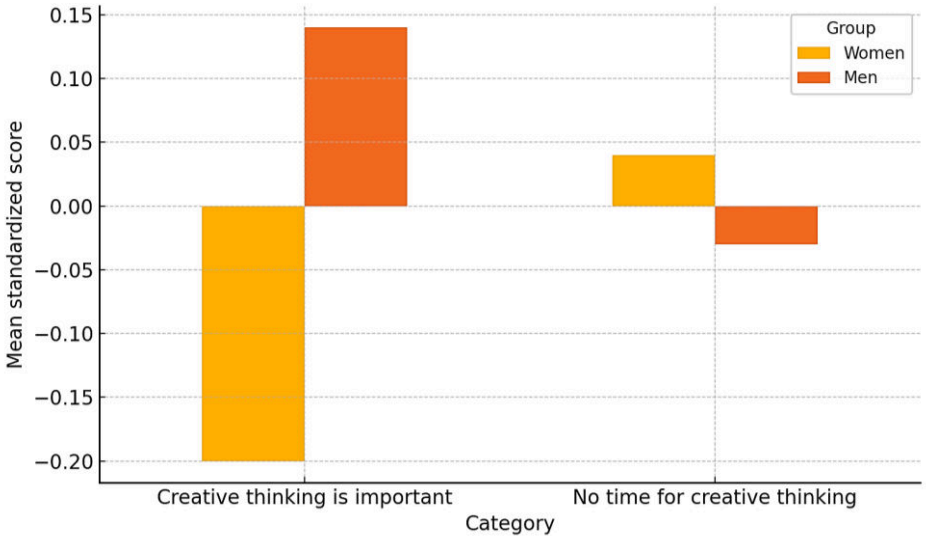

Figure 1. Mean standardized attitudes toward creativity by gender.
Source: own elaboration.

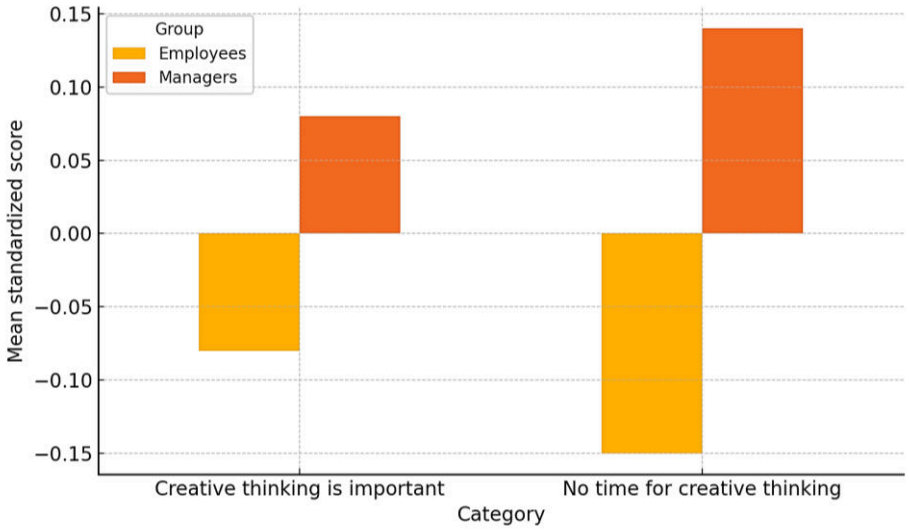

Figure 2. Mean standardized attitudes toward creativity by organizational role.
Source: own elaboration.

Overall, the findings highlight two important conclusions. First, creative thinking is widely appreciated among personnel in the creative sector, reinforcing the idea that creativity constitutes a shared organizational value. Second, perceived barriers such as lack of time are a common challenge that may hinder the translation of creative potential into innovative outcomes. These insights provide a foundation for developing information systems that not only recognize creativity as an intrinsic value but also address structural obstacles to its practice.

5. Discussion

The findings of this study provide a valuable foundation for translating the identified creative thinking attitudes into practical guidelines for designing innovation-oriented information systems (IS) within the creative sector. Since employees and managers consistently value creativity while simultaneously perceiving time as a barrier, IS solutions must be designed not only as tools for efficiency but also as enablers of ideation and innovation. The socio-technical approach suggests that effective IS should simultaneously address technological, cognitive, and organizational dimensions to achieve optimal alignment with user needs.

Firstly, information systems must reflect and support users' intrinsic valuation of creativity. This requires the integration of features that encourage exploration, experimentation, and idea-sharing rather than imposing rigid workflows that constrain creative potential. Systems designed for creative enterprises should promote autonomy, allowing users to shape their own digital environments according to the needs of their projects. For instance, customizable dashboards, flexible data visualization tools, and open collaboration spaces can stimulate creative problem-solving.

Secondly, the results highlight the need to facilitate time and space for creative ideation within digital workflows. Many respondents perceived a lack of time as a barrier to creative thinking. IS can mitigate this issue by embedding functions that optimize time management, automate routine tasks, and create digital "creative buffers"—dedicated spaces or modules where brainstorming, prototyping, and experimentation can occur without disrupting operational processes.

Thirdly, adaptive user experience (UX) features are essential to accommodate varied cognitive attitudes and working styles. Modern IS equipped with AI-driven personalization can dynamically adjust interfaces, suggest relevant resources, and adapt workflows to user preferences. Such adaptive systems can enhance engagement by aligning with the cognitive flexibility required in creative work.

Finally, integrating feedback mechanisms within IS is crucial for recognizing and promoting creative contributions. The study shows that employees value creativity but often face organizational barriers. By embedding collaborative evaluation tools, peer recognition systems, and AI-supported feedback loops, IS can strengthen motivation, enhance knowledge sharing, and support a culture of continuous innovation.

These principles emphasize that innovation-oriented IS should be user-centered, flexible, and creativity-enabling rather than solely task-oriented. Systems developed according to these guidelines can help creative enterprises sustain digital innovation by leveraging employees' positive attitudes toward creativity while addressing structural barriers.

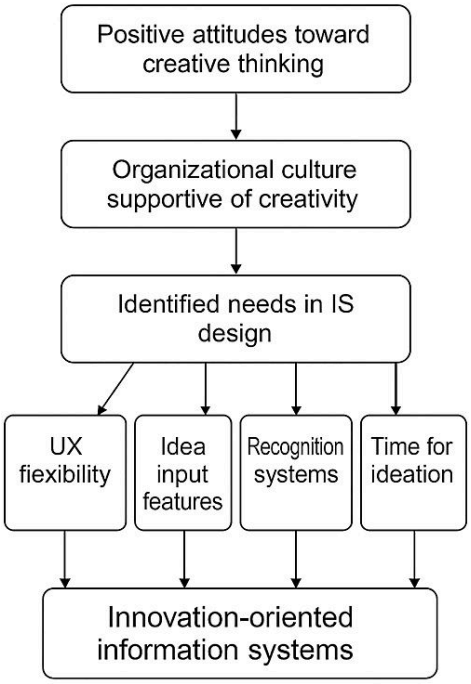

Figure 3. Flow diagram: From attitudes to IS features supporting creativity.

Source: own elaboration.

The conceptual framework developed in this study, presented in Figure 3, illustrates the flow from creative thinking attitudes to IS design features. The model demonstrates how attitudes such as the appreciation of creativity and perceived time constraints inform specific IS functionalities, leading to enhanced organizational innovation. This framework can serve as a practical reference for system designers, developers, and decision-makers involved in the digital transformation of creative enterprises.

These design implications underline the critical role of aligning technological solutions with human creativity, setting the stage for the concluding section that summarizes the study's contributions and outlines directions for future research.

To further strengthen the practical relevance of this framework, several information system functionalities can be proposed that directly correspond to the attitudinal dimensions identified in this study. For example, companies such as Miro (www.miro.com, August 20, 2025) or Notion (www.notion.com, August 20, 2025) offer customizable digital workspaces where employees can engage in collaborative ideation and brainstorming—illustrating how "creative buffers" can be embedded within routine workflows. Similarly, Asana's (www.asana.com, August 20, 2025) ideation modules and Trello's (www.trello.com, August 20, 2025) custom templates allow users to map out innovative ideas alongside task management functions, reflecting the dual need for efficiency and creativity.

An example of AI-powered personalization is seen in platforms like Monday.com (www.monday.com, August 20, 2025), where the interface dynamically adjusts based on project type or user input patterns. This aligns with the need for adaptive UX highlighted by respondents. Likewise, tools such as Slack (www.slack.com, August 20, 2025) integrations for peer recognition e.g., HeyTaco (www.heytaco.com, August 20, 2025) demonstrate how feedback mechanisms can be effectively integrated into daily IS use, promoting a culture of acknowledgment and ongoing innovation.

Figure 3 encapsulates this approach by showing how attitudes such as valuing creativity and time constraints translate into key IS functionalities—including adaptive UX, time-blocking tools, and feedback loops. These examples support the claim that aligning system design with cognitive and organizational realities in the creative sector is both necessary and achievable.

6. Summary

The study confirms that employees and managers in the creative sector share a consistently positive attitude toward creative thinking, which aligns with findings in previous research on organizational creativity. This shared value indicates that creativity is deeply embedded in the culture of creative enterprises, regardless of hierarchical position or gender. Although no

statistically significant differences were observed between the analyzed groups, both employees and managers contribute unique perspectives and expectations that must be considered when designing and implementing information systems.

The results highlight that positive attitudes toward creativity coexist with perceived organizational barriers, particularly time constraints, which may hinder the full expression of creative potential. This duality suggests that organizations need to address not only the encouragement of creative thinking but also structural factors that inhibit ideation. Information systems play a crucial role in this process, as they can be designed to both leverage existing creative values and mitigate obstacles that limit innovation.

The implications of this study suggest that user centered IS solutions should not only enhance operational efficiency but also actively promote collaboration, experimentation, and knowledge sharing. Systems that integrate adaptive features, facilitate time for ideation, and recognize creative contributions have the potential to transform the way creative enterprises approach digital innovation. The conceptual framework proposed here links employees' creative thinking attitudes with specific IS design features, offering a practical roadmap for developers and managers aiming to strengthen innovation capabilities through technology.

It is important to note that the study has certain limitations. The sample was limited to one geographic region and industry, which may affect the generalizability of the results. In addition, the reliance on self-reported data introduces the risk of response bias. Future studies should consider using broader samples and complementary data collection methods to improve the robustness of findings.

Future research should build upon these findings by exploring how creative attitudes influence actual patterns of IS adoption and use in creative organizations. Longitudinal studies, qualitative analyses, and cross-cultural comparisons could provide deeper insights into how adaptive IS features dynamically respond to varying levels of creative engagement across different user profiles and project phases. Moreover, integrating perspectives on artificial intelligence and emerging digital tools may further enhance our understanding of how technology can foster, rather than constrain, creativity.

In conclusion, the study contributes to both theory and practice by demonstrating the importance of aligning information systems with human creativity. By incorporating users' intrinsic motivations and addressing organizational barriers, future IS can become powerful enablers of sustainable digital innovation in the creative sector.

To build upon the current findings, future research should examine how these attitudes translate into real-world usage patterns of IS in creative organizations. Longitudinal studies could track changes in IS engagement over time, particularly as teams evolve or adopt new technologies. Diary methods would allow users to record everyday interactions with IS during creative tasks, offering detailed insights into barriers and enablers. Ethnographic observation of IS use in workplace settings could further illuminate how creative processes are supported or hindered in practice.

Moreover, incorporating perspectives on artificial intelligence, intelligent automation, and emerging UX design tools would help to refine IS functionality and improve its alignment with users' creative needs. These future directions may also contribute to developing more adaptive and intuitive systems that foster sustained innovation in the creative sector.

Acknowledgements

Co-financed by the Minister of Science under the "Regional Excellence Initiative".

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

ECO-MARKETING DILEMMAS IN THE PRO-ENVIRONMENTAL ORIENTATION OF BUSINESS MANAGEMENT

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Purpose: The study aims to provide a deeper insight into the dilemmas of eco-marketing in the pro-environmental orientation of business management by examining the correlations between cost efficiency and product price increases in the implementation of eco-marketing. The scientific novelty of the article lies in demonstrating a strong positive correlation between cost efficiency and product price increases in enterprises implementing eco-marketing within a pro-environmental management orientation.
Design/methodology/approach: The study employed literature review and statistical analysis using Spearman's rank correlation to investigate the relationship between cost efficiency and product price increases in the implementation of eco-marketing.
Findings: The results of the study indicate that there is a strong positive correlation between cost efficiency and product price increases in enterprises that implement eco-marketing in an pro-environmental management orientation.
Research limitations/implications: Further research in this area should take into account the complexity of decision-making processes in the implementation of an pro-environmental management orientation of the enterprise and the possibility of balancing costs and benefits of eco-marketing to improve efficiency in the short and long term.
Practical implications: A clear implication of the research is that a better understanding of the dilemmas of eco-marketing influences the perception of business costs and product prices through the prism of an pro-environmental orientation of business management. The results of the presented study could help enterprises understand how to increase competitiveness and strengthen their corporate image through eco-marketing.
Social implications: The study shows that companies that implement eco-marketing as part of an pro-environmental orientation strengthen their social responsibility, which can lead to more efficient resource management to reduce negative environmental impacts.
Originality/value: This article contributes to the discussion on the understanding of the dilemmas of eco-marketing in an pro-environmental orientation of business management by examining the relationship between cost efficiency and product price increases in the implementation of eco-marketing. The issue of understanding the dilemmas of eco-marketing is important and topical, as it enables the shaping of pro-environmental policies in business management.

Keywords: eco-marketing, pro-environmental corporate management corporate social responsibility.
Category of the paper: Research paper.

1. Introduction

Pro-environmental orientation in enterprise management is becoming a contemporary determinant of modern and responsible business. Enterprises implementing an pro-environmental orientation in enterprise management aim to achieve strategic goals, taking into account the principles of sustainable development and ecological responsibility. The implementation of an pro-environmental orientation can consist of the implementation of environmental management systems, changes in the supply chain, green innovation, eco-marketing, or education and communication with the environment. As a result, an pro-environmental orientation allows companies to achieve economic, social and environmental benefits, manifested in gaining competitive advantage, trust, and customer loyalty, as well as reducing the negative effects of the company's activities on the environment. Therefore, companies are increasingly taking account of environmental objectives by integrating them into their development, sales or marketing plans. In this context, eco-marketing is emerging, defined as an approach to marketing that is an integral part of the company, brand or product management process (Ziyadin et al., 2019). Eco-marketing consists of identifying and meeting consumer needs while taking into account, on the one hand, the principles of sustainable development and, on the other hand, the efficiency of the business (Klikovac-Katanić, Kosanović, 2012). However, the implementation of eco-marketing in the management of an enterprise may be associated with a number of dilemmas and challenges, which directly affect the level of product prices and cost efficiency. Based on this, the study aimed to provide a deeper insight into the dilemmas of eco-marketing in the pro-environmental orientation of business management by examining the relationship between cost efficiency and product price increases in the implementation of eco-marketing. The research methods used to achieve the objective are the critical analysis of the literature, a survey questionnaire, and Spearman's rank correlation analysis.

2. Problems of the implementation of eco-marketing in the context of an pro-environmental orientation of company management

Reflecting on the literature on the subject, it can be seen that the key problems associated with implementing an pro-environmental orientation in business management include the need to reconcile environmental and economic objectives (Remlein-Starosta, Krzymińska, 2013), the risk of greenwashing, (Wolniak, Hąbek, 2015) higher certification and production costs (Przygodzka, Kozłowska-Burdziak, Bąk, 2019), and difficulties in consumer education (Śmiechowska, 2011; Ruschak et al., 2023). Based on the literature on strategic management, it is possible to describe a theoretical model of eco-marketing dilemmas in enterprises implementing a pro-environmental management orientation (Vogtlander, Scheepens, Bocken, Peck, 2017). This model is based on three main dimensions: the economic-ecological model, the short-term versus long-term dilemmas model, and the internal versus external dilemmas model. Economic-ecological dilemmas involve the need to balance the costs of pro-environmental activities with the potential market benefits resulting from the implementation of eco-marketing. The second dimension refers to short-term and long-term dilemmas, where managers must choose between short-term profit maximization and long-term value creation for the enterprise through pro-environmental actions. Strategic management literature (Vilkaite-Vaitone, Skackauskiene, 2019) emphasizes that investments in eco-marketing and sustainable development may yield delayed benefits, such as increased customer loyalty, improved brand image, and access to new market segments. The third dimension concerns internal versus external dilemmas. On the one hand, the enterprise focuses on internal operational efficiency and cost minimization; on the other, it seeks to enhance its external image, corporate social responsibility, and relationships with stakeholders. By combining these three dimensions, the theoretical model of dilemmas highlights that enterprises face the necessity of balancing trade-offs between cost efficiency, pricing pressures, strategic orientation, and the expectations of both the market and society.

Research highlights that despite potential benefits for company image (Stefańska, 2016) and long-term savings (Mazur-Wierzbicka, 2016), companies often face barriers related to the need to restructure processes, market uncertainty and competitive pressures (Łuczka, 2016). The increase in the prices of eco-friendly products is often the result not only of higher manufacturing costs but also the result of financing complex communication and marketing strategies (Garbacz, 2004), which, combined with limited elasticity of demand, can negatively affect the profitability of the business.

In this context, the concept of eco-marketing emerges as a result of the implementation of pro-environmental orientation in business management (Astakhova, Astakhova, Reznikova, 2020). The fundamental dilemma of eco-marketing arises from the need to reconcile, on the one hand, the need to increase demand for pro-environmental products and, on the other

hand, to reduce the negative effects of the production and distribution of such products (Biernacki, 2017). Moreover, the implementation of the objectives of eco-marketing is associated with the need to incur expenditure on advanced technologies, staff training and the modification of the supply chain, which in the short term increases the costs of operations for companies pursuing an pro-environmental management orientation (Marques, Almeida, 2013).

The cost-effectiveness of an pro-environmental oriented enterprise should refer to the way in which the enterprise manages its resources to achieve positive results with the least possible financial outlay. However, paradoxically, aiming to reduce the negative impact on the environment, through the implementation of eco-marketing can lead to an increase in the variable costs of the enterprises' activities, so the implementation of eco-marketing may not affect the efficiency of the costs incurred. In this context, the following thesis can be formulated:

Thesis 1: "The implementation of eco-marketing does not affect the efficiency of the costs incurred".

It is worth noting that for enterprises in which the production of organic food requires the use of more expensive raw materials, the reduction of the scale of production or the abandonment of synthetic fertilisers, this can directly translate into a higher final price of products (Witek, 2018). On average, organic farms allocate 30% more financial resources to produce a unit of production compared to conventional ones (Nestorowicz, Pilarczyk, 2012; (Nestorowicz, Pilarczyk, 2014). This increases unit costs and translates into a higher price, resulting in a mismatch between environmental and economic objectives, causing a risk of loss of competitiveness, especially in price-sensitive markets. This can be expressed formally as the following thesis:

Thesis 2: "The use of eco-marketing increases product prices".

In conclusion, it is worth emphasising that the implementation of eco-marketing is a complex strategic challenge, requiring a profound transformation of the business models of companies oriented towards an pro-environmental approach to management. It should be noted that cost increases in the short term, associated with certification, production restructuring and market education, translate into long-term benefits including not only improvement of company image but also real operational savings. Therefore, when implementing an pro-environmental management approach, attention should be paid to identifying risk factors associated with, for example, greenwashing (Mesjasz-Lech, 2023) or targeting consumer groups (Jelonek, Pawełoszek, 2013). Future research in the field of the implementation of eco-marketing in the implementation of an pro-environmental orientation of company management should focus on assessing whether eco-marketing affects the efficiency of costs incurred in the company and increases product prices.

3. Research methodology and description of the sample

The study of eco-marketing in the pro-environmental orientation of enterprise management, part of which is presented here, was carried out using a survey questionnaire, as part of the author's own research. In the first stage of the research procedure, based on the analysis of the literature, the main conclusions of which were presented in the previous section of the article, two theses were formulated and expressed in the form of questions in the questionnaire. The first thesis: "The implementation of eco-marketing does not affect the efficiency of the costs incurred" and the second thesis: "The use of eco-marketing increases product prices", served as the basis for conducting the empirical research.

The survey was conducted using the CATI (Hair et al., 2014) method on a sample of 1025 enterprises operating in Poland. The population of the analysed enterprises were micro, small, medium-sized and large enterprises of the private sector. The respondents were senior managers of these enterprises. The questions in the survey questionnaire were rated by the respondents on a Likert scale, from 1 to 5, where 1 indicated "strongly disagree", and 5 "strongly agree" (Vogel, Koutsombogera, Costello, 2020). To analyse the correlation between the implementation of eco-marketing, which does not affect cost efficiency, and the use of eco-marketing, which increases product prices, Spearman's rank correlation was used in the second stage of the research procedure. The ranges in the analysis of the strength and direction of the Spearman's rank correlation were [-1, +1] (Suchecki, 2013). The estimation of r_s is based on the assumption of perfect latent order and the assignment of quantiles according to the marginal data, which made it possible to conduct tests based on paired data in order for the adopted model to illustrate the mechanism of the analysed correlation.

The article focuses on providing a deeper insight into the dilemmas of eco-marketing in the pro-environmental orientation of corporate management. Particular attention was devoted to examining the impact of eco-marketing on changes in cost efficiency and product pricing.

4. Empirical research results

The conducted research aims to provide a deeper insight into the dilemmas of eco-marketing in the pro-environmental orientation of business management by examining the relationship between cost efficiency and product price increases in the implementation of eco-marketing. In the first stage of the research procedure, the frequency of responses was assessed for two questions from the survey questionnaire. The first question was: "The implementation of eco-marketing does not affect the efficiency of the costs incurred". The second question was: "The use of eco-marketing increases product prices". Table 1 shows the frequency of responses provided by respondents in percentage terms, on a five-point Likert scale.

Table 1.
Analysis of frequency

5-point Likert scale	The implementation of eco-marketing does not affect the efficiency of the costs incurred	The use of eco-marketing increases product prices
1 – strongly disagree	9.2%	9.2%
2 – disagree	10.6%	8.9%
3 – neither agree nor disagree	38.0%	18%
4 – agree	32.3%	38%
5 – strongly agree	9.9%	26%

Source: Author's compilation.

As can be seen from the data presented in Table 1, almost 42% of the respondents declared that they strongly agree and agree with the thesis that in their enterprise the implementation of eco-marketing does not affect the efficiency of the costs incurred. In addition, the study found that 64% of respondents strongly agreed and agreed that in their company the use of eco-marketing increases product prices. Therefore, it can be concluded that in the analysed companies, compensation for the costs incurred for the implementation of the eco-marketing measures is sought by increasing the price of the products. However, in such a case, the price increase must be offset by customer benefits (e.g. better quality, certified environmental care). Otherwise, customers may perceive the price increase as unjustified, which may undermine the effectiveness of the eco-marketing strategy.

In the second stage of the research procedure, Spearman's rank correlation coefficient was calculated. Testing the strength and direction of the relationship, Spearman's rank correlation was calculated as $rs \approx 0.91$. The results obtained indicate a very strong, positive (monotonic) correlation between the answers to both questions. This means that respondents who express stronger agreement with the thesis that "the implementation of eco-marketing does not affect the efficiency of the costs incurred" (higher scores in Question 1) tend to express stronger agreement with the thesis that "The use of eco-marketing increases product prices" (higher scores in Question 2). The adopted latent order model suggests that the correlation between ranks is very systematic. Respondents were ordered according to a single characteristic that determines their responses. Therefore, the higher the "level of agreement" (or a certain attitude towards eco-marketing), the higher the scores obtained by both theses, resulting in a strong positive rank correlation.

5. Discussion

In attempting to understand the dilemmas of eco-marketing in the pro-environmental orientation of business management by examining the correlations between cost-effectiveness and product price increases in the implementation of eco-marketing, it is worth noting that, despite obtaining a statistically very strong correlation, there are some paradoxes arising from

respondents' perceptions of eco-marketing. Logically, it might seem that if eco-marketing does not affect cost efficiency, it should also not increase product prices. However, respondents seem to distinguish between the two aspects. This may mean that they perceive cost management efficiency as separate from pricing strategy, resulting in a consistent (but paradoxical) pattern of responses. It is possible that, according to the respondents, eco-marketing does not change the way a company incurs costs (e.g. operational costs remain under control). At the same time, respondents recognize eco-marketing activities (e.g. image change, product positioning) that can result in changes in product prices.

The strong positive Spearman's rank correlation suggests that respondents express their attitudes consistently. It is also possible that respondents with a more "optimistic" or "pessimistic" attitude, in the context of eco-marketing, indicate similar answers in both cases, even though the questions refer to different aspects of the company.

6. Conclusions

Summarising the considerations presented in this paper, it is worth emphasising that, despite generating higher operating costs at the initial stage of implementation, in the long term, eco-marketing can lead to improved efficiency by reducing energy consumption, reducing environmental penalties or increasing customer loyalty. When considering the dilemmas of eco-marketing in the context of the pro-environmental orientation of business management, it is worth noting that the implementation of eco-marketing is associated with some paradoxes that may affect the functioning of the enterprise on many levels. The implementation of eco-marketing solutions may generate an increase in operating costs, which may be the result of environmental certification or process modernisation. Maintaining ecological standards is often associated with higher operating costs, such as more expensive raw materials or specialised equipment, which can further increase costs. To compensate for increased costs, companies are forced to increase the price of products. However, the price level of the products must be acceptable to the customer and competitive in the market. The price increase must be compensated by clear benefits for the consumer (e.g. better quality, certified environmental care). Otherwise, consumers may perceive increases as unjustified, which would undermine the effectiveness of the marketing strategy. A difficulty that may arise from eco-marketing is a situation where a company simultaneously experiences cost increases and price increases, but does not observe commensurate improvements in efficiency. In such a case, the dilemma is whether to continue with the eco-marketing activities if the synergies are not visible or to abandon the expensive solutions, which could damage the image and market position.

It is worth emphasizing that the results of the presented research will be useful for managers in the decision-making process, as they provide guidance on implementing eco-marketing within a pro-environmental management orientation. They can be applied to optimize pricing strategies while taking into account the costs of pro-environmental activities. Another application of the research findings may involve building brand image through the effective use of eco-marketing or planning sustainable development policies and shaping pro-environmental business practices. Additionally, the research results may be valuable for scientists and policymakers involved in developing policies that support pro-environmental business management.

This study supports the currently prevailing view that ill-considered eco-marketing strategies carry the risk of greenwashing and loss of trust, which may consequently increase the cost of operations. Therefore, decisions to implement eco-marketing must take into account both the internal processes of the company and the expectations of the market. Directions of further research in this area should take into account the complexity of decision-making processes and the possibility of balancing costs and benefits to improve efficiency, in the short and long term. In the future, research in this area should focus on expanding the scope of analyzed variables and deepening the understanding of the relationships between costs, pricing strategies, brand image, and the effectiveness of pro-environmental activities. Among the key independent variables, it is worth considering the level of investment in eco-marketing, corporate social responsibility (CSR) strategies, and pro-environmental innovations. As dependent variables, future studies could examine cost efficiency, the shaping of pricing strategies, customer loyalty, and brand value. Additionally, moderating variables such as company size, industry, strategic orientation, and market maturity level should be included, as they may influence the strength of the relationship between eco-marketing implementation and business performance. Regarding research methodology, the use of advanced analytical techniques is recommended. The application of structural equation modeling (SEM) would allow for the examination of complex relationships between costs, prices, CSR, and enterprise competitiveness. An important direction for future studies is also the adoption of a longitudinal approach. Panel studies conducted over a period of 3-5 years would make it possible to monitor the long-term effects of eco-marketing implementation in enterprises. Such an approach would enable the assessment of how pro-environmental initiatives influence pricing strategies, cost efficiency, customer loyalty, and brand perception across different time horizons. Furthermore, it would be valuable to conduct comparative studies across industries and markets.

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ORGANIZATION AND MANAGEMENT SERIES NO. 231

APPLICATION OF AI AND VR IN PRODUCTION MANAGEMENT

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Purpose: This paper investigates the use of Artificial Intelligence (AI) and Virtual Reality (VR) in production management. The goal is to identify research trends, integration models with MES/ERP systems, and key challenges associated with the implementation of these technologies in industrial practice, particularly in the context of Industry 4.0 and 5.0.
Design/methodology/approach: The research combines a Systematic Literature Review (SLR) with bibliometric analysis based on Scopus data up to May 1, 2025. The SLR focuses on peer-reviewed publications related to AI and VR in production. Bibliometric analysis includes publication dynamics, geographic distribution, institutional affiliations, authorship, and subject area classifications.
Findings: A marked increase in publication output has been observed since 2016, with a peak in 2023. AI and VR are increasingly used in production layout design, predictive maintenance, risk management, training, and system integration. Engineering and Computer Science dominate the field. China, the USA, and India lead in publication volume. However, few studies focus on integrated AI–VR systems or real-world implementations.
Research limitations/implications: The study is limited to English-language publications indexed in Scopus and focused solely on production (excluding quality management). Future research should address real-case studies, ROI/KPI evaluation, and organizational challenges in AI/VR adoption.
Practical implications: Results support industrial decision-makers in selecting, integrating, and scaling AI/VR tools. Emphasis is placed on improving interoperability, process flexibility, and workforce training within digital production systems.
Social implications: The research highlights how immersive and intelligent technologies can enhance safety, competence, and human-centered design in production, contributing to sustainable development and smart work environments.
Value: This is the first study to provide a focused, bibliometric SLR on AI and VR applications in production management. It offers a structured synthesis useful for scholars, practitioners, and policy designers seeking to align digital transformation with operational needs.
Keywords: Artificial Intelligence, Virtual Reality, Production Management, MES/ERP Integration, Industry 5.0.
Category of the paper: Literature review.

1. Introduction

The contemporary industrial environment is undergoing a profound transformation driven by the integration of advanced digital technologies under the umbrella of the Industry 4.0 paradigm. A pivotal aspect of this transformation is the redefinition of production management-shifting from a sequential and reactive approach toward adaptive, data-driven, and AI-supported systems. At the core of this shift lie cyber-physical systems (CPS), the Internet of Things (IoT), real-time data analytics, and intelligent decision-making algorithms, all of which are revolutionizing the planning, supervision, and continuous improvement of manufacturing processes (Zeqiri et al., 2025; Saranya et al., 2025).

In this context, Artificial Intelligence (AI) and Virtual Reality (VR) technologies play an increasingly significant role as tools supporting integrated production management. AI is applied in failure prediction, schedule optimization, adaptive resource control, and operational data analysis, thereby enhancing decision-making at both strategic and operational levels. VR, in turn, facilitates the creation of immersive environments for testing production systems, conducting employee training, designing ergonomic workstations, and simulating operational and emergency scenarios (Bolbotinović et al., 2025; Muralidhar et al., 2025).

With the transition toward the Industry 5.0 concept-which emphasizes human-machine collaboration, personalization, and sustainable development-the importance of human-centred design in production management is growing. AI and VR not only support automation but also serve as tools for enhancing workforce competencies, increasing operational safety, and building work environments that enable seamless transitions between physical and digital activities (Shabur et al., 2025).

In industrial practice, these technologies are increasingly implemented through Digital Twin concepts, integrating data from real-world processes with dynamic simulation models. This enables optimization of material flows, scenario-based planning, validation of decision alternatives, and comprehensive support in production and quality management (Uhlmann et al., 2025; Ma et al., 2025).

Despite the growing number of implementations and scientific publications, significant limitations remain, including the lack of comprehensive models for integrating AI and VR with production management systems (e.g., MES, ERP), the limited number of studies based on real operational data, and insufficient methodologies for assessing the added value of implementations (e.g., ROI, KPIs, VR training effectiveness). Furthermore, there is a noticeable shortage of systemic approaches that take into account not only technological but also organizational, normative, and cultural dimensions (Shee et al., 2024; Sharma et al., 2024).

In light of these observations, there is a justified need for an in-depth analysis of the scientific literature aimed at identifying dominant application areas of AI and VR in production management, classifying existing integration models, and diagnosing research gaps in the context of implementing these technologies in real industrial environments.

The objective of this article is to conduct a systematic review of the literature concerning the use of AI and VR in production management, with a particular focus on their impact on operational efficiency, process flexibility, and the development of integrated decision-making environments. The study addresses the following research questions:

- What are the dominant directions in the use of AI and VR in production management?
- What models of integration with operational management systems are identified in the literature?
- What limitations and challenges accompany the synergistic use of AI and VR from a managerial perspective?

Answers to these questions will allow for the systematization of current scientific knowledge, the identification of research needs, and the formulation of recommendations for future studies and implementation practices in the domain of intelligent production management.

2. Literature Review

The aim of this study is to conduct a systematic analysis of the scientific literature concerning the applications of Artificial Intelligence (AI) and Virtual Reality (VR) in the domain of production management. Particular emphasis is placed on identifying dominant research directions, methods of integrating these technologies with operational systems (e.g., MES, ERP), as well as the challenges and limitations associated with their implementation in real industrial environments. To achieve this, the study adopts a Systematic Literature Review (SLR) approach, which enables a reliable and replicable synthesis of existing research findings and facilitates the identification of gaps and future development trajectories (Garcia-Peñalvo, 2022; Milner, 2015; Ramey, Rao, 2011).

The literature review process followed five key stages: (1) research design, (2) data extraction, (3) record selection, (4) analysis, and (5) interpretation of results. During the design phase, a research gap was identified concerning the integration of AI and VR into production management processes, and a set of research questions was formulated regarding application areas, types of technological solutions, and the factors facilitating or hindering their implementation.

In the data collection phase, publications were retrieved from the Scopus database-one of the most comprehensive bibliographic indexes for technical, engineering, and management sciences. The search criteria included English-language publications available up to May 1, 2025. Logical combinations of key phrases relevant to the research topic were used in the search queries, such as: “virtual reality”, “artificial intelligence”, “machine learning”, “production”, “manufacturing”, “smart factory,” “MES”, “process optimization”, “simulation”, and “training”.

The retrieved records were assigned to the thematic area of production management, excluding documents focused solely on quality-related aspects. Only peer-reviewed sources-including scientific articles, review papers, and conference proceedings-were included for further analysis.

Simultaneously, a bibliometric analysis was conducted using the "Analyze Results" function available in the Scopus system. The collected data covered the number of publications per year, countries of origin, institutional affiliations, authors, and subject classifications. These data were processed and presented in the form of tables and charts to illustrate the distribution of publications and to identify key research centres and emerging trends.

The application of the SLR approach-complemented by quantitative analysis-enabled a comprehensive exploration of the research topic, facilitating a systematic classification of AI and VR applications in production management, the identification of implementation barriers, and the formulation of potential directions for future research, development, and industrial deployment.

3. Methods

Contemporary applications of Artificial Intelligence (AI) and Virtual Reality (VR) in production management have evolved from experimental solutions to mature technologies that support the daily operation of industrial facilities. Based on a review of the literature and Scopus data, the main application areas have been identified, including: production layout and process design, operational planning, maintenance management, workplace safety, personnel training, and integration with MES and ERP systems.

3.1. Production Design and Planning

3.1.1. Virtual Modelling of Production Layouts

VR enables the creation of interactive 3D models of factory layouts-including machine placement, workstations, logistics zones, and transport paths. Thanks to its immersive nature, VR facilitates spatial simulations, ergonomic analyses, layout scenario testing, and the early detection of bottlenecks or accessibility issues. For instance, in the automotive industry,

VR has been used to optimize component flow from warehouse to assembly line based on real production data. Choi et al. (2015) showcase VR applications for designing production cells, evaluating resource placement, operator load, and cycle times.

3.1.2. Process Modelling and Variant Analysis

VR also supports modelling of operational flows and technological sequences in a digital environment. Engineers and process designers can interact with virtual machines-simulating assembly, inspection, maintenance, or changeovers-without interrupting physical processes. These solutions enable testing of new technologies in terms of time, ergonomics, and disruption susceptibility. VR models, fed by CAD/CAM and real operational data (e.g., MTM measurements), allow for digital process prototyping and iterative optimization before physical production begins (Pöhler et al., 2021).

3.1.3. AI in Operational and Tactical Planning

AI is widely used in operational and tactical planning. Machine learning and metaheuristic algorithms (e.g., genetic algorithms, PSO, simulated annealing) support order scheduling, resource allocation, buffer and changeover management. AI can dynamically adjust production plans based on machine availability, operator performance, or demand fluctuations. Advanced predictive models forecast material needs from historical and real-time operational parameters to support real-time decision-making (Vrontis et al., 2022).

3.1.4. Integrated Planning and Simulation Environments

Digital Twin advancements enable integration of AI and VR into a unified decision- and simulation-support system. Operators may test layout changes in VR, while AI evaluates their impact on performance metrics (OEE), takt times, energy consumption, and throughput. These combined systems enhance deployment safety, expedite decision-making, and support ongoing improvement (Karaoglu et al., 2019; Stojadinovic, 2024).

3.1.5. Benefits and Implementation Challenges

Key benefits include:

- reduced time-to-market,
- lower design errors and modification costs,
- improved resource utilization,
- enhanced operator ergonomics and safety,
- enabling design for quality and maintainability.

However, challenges persist:

- the need for high-quality input data (CAD models, process data),
- lack of interoperable platforms linking AI, VR, MES/ERP,
- difficulty adapting AI to low-volume production,
- shortage of technical-analytical skills among engineers (Boopathy, Gurrammagari, 2025; Yüksel, 2024).

Despite these obstacles, growing literature and field observations highlight rapid development in sectors such as aerospace, automotive, home appliance, and contract manufacturing. AI–VR integration is becoming the cornerstone of modern production management strategies in the digital transformation age (Alamgir et al., 2025).

3.2. Maintenance Management and Failure Prediction

The modern approach to maintenance management is shifting from reactive and preventive models toward predictive strategies based on real-time operational data. AI and VR form complementary tools that enable early detection of failure symptoms, their visualization, root-cause analysis, and training staff in a safe digital environment.

3.2.1. AI in Predictive Maintenance

AI powers Predictive Maintenance (PdM) systems that utilise data from sensors measuring vibration, temperature, flow, or voltage. Machine learning algorithms (decision trees, SVM, XGBoost) and deep neural networks (MLP, LSTM) detect anomalies, estimate remaining useful life (RUL), and recommend preemptive actions. With edge computing architectures, these systems facilitate low-latency responses and reduce network load. Benefits include reduced downtime, optimized service schedules, extended component lifespan, and failure prediction at component level (e.g., bearings, valves) (Cinar et al., 2020).

3.2.2. VR for Inspection Simulation and Service Training

VR complements AI by providing spatial visualization of machine conditions and immersive training for maintenance staff. Virtual line models replicate equipment layouts and diagnostics tools, allowing safe practice of procedures like component replacement in hard-to-reach areas, lubrication checks, or emergency responses. VR environments can be powered by predictive model outputs, enabling trainees to immediately respond to AI-identified anomalies (Kour et al., 2022).

3.2.3. Implementation Challenges

Key challenges include:

- integrating heterogeneous data sources (IoT, SCADA, CMMS),
- establishing adequate computing infrastructure,
- validating predictive models under variable operational conditions,
- overcoming organizational resistance to AI-supported decisions,
- addressing the shortage of technical-analytical personnel.

Nevertheless, maintenance systems are evolving toward proactive, integrated ecosystems combining AI, VR, IoT, and edge computing in unified predictive-decision frameworks (Sharma, Gupta, 2024; Uddin et al., 2024).

3.3. Safety and Risk Management

Workplace safety and operational risk management are crucial components of modern production systems. With the digital transformation in Industry 4.0 and 5.0, technologies supporting hazard identification, emergency scenario simulation, and safety culture maturity become increasingly important. AI and VR enable integrated warning, visualization, and training systems for comprehensive risk management in industrial settings (Uddin et al., 2024).

3.3.1. VR for Safe-Environment Design and Testing

VR allows for digital reconstruction of plant layouts and interactive hazard analysis. Safety engineers can identify blind spots, collision trajectories, evacuation obstacles, or signage errors. Emergency procedures-such as evacuation, e-stop activation, fire or chemical leak responses-can be tested in controlled virtual simulations, supporting ALARP principles at the design stage (Li, Yu, 2023).

3.3.2. AI in Monitoring and Predicting Dangerous Events

AI processes data from industrial cameras, environmental sensors, access control, and logistics logs. Object detection and behaviour recognition algorithms (e.g., YOLO, Faster R-CNN) identify individuals in restricted areas, missing PPE, or improper machine interactions. Predictive techniques detect patterns-like operator fatigue or sudden pace changes-preceding incidents. These systems can trigger safety alerts, initiate preventive protocols, or halt machinery automatically in automated settings (Johnson, 2019).

3.3.3. Integrated VR–AI for Training and Risk Assessment

Combined VR–AI environments enable realistic hazard training (e.g., fire, chemical leak scenarios), with AI evaluating decision accuracy, reaction time, and procedure adherence. AI compares behaviour against best-practice patterns, adjusting content and generating competency metrics-supporting continuous BHP (occupational health and safety) training (Mahmoudi-Dehaki, Nasr-Esfahani, 2024).

3.3.4. Implementation Barriers

Challenges include:

- high costs of creating realistic VR environments for niche industries,
- integration complexity with existing EHS/QHSE systems,
- organizational resistance to behavioural monitoring,
- absence of standard effectiveness metrics for simulations and training.

Despite these barriers, AI and VR deployment in safety brings resilience, proactivity, and reduced risk of production downtime, operational losses, and legal liabilities (Yüksel, 2024).

3.4. Operational Training and Onboarding

Effective training and onboarding in complex production settings are vital for ensuring safety, quality, and operational continuity. As technology complexity grows, traditional methods (lectures, shadowing) prove inadequate. VR and AI offer new possibilities for immersive, adaptive, and fully standardized training.

3.4.1. VR for Immersive Workplace Training

VR realistically replicates workplace environments, allowing trainees to perform assembly, inspection, or service tasks safely-without risk to equipment or health. Scenarios include machine operation, emergency response, quality control, and ergonomic assembly. VR training provides full repeatability, measurable performance metrics (time, error count, sequence accuracy), and independence from production availability or instructors. It is especially valuable in high-risk industries (Hecker et al., 2021; Dyck et al., 2022).

3.4.2. AI in Adaptive Teaching and Competency Assessment

AI personalizes training by analyzing movement patterns, reaction times, errors, and decision-making. Systems adjust difficulty, suggest repetitions, or offer additional modules-forming Intelligent Tutoring Systems (ITS)-and generate competency indices (e.g., Operational Readiness Index, OPRI). Integration with LMS or HRIS supports organizational competency tracking (Dudhee et al., 2024; Kushwaha, Sharma, 2025).

3.4.3. Onboarding and Competency Standardization

VR and AI facilitate smooth onboarding and periodic qualification checks by enabling:

- faster onboarding without production disruption,
- standardized competency across locations,
- reduction of subjective instructor assessments,
- multilingual, scalable training.

Simulations can be aligned with standards (ISO 9001, 45001, IATF 16949) and internal procedures (SOPs), enhancing compliance with quality and safety management systems (Dudhee et al., 2024; Kushwaha, Sharma, 2025).

3.4.4. Organisational Benefits and Technical Limitations

Benefits:

- shortened training/adaptation time,
- fewer errors by new employees,
- improved safety and ergonomics,
- increased motivation (gamification elements),
- easier documentation of progress.

Limitations:

- high cost of creating realistic VR processes,
- need for domain experts for scenarios,
- difficulty modeling psychological factors (stress, fatigue),
- requirement for continuous simulation updates (Muszyńska et al., 2019; Zigart et al., 2023).

3.4.5. Future Prospects

The future points toward integration of VR, AI, haptics, Augmented Reality (AR), biometric analytics, and wearables-leading to "competency digital twins" that combine simulation, real work, and supervisor assessments, allowing precise human capital management (Mak et al., 2020).

3.5. Integration with MES/ERP Systems

Effective implementation of AI and VR in industrial environments requires integration with existing MES and ERP systems. A coherent, interoperable digital ecosystem allows full utilization of AI's decision support and VR's simulation capabilities via real-time data exchange and synchronized actions.

3.5.1. AI Integration: Architecture and Functionality

AI can be implemented as a layer over or inside MES/ERP architectures. Common applications include:

- cycle time, failure, and downtime prediction based on MES data,
- recommendations for job scheduling and changeovers using ERP data,
- detection of process and cost anomalies via unsupervised learning,
- assessment of operator decisions and competencies using production and HR data.

This integration requires middleware/API, data structure compatibility, metadata availability, and real-time updates (Malzer et al., 2022; Mamone, 2025).

3.5.2. VR Integration: Communication and Synchronization

VR draws data from MES and ERP for accurate reproduction of production states. This enables:

- automated VR training scenario generation from real operational cases (e.g., failures),
- dynamic model updates (layouts, machine statuses, production batches),
- interactive decision simulation (e.g., resource reallocation),
- synchronization with Digital Twins reflecting current operations.

Synchronization may be real-time or batch-mode, using OPC UA or MQTT standards (Curiel-Ramirez et al., 2024; Menck et al., 2012).

3.5.3. Implementation Challenges

Barriers include:

- lack of uniform protocols and data standards across vendors,
- legacy systems unable to handle unstructured data (e.g., VR visual streams),
- semantic inconsistencies (e.g., differing identifiers for batches, operators),
- organizational resistance to AI-based decisions,
- risk of data mismatches with partial synchronization.

Integrating VR with ERP often necessitates middleware or indirect MES-based integration (Curiel-Ramirez et al., 2024; MamiMekalai et al., 2024).

3.5.4. Strategic Importance of Integration

AI–VR integration with MES/ERP is strategically essential for building digital, flexible production environments. It enables:

- holistic optimisation of technical and managerial processes,
- automated, data-driven decisions,
- higher operational resilience,
- realization of smart factory and Industry 5.0 objectives.

A fully integrated environment for data, processes, and competencies underpins future-ready manufacturing organizations-boosting competitiveness, agility, and compliance (Curiel-Ramirez et al., 2024; Horbach, 2013).

4. Results

4.1. Objective and Scope of the Analysis

The aim of the conducted bibliometric analysis was to identify and systematize the structure and dynamics of scientific research concerning the application of Artificial Intelligence (AI) and Virtual Reality (VR) in the context of production management. Both technologies represent key enablers of industrial transformation under the paradigms of Industry 4.0 and 5.0. However, their effective implementation in industrial environments continues to face significant technological, organizational, and integration-related challenges. In this regard, bibliometric analysis of the scientific output provides a structured overview of the main research directions, identification of institutional and geographic leaders, evaluation of publication intensity, and the recognition of research gaps requiring further empirical investigation.

In contrast to traditional literature reviews, bibliometric analysis adopts a quantitative approach to the entire corpus of publications that meet predefined search criteria. This method allows for the identification of thematic development patterns over time, analysis of disciplinary distribution, mapping of relationships between authors and institutions, and the localization of interdisciplinary synergies. As a result, it offers an objective and replicable representation of the current state of knowledge, forming a foundation for further studies on the implementation of AI and VR in production management.

The temporal scope of the analysis covered publications from 1996 to 2025, including all documents indexed in the Scopus database as of May 1, 2025. The study focused exclusively on scientific publications addressing the use of artificial intelligence and virtual reality in the context of production-specifically, in areas such as process planning, production optimization, layout modelling, operational training, maintenance management, and integration with MES and ERP systems.

The data were retrieved from the Scopus database, recognized as one of the most authoritative sources of scientific literature in the fields of production engineering and management. The datasets were analyzed along selected dimensions: publication counts over time, thematic distribution, author country of origin, institutional affiliations, and most prolific authors. These findings serve as the basis for the detailed analyses presented in the following subsections.

4.2. Quantitative Analysis of Publications

4.2.1. Publication Dynamics Over Time

The analysis of publication dynamics related to the use of Artificial Intelligence (AI) and Virtual Reality (VR) in production management reveals a clear and accelerated growth of interest in this area over the past decade. According to Scopus data (as of May 1, 2025), until around 2015, the number of publications on the topic remained relatively low, typically ranging from a few to a dozen entries per year.

A significant turning point occurred after 2016, with a noticeable intensification of scientific research, peaking in the period 2020-2023. This surge is strongly associated with the rapid advancement of Industry 4.0, the growing importance of production process digitalization, and the accelerated technological transformation triggered by the COVID-19 pandemic. Notably, the year 2023 marked a record high in the number of publications, confirming both the maturity of the topic and its firmly established status within academic and industrial communities.

Preliminary data for 2025, covering the period up to May 1, also indicate sustained high levels of research activity, although a full evaluation of the year's dynamics will only be possible after its completion. This trend is illustrated in Figure 1, which presents the annual distribution of publications during the analyzed period (1996-2025).

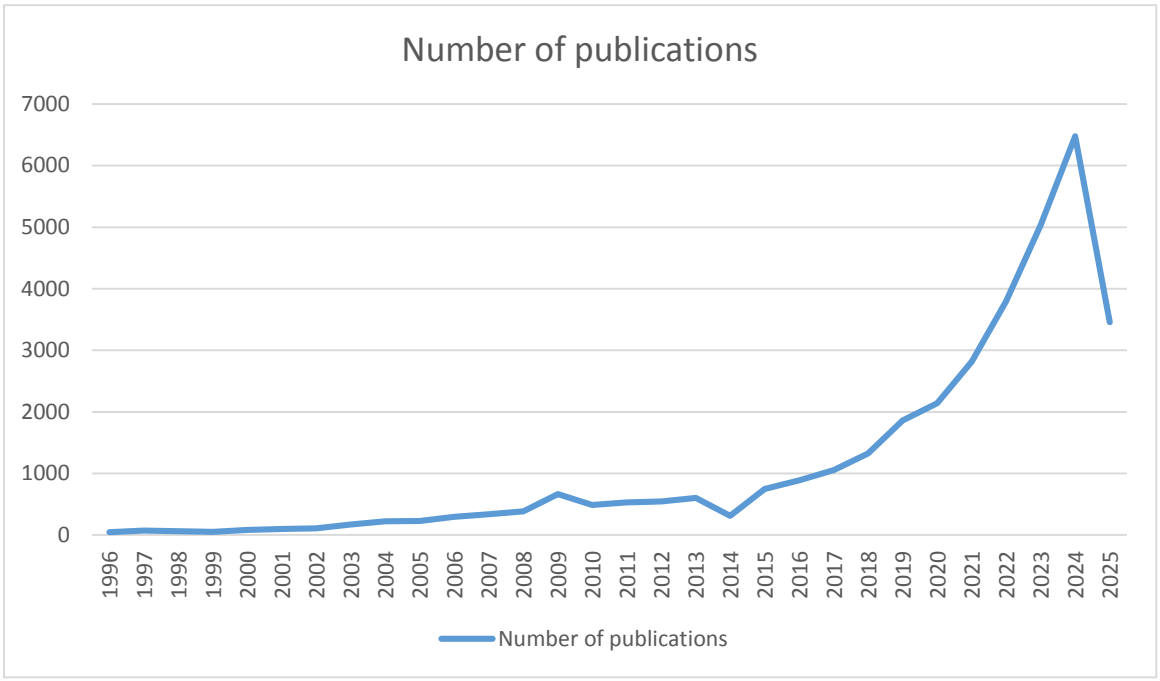

Figure 1. Publication trends on the use of AI and VR in production management (1996-2025).
Source: authors' elaboration based on Scopus data, as of May 1, 2025.

4.2.2. Publications by Country of Author Affiliation

The geographical analysis of scientific publications helps identify countries most actively contributing to the advancement of knowledge in the field of AI and VR applications in production management. According to data from the Scopus database (as of May 1, 2025), the leading contributors by volume of publications are China and the United States-both countries with well-established positions in industrial technology research and deployment.

China ranks first, with a total of 7500 publications in the analyzed domain, underscoring its dominant role in the digital transformation of manufacturing. The United States follows with 6581 publications, reflecting sustained activity in both theoretical research and practical implementations. Other prominent contributors include India (2626), Germany (2495), and the United Kingdom (2370)-all actively developing Industry 4.0 concepts and advanced digital production models.

The top ten also include European countries such as Italy, Spain, France, and Canada, whose contributions demonstrate growing interest in AI and VR integration, particularly in areas such as production planning, optimization, and operational training.

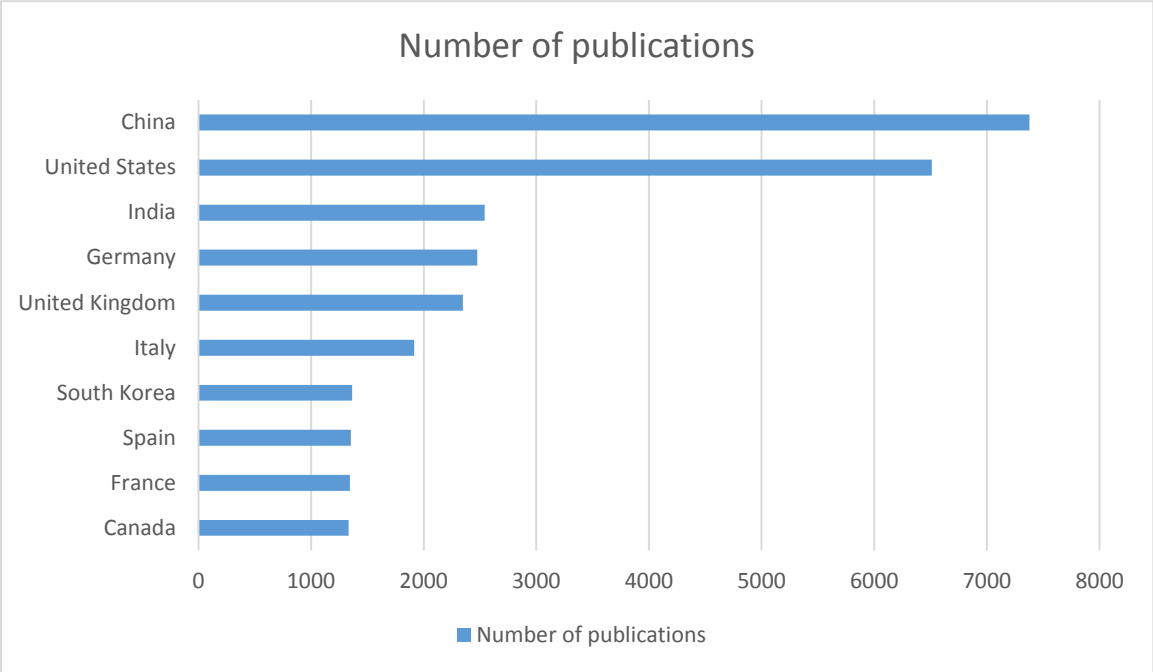

Figure 2. Number of publications on AI and VR in production management – Top 10 most active countries.

Source: authors' elaboration based on Scopus data, as of May 1, 2025.

These findings highlight the importance of geographical context in shaping research and implementation trajectories for immersive and intelligent technologies. At the same time, they suggest that a concentration of research activity in a few leading countries may result in asymmetries in technological adoption, driven by national industrial policies, R&D funding availability, and levels of infrastructure digitalization.

4.2.3. Leading Institutional Affiliations

The analysis of author affiliations identifies academic institutions playing a key role in the advancement of research on AI and VR applications in industrial contexts. Scopus data indicate that leading institutions are predominantly based in China and other Asian countries, reflecting a broader shift in digital technology research toward the East Asian region.

The Chinese Academy of Sciences ranks first, contributing 458 publications. Tsinghua University follows with 382 publications, and CNRS – Centre National de la Recherche Scientifique in France ranks third with 374, confirming the presence of active European institutions. Other notable institutions include the Ministry of Education of the People's Republic of China, Beihang University, Shanghai Jiao Tong University, and Zhejiang University.

Also represented are European and Singaporean universities such as Delft University of Technology, Technische Universität München, and Nanyang Technological University-indicating the rising importance of highly specialized international engineering centers.

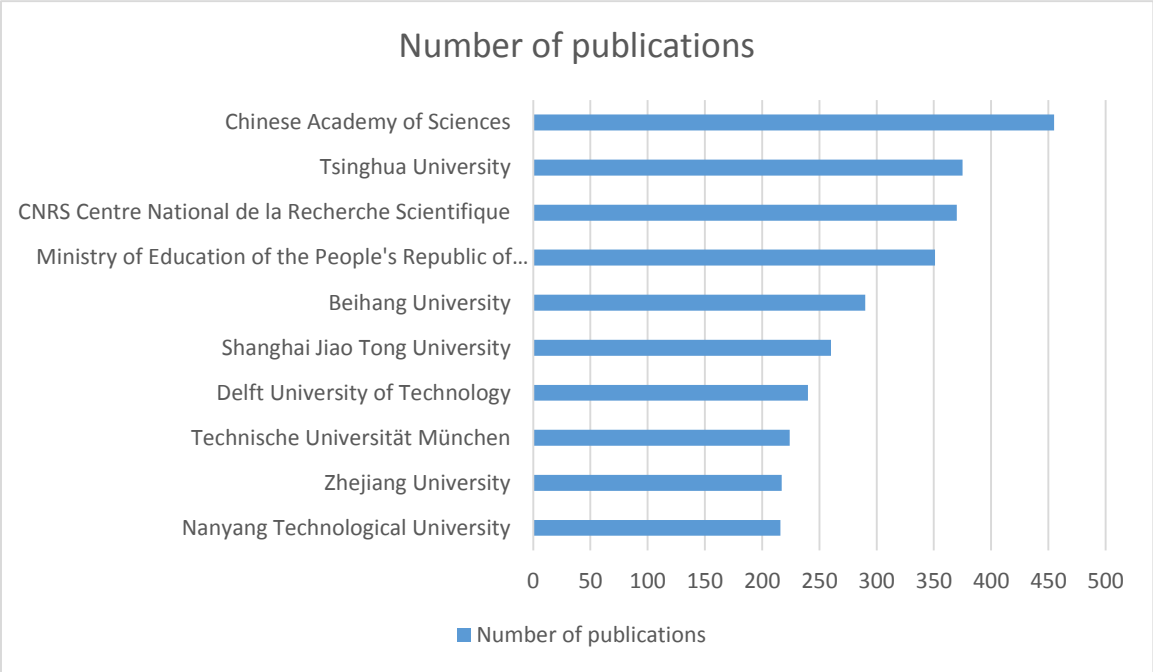

Figure 3. Top 10 most active research institutions in AI and VR for production management.
Source: authors' elaboration based on Scopus data, as of May 1, 2025.

These results suggest that research on the integration of AI and VR into manufacturing processes is concentrated in selected academic and governmental institutions. At the same time, there is increasing international collaboration and growing European participation, which may support the global diffusion of knowledge and broader adoption of these technologies.

4.2.4. Most Active Authors and Co-authors

An analysis of the most prolific authors allows the identification of researchers contributing most significantly to the development of knowledge on AI and VR in production environments. Such rankings also help identify opinion leaders, the research institutions clustered around them, and potential directions for international collaboration and thematic specialization.

Based on bibliometric data from Scopus (as of May 1, 2025), a list of the top ten most publishing authors in this field was compiled and is presented in Figure 4. The most active researcher is clearly Andaluz, V.H., with 59 publications, followed by Du, J. (39 publications) and Wang, F.Y. (35 publications).

These authors are predominantly affiliated with institutions in China, South Korea, Turkey, and the United States, indicating a concentration of expertise in East Asia and selected centers in Europe and North America. Other highly active researchers include Cecil, J., Onur, M., Billinghurst, M., Sepehrnoori, K., Vale, Z., and Rossmann, J., all of whom significantly contribute to the study of immersive and intelligent technologies in production management.

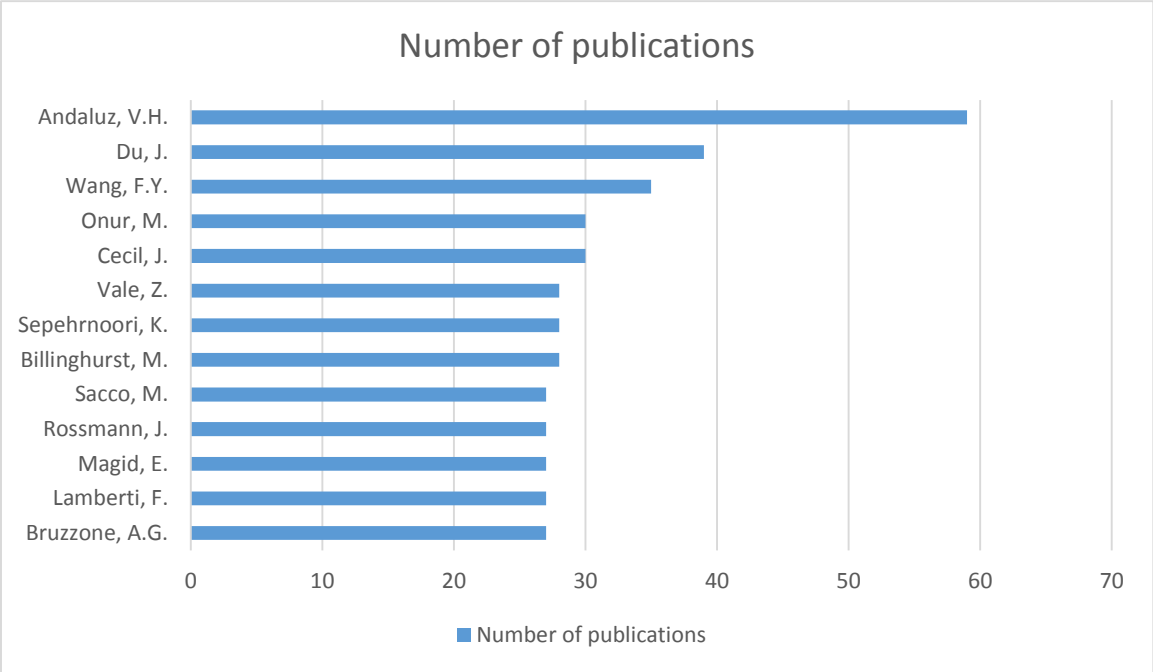

Figure 4. Top 10 most active authors in AI and VR in production.

Source: authors' elaboration based on Scopus data, as of May 1, 2025.

This analysis suggests that knowledge development in this field is largely shaped by a relatively narrow circle of experts, which may foster deep specialization but also carries the risk of limited methodological and thematic diversity. Therefore, initiatives aimed at internationalizing research teams and integrating diverse disciplines into interdisciplinary projects are strongly recommended.

4.2.5. Main Thematic Areas (Scopus Subject Classification)

To determine the disciplinary structure of research on AI and VR applications in manufacturing, an analysis of Scopus subject classifications was conducted. The analysis covered the ten disciplines with the highest number of publications, providing insight into the scientific foundations and interdisciplinary linkages of this research domain.

The highest number of publications was recorded in Computer Science (22,504), underscoring the central role of algorithms, machine learning, and software engineering in AI and VR system design. The second most dominant category is Engineering (17,007), encompassing studies on industrial applications, production system design, digital twin integration, and process automation.

Mathematics ranks third (7395 publications), reflecting the extensive use of mathematical modeling, optimization, and data analysis. Other notable disciplines include Social Sciences, Physics and Astronomy, Energy, Materials Science, Business, Management and Accounting, Decision Sciences, and Medicine.

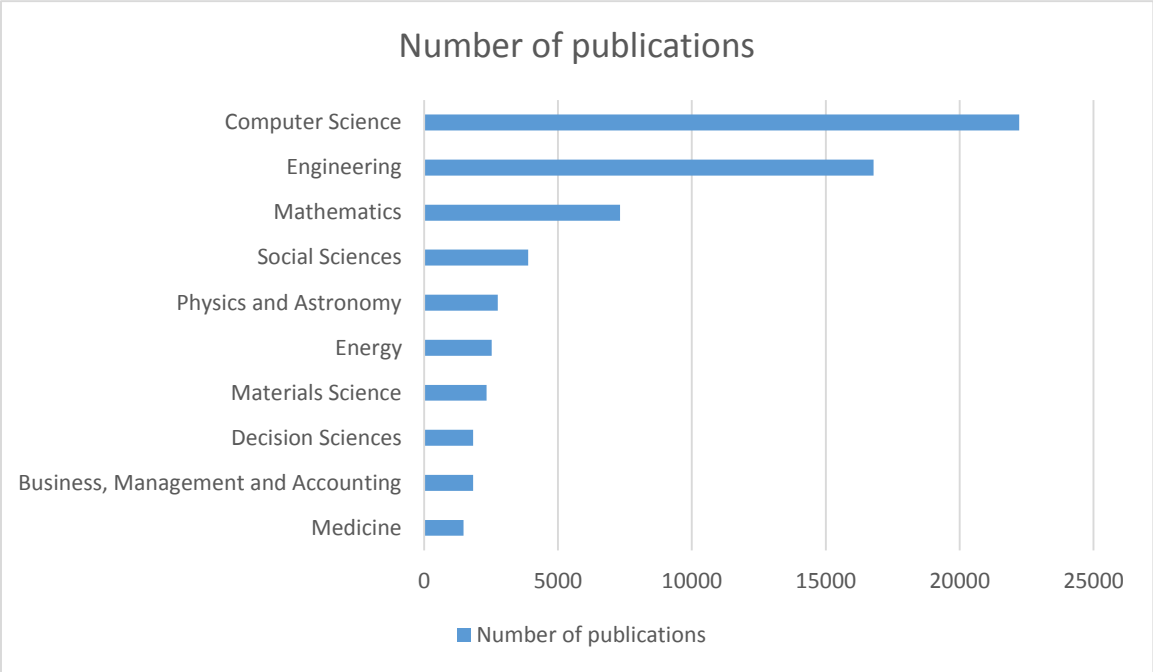

Figure 5. Ten most represented scientific disciplines (Scopus classification) in publications on AI and VR in production.

Source: authors' elaboration based on Scopus data, as of May 1, 2025.

These results reveal a strong dominance of technical and technological disciplines, while also highlighting the presence of organizational, managerial, and social perspectives. This diversity confirms the interdisciplinary nature of the field and the need to integrate engineering expertise with process analysis and technology implementation skills in complex industrial settings.

5. Discussion

The conducted bibliometric and systematic literature analysis allowed for a structured examination of the state of research on the application of AI and VR in production management. The results revealed not only the dynamics of publication growth and the concentration of contributions in specific countries and institutions, but also the prevailing thematic orientations of the field. Building on these findings, this discussion addresses three key aspects: comparison with prior studies, the identification of methodological and implementation challenges, and the formulation of theoretical, practical, and future research implications.

5.1. Key Contributions and Novel Findings

This study makes a significant contribution to the existing body of literature by presenting the first fully integrated bibliometric and systematic review on the applications of Artificial Intelligence (AI) and Virtual Reality (VR) in production management within the paradigms of

Industry 4.0 and 5.0. Unlike previous studies, which typically focused on one of these technologies or analysed their applications solely from a technological perspective, this research encompasses implementation, functional, and systemic dimensions.

The bibliometric analysis identified a sharp increase in research interest in AI/VR integration after 2016, particularly in countries such as China, the United States, India, and Germany. The highest number of publications were recorded in areas such as production layout design, predictive maintenance, immersive training, and operational planning. At the same time, a strong concentration of research was observed within the fields of engineering and computer science, while studies focused on organizational, decision-making, and systemic aspects remain relatively underrepresented.

The reviewed literature indicates that AI is predominantly used for failure prediction, schedule optimization, and adaptive process control, whereas VR is primarily applied in operational training, spatial modelling, and decision scenario testing. Both technologies are increasingly incorporated within the concept of Digital Twins; however, their actual integration with MES/ERP systems remains limited and is rarely analysed systematically.

This study also highlights key research gaps, such as the lack of empirical analyses based on real-world implementations, the insufficient use of effectiveness indicators (e.g., ROI, KPI), and the absence of unified integration platforms. Moreover, the need to consider broader socio-organizational and ethical contexts in the deployment of intelligent and immersive technologies is underscored.

In summary, the article provides a structured overview of the current research landscape, identifies dominant trends and underrepresented topics, and formulates concrete recommendations for future academic and industrial research, serving as a valuable knowledge base for scholars, industry practitioners, and digital transformation project developers.

5.2. Comparison with Prior Studies

The findings of this study align with, but also extend beyond, earlier research efforts focused on the use of Artificial Intelligence (AI) and Virtual Reality (VR) in production management. Prior studies have typically adopted a monothematic perspective, concentrating either on AI or VR separately. For example, Razmak et al. (2025) examined the transformative role of AI in production and operations management, emphasizing its potential to complement or replace human labor, yet without addressing its integration with immersive technologies such as VR. Similarly, Guo et al. (2020) conducted a systematic review of VR in industrial maintenance, but the scope remained narrow and did not explore decision-support functions or real-time integration with enterprise systems.

In contrast, the present study provides a comprehensive and integrated bibliometric and SLR-based exploration of both AI and VR applications across all core production management functions, including layout design, predictive maintenance, training, risk management, and ERP/MES integration. This approach more closely reflects real-world implementation

strategies within Industry 4.0 and 5.0 frameworks, where technological convergence is the norm.

In terms of geographic and disciplinary patterns, our results are consistent with prior findings by Espina-Romero et al. (2024), who observed that the majority of AI-related manufacturing research is concentrated in China, the US, and Germany. However, this study goes further by examining not only volume-based metrics, but also the thematic distribution of publications and the evolution of research intensity over time.

Furthermore, earlier works have often highlighted critical implementation challenges, such as uncertainty over the degree of human-AI collaboration (Sauer, Burggräf, 2025), or the limited maturity of VR tools in real-world production settings (Lei et al., 2023; Silva et al., 2020). This study confirms such challenges but extends the analysis by proposing specific integration models, identifying key disciplinary gaps, and offering a taxonomy of underrepresented research areas, including SME adoption and interoperability.

Finally, while prior studies like Lalić et al. (2020) recognized the potential of VR in employee training, they lacked robust empirical indicators or decision-making frameworks. Our study addresses this by advocating for structured effectiveness metrics (e.g., ROI, OEE, learning curves), positioning itself as a practical reference point for future academic research and industrial deployment strategies.

In summary, this article complements existing literature but distinguishes itself through its integrated technological scope, systemic industrial framing, and focus on both bibliometric rigor and managerial relevance.

5.3. Limitations and Methodological Considerations

Despite the comprehensive nature of the conducted study, several limitations must be acknowledged in relation to the methodology and scope of the systematic literature review (SLR) and bibliometric analysis. These limitations impact the generalizability of findings and indicate directions for methodological refinement in future research.

First, the review is based exclusively on publications indexed in the Scopus database, which, although recognized for its broad coverage in engineering and management disciplines, may omit relevant studies published in local or non-English-language journals. Additionally, the inclusion criteria favored peer-reviewed journal articles and conference proceedings, excluding grey literature and industry reports that could offer valuable insights into real-world implementations of AI and VR in production environments.

Second, the search strategy-while developed with precision-was based on specific keyword combinations (e.g., “artificial intelligence”, “virtual reality”, “production”, “MES”, “ERP”), which may have led to the omission of studies using alternative terminologies or focusing on adjacent technologies (e.g., XR, AR, machine vision). As such, the findings reflect a focused yet inherently filtered snapshot of the broader research landscape.

Third, although the bibliometric analysis enabled objective mapping of publication trends, author affiliations, and subject categories, it was limited by the structure of metadata available in Scopus. For instance, nuances related to the type of AI or VR implementation, context of use (e.g., training vs. maintenance), or organizational scale (e.g., SME vs. large enterprise) could not be fully captured in the quantitative layer.

Fourth, the qualitative synthesis of dominant application areas (e.g., layout planning, predictive maintenance, training) was conducted based on titles, abstracts, and keywords, without full-text analysis of each article. This approach, while ensuring feasibility and replicability, may have introduced interpretation bias or overlooked nuanced insights embedded in case-study sections.

Finally, the study did not apply advanced scientometric techniques such as co-citation or keyword co-occurrence networks, which could further enhance the understanding of thematic convergence and research clustering. The integration of such techniques is recommended for future work aiming to deepen the structural understanding of the field.

In summary, while the present study provides a solid empirical and conceptual foundation for understanding the state of research on AI and VR in production management, its methodological scope is bounded. Future studies should consider multi-source databases, triangulation with industry data, full-text content analysis, and more sophisticated bibliometric tools to achieve greater depth and breadth.

5.4. Future Research Directions

Building upon the identified gaps and thematic concentrations, several promising directions for future research can be delineated to advance the theoretical understanding and practical implementation of Artificial Intelligence (AI) and Virtual Reality (VR) in production management.

First, further studies should explore integrated frameworks combining AI and VR within unified decision-making environments. Despite numerous publications addressing these technologies separately, only a limited number of contributions examine their joint application in real-time operational contexts, such as dynamic rescheduling or real-world training adaptation. Developing holistic models that leverage both data-driven intelligence and immersive visualization could significantly enhance adaptability and responsiveness in smart manufacturing.

Second, there is a pressing need for empirical research based on real industrial data. A vast majority of studies are conceptual or based on simulated environments, often lacking robust validation. Future work should prioritize industry-academic collaborations to access operational datasets and validate the effectiveness of AI/VR systems in live production settings, particularly regarding system reliability, employee adaptation, and return on investment (ROI).

Third, the literature review revealed a lack of standardized performance metrics for evaluating the success of immersive technologies and intelligent algorithms. Future research should propose and test unified evaluation frameworks-especially those linking key performance indicators (KPIs) with production outcomes, training effectiveness, and safety improvements. Comparative studies across sectors and enterprise sizes would also support generalizability.

Fourth, research should delve into contextual factors affecting implementation success, such as organizational culture, workforce readiness, technological maturity, and sector-specific regulations. These factors are often overlooked but critically influence the adoption curve and scale of deployment, particularly in small and medium-sized enterprises (SMEs).

Fifth, emerging technologies such as Extended Reality (XR), Digital Twins, and Edge-AI warrant more focused investigation, especially in relation to energy efficiency, predictive maintenance, and human–machine interface optimization. Their synergy with existing MES and ERP platforms also remains underexplored and offers fertile ground for interdisciplinary research.

Finally, comparative cross-national and cross-industry analyses could illuminate how regional policy frameworks, economic incentives, and infrastructure readiness impact the adoption of AI and VR. Such studies would help tailor implementation strategies and inform national or regional roadmaps for smart manufacturing.

5.5. Practical and Theoretical Implications

The findings of this study yield several important implications for both academic research and industrial practice in the field of production management enhanced by Artificial Intelligence (AI) and Virtual Reality (VR).

From a theoretical perspective, the conducted bibliometric analysis contributes to the systematization of the research landscape, highlighting dominant themes, neglected topics, and institutional concentrations. The integration of AI and VR technologies into production environments emerges as a multidisciplinary domain, spanning engineering, computer science, and management. This indicates the need to refine existing theoretical models that explain technology adoption in manufacturing, moving beyond linear or isolated approaches toward frameworks that capture technological convergence, organizational dynamics, and human-centered design.

Furthermore, the analysis underlines the fragmentation of current research between technological development and organizational application. This gap suggests a demand for new conceptual models that incorporate socio-technical factors, digital capabilities, and operational maturity as key enablers of successful AI/VR deployment. Such models would benefit from being empirically tested across different industrial contexts.

From a practical standpoint, the results provide actionable insights for production managers, technology developers, and policymakers. In particular, the identification of key application areas-such as layout design, predictive maintenance, and immersive training-can guide resource allocation and strategic planning for digital transformation initiatives. The study also exposes persistent implementation barriers, such as system interoperability, lack of performance evaluation standards, and limited access to real operational data. Addressing these constraints will be essential for scaling up deployments in diverse industrial sectors.

The study additionally points to the strategic importance of integrating AI and VR with MES/ERP systems, as such integration allows for real-time synchronization, automated decision-making, and operational transparency. This highlights the necessity for collaborative platforms between IT vendors, process engineers, and plant operators to co-develop scalable solutions.

Finally, the research emphasizes the role of human capital and organizational readiness as critical success factors. Immersive training, AI-driven coaching systems, and adaptive learning environments can accelerate workforce upskilling and improve safety, efficiency, and employee engagement in smart factories.

5.6. Limitations and Future Research Directions

Despite its comprehensive scope and methodological rigor, this study presents several limitations that should be acknowledged and addressed in future research efforts.

First, the data source was limited to the Scopus database, which although widely recognized for its coverage of scientific literature may omit relevant publications indexed elsewhere (e.g., Web of Science). This may lead to a partial representation of the full research landscape, particularly in practice-oriented domains or grey literature.

Second, while the analysis aimed to exclude publications focused solely on quality management, classification ambiguities and overlapping keywords might have led to the inclusion of borderline cases or the exclusion of relevant records. Additionally, bibliometric techniques provide quantitative insights, but may overlook nuanced conceptual developments or methodological subtleties present in individual studies.

Third, the temporal scope of the data, extending to May 2025, imposes a snapshot perspective. Given the dynamic evolution of AI and VR technologies, especially in industrial settings, future developments might shift the thematic and geographic centers of research, requiring updates of the present findings.

Moreover, the lack of a detailed impact assessment framework-such as benchmarking models or maturity scales-limits the ability to evaluate the real-world effectiveness of AI/VR implementations. Future research should focus on the development of such frameworks, integrating objective indicators like ROI, OEE, KPI, or immersive training effectiveness metrics.

In light of these limitations, several future research directions emerge:

- Development and empirical validation of integrated models combining AI and VR functionalities with production management systems.
- In-depth case studies analysing implementation processes, barriers, and enablers in specific sectors (e.g., automotive, aerospace, pharmaceuticals).
- Exploration of ethical, legal, and organizational challenges related to decision automation, data governance, and human-machine interaction in smart factories.
- Investigation of the role of SMEs in the adoption of immersive and intelligent technologies, with attention to scalability, cost-effectiveness, and support ecosystems.
- Cross-comparative analyses of regional and institutional strategies for AI/VR integration in industrial policies and innovation programs.

By addressing these areas, future studies can deepen the theoretical foundation of smart production and bridge the gap between academic discourse and industrial transformation.

6. Conclusion

The integrated application of Artificial Intelligence (AI) and Virtual Reality (VR) in production management currently represents one of the key directions of industrial development in the context of Industry 4.0 and 5.0. The conducted systematic and bibliometric analysis has demonstrated that these technologies-initially perceived as experimental-are increasingly being implemented in industrial practice, ranging from production layout design and maintenance management to operational training and integration with MES/ERP systems.

The greatest intensification of research occurred after 2020, as confirmed by bibliometric data indicating a sharp increase in the number of publications, particularly in East Asian countries (China, South Korea), the United States, and selected European research centers. The dominant scientific disciplines are computer science and engineering, while the leading topics include digital twins, operational planning, failure prediction, and immersive VR training.

Despite rapid development, significant research gaps have been identified, including the absence of comprehensive integration models, limited use of empirical data, and implementation constraints stemming from organizational and technological barriers. There is also a need for more in-depth studies on the impact of AI and VR on human capital, workplace safety, and the effectiveness of operational management systems.

The knowledge gathered through this study not only allows for the identification of current research and technological trends but also enables the formulation of recommendations for future development. In particular, the analysis points to the necessity of undertaking interdisciplinary projects that integrate technological, organizational, and social components-allowing for the full exploitation of the potential of AI and VR in modern production management.

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SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

ASSESSING THE MATURITY OF A SAFETY CULTURE IN A MANUFACTURING COMPANY – A CASE STUDY

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Purpose: The aim of this article is to verify the maturity level of the safety culture in a manufacturing company, which has evolved as a result of the implementation of a safety improvement program in the years 2021-2024.
Design/methodology/approach: The study used a case study method, enabling an in-depth analysis of the process of implementing solutions to improve safety. For the purposes of mapping the safety culture carried out in 2021-2024, an analysis of key organisational documents and behavioural observation (BBS) was conducted, focused on identifying behaviours conducive to undesirable events and shaping safe attitudes among employees. The diagnosis was based on a proprietary tool built on the Bradley Curve and the Safety Culture Mapping matrix. Twelve safety dimensions were assessed, covering the areas of leadership, organisation, and processes and activities (including policy and strategy, requirements and standards, performance management, structure and roles, resources, awareness and motivation, attitudes, communication, incident investigation, observations and audits, learning and development).
Findings: The results of the study show that in 2021, the maturity of the safety system was low, with relatively strong incident investigation and audit practices, but significant deficits in the areas of policy, strategy and planning, performance management, communication and employee motivation. In response to the low results, an integrated improvement programme based on the CLEAR strategy and Operation Compass was implemented, which strengthened the consistency of actions by formalising policies, clarifying roles, incorporating safety objectives into bonus and promotion mechanisms, and multi-channel communication. Behavioural observations became a key operational intervention. As a result, by 2024, a significant increase in maturity was recorded in most of the dimensions examined. A decrease in accidents has been confirmed, which, together with the standardisation of accident investigations and improved reporting, indicates that integrated, data-driven safety management characterises the organisation as a learning organisation that strengthens the safety culture and reduces risk and operating costs.
Research limitations/implications: Due to the case study nature of the research, the research tools have not been validated, which is recommended when applying them to another company. The tools presented can serve as an example for the implementation, evaluation, and use of similar instruments in manufacturing and service companies.

Practical implications: The tools presented can be used for benchmarking analysis in the context of measuring safety culture.
Social implications: The research indicates a strengthening of proactive attitudes among employees, leading to a reduction in accidents and the development of a culture of trust and learning within the company.
Originality/value: The originality of the research lies in the presentation of a combination of various tools, thanks to which a company can take steps to improve its safety culture.
Keywords: safety, safety culture, Safety Culture Mapping, Behaviour Based Safety.
Category of the paper: Case study, Research paper.

1. Introduction

Contemporary organisations operate in conditions of highly complex processes, cost and technological pressure, and constantly growing stakeholder expectations, which means that safety culture is no longer just a component of the health and safety system, but has become a prerequisite for operational resilience and management quality. In cultural terms, safety is not just a set of procedures, but a set of assumptions, values and patterns of behaviour that guide everyday decisions and practices, determining how employees perceive risk and how they respond to it (Schein, E.H., Schein, P.A., 2017). Understood in this way, culture serves as a cognitive and normative guide for organisations (Guldenmund, 2000). The importance of safety culture is particularly evident when examining accident rates. This area is greatly influenced by the quality of leadership practices, consistency of communication and operational discipline, as well as modelled and reinforced behaviours at work (Zohar, 1980).

Safety culture cannot be implemented without adapting to legal regulations, both mandatory and non-mandatory (e.g. ISO 45001 standards). Initiatives to institutionalise a safety culture are becoming increasingly common, and in high-risk companies, systemic compliance is combined with the development of soft learning and communication mechanisms. As a result, organisations are expected not only to comply formally, but also to be capable of continuous improvement, learning from events and transparent reporting of progress. Against this background, the implementation of a safety culture should be understood as a process of improvement involving the linking of policies, structures and roles with operational practices (Hudson, 2007; Cooper, 2000). Maturity assessment — conducted in a multidimensional manner and using triangulation of different methods — allows for the diagnosis of gaps and the conscious allocation of development efforts to areas that need it most.

This work is set in the reality of a manufacturing company and responds to the practical need to verify whether and to what extent an integrated safety culture improvement programme is effective. In this context, the aim of the research is to assess the maturity of the safety culture in the company and to identify the effects of the improvement programme implemented in

2021-2024. This objective justifies addressing the issue, as the combines regulatory and market requirements with the internal need to reduce risk and build a learning organisation.

2. Safety culture as a component of organisational culture

Organisational culture is defined in the literature as a system of shared and learned assumptions, values, norms and patterns of behaviour that guide the interpretation of situations, the assessment of what is appropriate, and the selection of actions in everyday practice (Schein, E.H., Schein, P.A., 2017). It includes both formal elements — enshrined in statutes, codes or procedures — and informal, i.e. unwritten rules, symbols, language and rituals that often subconsciously and habitually organise human interaction. In this sense, culture serves as a cognitive and normative signpost indicating ways of acting, while also stabilising expectations and behaviours, building internal cohesion and the uniqueness of an organisation in relation to its environment (Deal, Kennedy, 2000; Ravasi, Schultz, 2006). One of the most well-known approaches is the concept developed by E.H. Schein (2010), according to which culture is a pattern of shared basic assumptions developed by a group in the process of solving problems of adaptation to the environment and internal integration, recognised as sufficiently effective to be passed on to new members as an appropriate way of perceiving, thinking and feeling. The author emphasises the layered structure of culture: from visible artefacts (language, symbols, rituals, modes of communication and control) to declared values. Other authors emphasise the operational side of organisational culture. T.E. Deal and A.A. Kennedy (2000) define organisational culture as the way things get done in an organisation, emphasising its role in everyday decision-making and problem-solving. In turn, D. Ravasi and M. Schultz (2006) describe culture as a set of shared assumptions that determine what behaviours are considered appropriate in different situations and how they are implemented and passed on to new members. G. Hofstede (2010), on the other hand, points out that culture, including organisational culture, is differentiating in nature, allowing members of one community to be distinguished from another. To summarise the meaning of the selected definitions of organisational culture, it should be emphasised that the phenomenon of organisational culture is not a set of static declarations, but a dynamic result of processes of continuous improvement of the organisation's activities.

An important component of organisational culture, often analysed separately, is safety culture (Clarke, 1999; Cooper, 2000). This issue gained significance after the Chernobyl nuclear disaster, where it turned out that the organisation's poor safety culture contributed to a tragedy that could have been prevented (International Atomic Energy Agency, 1986). A highly developed organisational culture and, consequently, safety culture is reflected in the positive behaviour and attitudes of employees, as they are the primary source of errors and

dangerous behaviours that result in accidents at work and occupational diseases. In the classic regulatory approach (ACSNI, 1993), safety culture is a product of individual and group values, attitudes, perceptions, competencies and behaviour patterns that determine the level of commitment and the style and effectiveness of occupational safety and health management (Guldenmund, 2000). J. Reason (2016) develops this approach, pointing out that a mature safety culture is based on the coexistence of a culture of information and reporting, learning from mistakes, fair treatment and organisational flexibility. In practice, this may mean emphasising the value of life and health, systematically minimising risk and the ability to continuously improve the safety system. It has been found that there are a number of organisational factors that influence the health and safety culture in an organisation, the most important of which are: effective communication, committed resources, transparent management, high-quality training, comfortable workplaces, and a focus on health and safety and continuous improvement in this area (ACSNI, 1993).

3. Selected tools for measuring safety culture

The level of safety culture is most often inferred indirectly by measuring the safety climate**.** According to D. Zohar (1980), the safety climate is determined by employees' perceptions of how health and safety policies, procedures and practices actually work in the organisation. He emphasises that an important element of the safety climate is the perception by the organisation's employees of the relative importance of safe behaviour in their daily activities. According to A. Neal and M.A. Griffin (2002), the climate influences motivation and knowledge in the field of safety, and through them – behaviour consistent with the rules and behaviour that supports safety. In turn, M. Flin and co-authors (2000) propose that climate be identified by characteristics that are specific to safety culture and recognisable in the attitudes and assessments of employees at a given point in time. The authors of a tool dedicated to climate diagnosis defined it as the shared perceptions of team members regarding safety policies, procedures and practices on the part of management and working groups, which enables a comparable, quantitative measurement between departments and organisations (Kines et al., 2011). In summary, in light of the above definitions: safety climate is a measurable, situational dimension of how safety issues are perceived and addressed in an organisation, refers to deeper, relatively permanent assumptions and values.

In light of the recommendations of the relevant EU bodies (Brück, 2011), three complementary approaches to safety culture diagnosis are distinguished: academic, analytical and pragmatic**,** recommending a holistic approach (triangulation) rather than a single research technique. This means combining quantitative data (e.g. from safety climate surveys) with qualitative data (interviews, observations, review of artefacts and documents) and discussions

with management and employees. The most common quantitative method is to measure safety climate using standardised surveys, e.g. the NOSACQ-50 questionnaire, which is tool-verified and used in multiple languages and across industries. It captures the climate as the shared perception of safety policies, procedures and practices by team members. The second category consists of simple review tools that facilitate a preliminary assessment of culture maturity. An example is the Score Your Safety Culture Checklist, consisting of 20 dichotomously rated statements. A tool can also be used for assessment, in which the development of safety culture is mapped along a "Culture Ladder" characterised by the following levels: pathological, reactive, calculative, proactive and generative. Its purpose is to identify a path that will lead the organisation to achieve world-class occupational health and safety and environmental protection. An example of triangulation is the LSCAT (Loughborough Safety Climate Assessment Toolkit). It combines surveys with individual interviews, focus groups, document analysis and records. This allows for the assessment of various aspects of culture and the comparison of qualitative and quantitative results (Brück, 2011).

Another tool for measuring the maturity level of safety culture is the Bradley curve. Its purpose is to present safety culture as a continuum of maturity, on which organisations move from reactive to interdependent behaviours, and the accompanying internalisation of safety norms translates into a systematic decrease in injury rates (Bernard, 2018). In a theoretical sense, the model provides a normative framework for maturity, emphasising a shift in the sources of agency: from external control and conformity (dependent level) through individual responsibility (independent) to collective responsibility (interdependent). At the operational level, the curve is sometimes combined with safety climate surveys, which facilitate the mapping of organisational units into four levels of maturity and internal benchmarking (Siuta et al., 2022). Although the model has great communicative and developmental value, its psychometric validation is limited, which is why triangulation with reliable climate measurements, behaviour audits and leading indicators is recommended (Goncalves Filho, Pinto, Waterson, 2018).

According to Hudson (2007), safety culture maturity is typologically classified from pathological cultures (ignoring safety) through bureaucratic cultures (dominance of compliance and metrics) to generative cultures (safety is integral to the mission and learning). Unlike Bradley's approach, which primarily focuses on motivation and agency, Hudson's typology emphasises the quality of information flow and learning (e.g. a culture of reporting, fair treatment, flexibility), which is strongly linked to the concept of a "learning organisation". For this reason, this framework is a frequent reference point for the design of reporting, learning and fair accountability systems.

The literature shows that safety culture is intensively studied in most high-risk sectors, such as construction (Chinda, Mohamed, 2008), maritime environments (Cox, Cheyne, 2000), healthcare (Halligan, Zecevic, 2011), aviation (O'Connor et al., 2011), shipping (Havold, 2005) and railways (Clarke, 1998).

In Poland, there is a clear institutionalisation of practices aimed at diagnosing and strengthening safety culture in large companies in the infrastructure and high-risk sectors. This is particularly evident in the railway sector, where numerous companies – as signatories to the "Declaration on the Development of Safety Culture" – include regular reviews, measurements and development activities in their management systems, and their experiences are aggregated and disseminated by the Railway Transport Office (Deklaracja w sprawie rozwoju kultury bezpieczeństwa w transporcie kolejowym, 2023). In coal and non-ferrous metal mining, safety culture is described and communicated as a strategic value, and interventions are both systemic and behavioural in nature. Jastrzębska Spółka Węglowa S.A. emphasises the priority of safety culture by launching regular campaigns addressing specific occupational risk profiles and reinforcing beliefs that promote responsible operational behaviour („Bo mam do kogo wracać" – nietypowa akcja dla pracowników KGHM, 2025). KGHM Polska Miedź S.A. strengthens cultural components, including a sense of personal responsibility and shared responsibility, through actions and continuous monitoring of accident rates and improvement initiatives, reported in accordance with ESG standards. ORLEN consistently combines process safety discipline with the development of a safety culture. Integrated reports highlight both formal elements (ISO 45001, audit standards, PSM (Price Sensitivity Meter) indicators) and soft elements (education, behaviour observation, learning from events) (Bezpieczeństwo procesowe – Raport zintegrowany, 2022). The energy company Veolia describes its activities as safety culture building programmes implemented in dispersed locations and reinforced by a health and safety policy that establishes the development of a safe working culture as one of its systemic objectives (Bezpieczeństwo i ochrona zdrowia pracowników, n.d.). In civil aviation, an example of a company that operationalises the Just Culture paradigm in its management practices is LS Airport Services S.A. (Oświadczenie dotyczące Polityki Bezpieczeństwa, 2023) The company links safety culture to the quality of reporting and communication, which results from its adopted policies and participation in industry safety workshops coordinated by the aviation authority. The above cases indicate that the largest Polish companies in high-risk industries treat safety culture as a strategic variable, and its assessment is both quantitative (accident metrics, process indicators, audits) and qualitative (campaigns, training, behaviour analysis, contractor involvement).

In a comparative perspective, two dominant logics of institutionalising safety culture can be observed outside Poland: the European one, in which the sectoral regulator co-creates model frameworks and self-assessment tools (Safety culture, n.d.), and the Anglo-Saxon, where the emphasis is on safety management systems (SMS), a culture of fair treatment and organisational maturity measured by standardised indicators (AHRQ Hospital Survey 2.0: User's Guide, 2021).

4. Research objectives and methodology

Safety is a key value for organisations, and a high level of safety reflects a company's commitment to operational excellence and an increase in the level of organisational culture. The aim of the study is to assess the level of implementation of safety culture in company X. The company in question designs and manufactures vertical windows and patio doors and has been operating on the Polish market since 1990. The organisational structure of the production area consists of five production halls, where various types of windows, doors and non-standard shaped elements are manufactured, as well as a warehouse and a powder coating plant.

A case study was used as the research method, enabling a detailed description of the process of implementing solutions to improve safety. As part of the research, safety culture mapping was carried out in 2021 and 2024 using an analysis of key documents relating to organisation and safety management, as well as behavioural observation.

Safety culture mapping involves diagnosing and analysing attitudes, values, behaviours and practices related to safety in an organisation (Future Sky Safety, n.d.). This is related to changes in the organisation that lead to organisational improvement (Drucker, 2024). Behavioural observation (BBS - Behaviour Based Safety) is an activity that involves monitoring and analysing the behaviour of employees in their everyday workplace, in the most natural conditions possible. Such research is designed to help identify actions, tools or procedures that may contribute to the occurrence of accidents or near misses, and to observe the environment (Szczygielska, 2015). The aim of BBS is to increase employee awareness, build safe habits and implement rules and procedures to minimise risky situations. Feedback is a very important element. The response to a potentially dangerous behaviour should be immediate. It should consist of immediately stopping the employee from continuing the behaviour, expressing concern and conducting a conversation aimed at identifying the hazard and possible remedies. Promoting the idea of BBS helps to minimise the number of injuries and accidents at work, and using this procedure reinforces safe behaviour among employees not only during their work but also in their everyday lives, as they pay more attention to safe behaviour (Behavior Based Safety – What it is and how it works, n.d.).

Table 1.
Safety dimensions in company X

Leadership	leadership commitment
	safety policy, strategy, plan
	requirements, procedures, standards
	performance management – KPIs, reviews, PDCA, change management
Organisation	structure, assigned roles, responsibilities
	resources and potential
	awareness and motivation
	beliefs and attitudes - operational discipline, focus on task completion and goal achievement

Cont. table 1.

Processes and activities	communication
	investigation of incidents (accidents, near misses)
	observations, audits, inspections
	learning and development

Source: Company X's own materials.

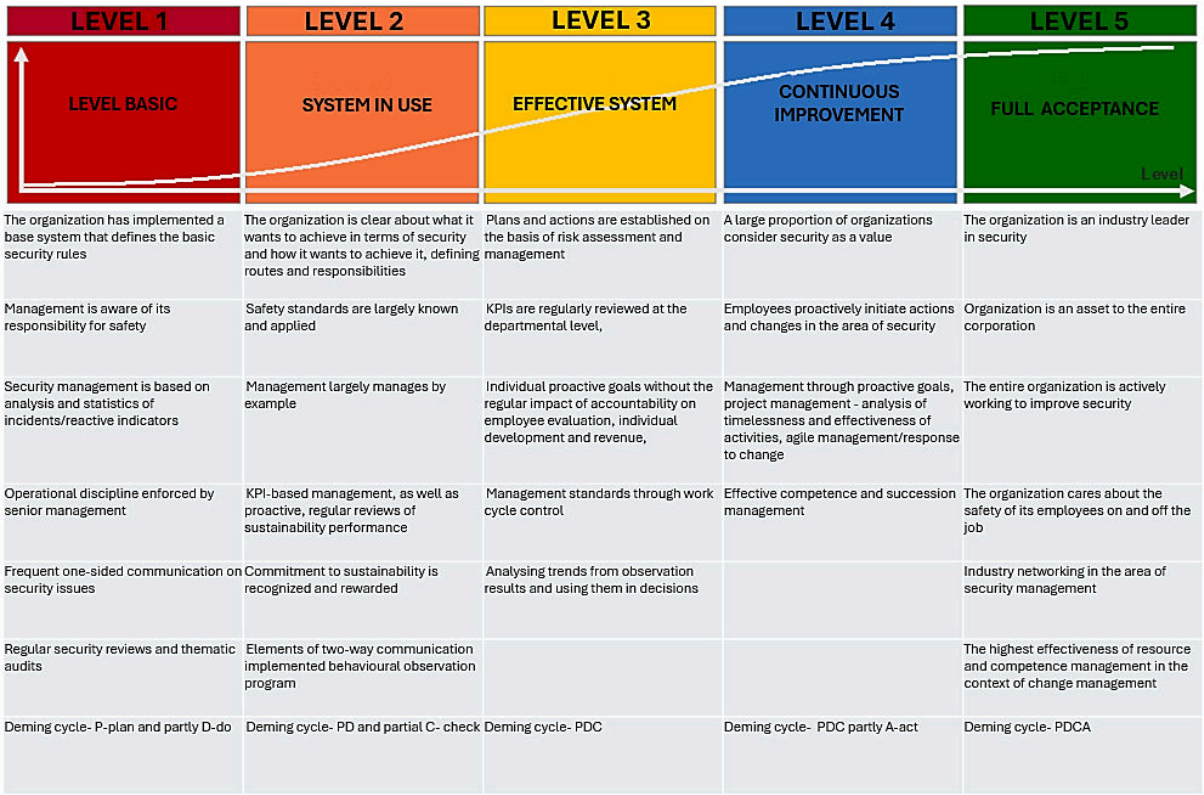

Figure 1. Safety Culture Mapping.

Source: Company X's own materials.

A proprietary tool based on the Bradley Curve was used to diagnose the state of the safety culture. Twelve safety dimensions were identified (Table 1), which were assessed using Safety Culture Mapping (Fig. 1) on a scale from 1 to 5, where 1 meant "completely disagree" and 5 meant "completely agree".

5. Implementation of activities related to building a safety culture

The decision to launch a safety improvement programme in the surveyed company in 2021 was made taking into account several key safety elements. The most important was to ensure the protection of the life and health of employees, as creating a safe working environment has a significant impact on the comfort of performing duties, promotes a sense of peace and positive attitudes towards work. Another factor taken into account was the reduction in the number of accidents, which also translates into a reduction in direct and indirect costs, including medical

expenses, compensation, implementation and training of replacements, and production downtime costs. A high level of safety culture also strengthens staff motivation and loyalty. In light of the above, the management team formulated a plan to improve working conditions, precisely defining the objectives and strategy for their implementation.

An analysis of key documents for the study showed that the strategy in the company is based on five pillars (CLEAR): customer focus (C), leadership (L), efficiency (E), accountability (A) and reliability (R). The first of these is a customer-oriented approach, in which all decisions are made from the perspective of the customer's needs and expectations. This includes concern for product quality, safety and reliability, as well as stakeholder relations and a sustainable approach to production, reflected in the selection of certified suppliers, the reduction of the negative impact of processes on the environment and the support of pro-environmental initiatives in local communities. Joint leadership is based on partnership, exchange of experience and mutual support, and its goal is to build a unified and strong organisation capable of achieving a leading position in the industry. Efficiency means effective decision-making and operations based on the optimal use of material resources, minimising waste and maximising added value, while investing in the development of employee skills, sharing knowledge and supporting innovation. Responsibility refers to the involvement of all stakeholders in decision-making processes, clear communication of goals and values, and the implementation of common, long-term priorities that include not only growth and profits, but also sustainable development and social initiatives. Reliability, on the other hand, is the foundation for building customer trust and loyalty, and by consistently meeting their needs and striving for continuous improvement, the organisation maintains its brand among the most reliable and valued on the market.

On this basis, it can be concluded that the company's goal is to create a safe and development-friendly working environment through investments in modern technologies, training and a culture of mutual respect, which promotes employee commitment and loyalty. Building relationships with customers based on high-quality products, timely order fulfilment, professional service and loyalty programmes is also of key importance. An important element is cooperation with suppliers, based on mutual trust, timeliness and high quality of materials, while taking into account the principles of sustainable development. Thanks to this, the organisation strengthens its position on the market, providing customers with safe, durable products that are in line with social and environmental values.

An analysis of risk assessment documentation has shown that four main risk groups have been defined in the company under review: mechanical (including injuries during machine operation, falls, injuries from glass and aluminium), chemical (flammable and toxic substances requiring strict compliance with safety rules), physical (wood dust, noise) and ergonomic (incorrect posture, heavy lifting). The identification of these factors enables the assessment of occupational risks and the development of preventive measures, such as procedures, technical safeguards and personal protective equipment.

The company under review places particular emphasis on clear and reliable communication, including communication regarding safety rules. One of the main tools is the Moja XXX mobile app, which is used to quickly report accidents, procedures and training. For production employees, additional workshops and on-the-job training, posters and information boards, daily and periodic team meetings enabling the exchange of information and the reporting of initiatives within employee programmes, as well as job instructions ensuring knowledge of safe working practices are provided. In addition, newsletters are sent out and information is posted in dedicated areas, such as canteens.

As part of the preparations for implementing a safety culture in the company, an audit was conducted in 2021 with the participation of an external consultant. Based on this, a diagnosis of the initial state was made and recommendations for actions to improve the existing situation were developed.

An analysis of the results obtained in 2021 (Table 2) indicates a relatively low level of organisational maturity in the area of safety management. The highest scores were achieved in the areas of leadership commitment and processes related to incident investigation and audits and inspections, which suggests that the organisation is somewhat focused on identifying risks and monitoring their occurrence. However, other elements, such as security policy, strategy and planning, as well as systemic performance management, were rated significantly lower, which may indicate a lack of a consistent and long-term concept for activities in this area. In the organisational sphere, there is a deficit in employee awareness and motivation, which limits the effectiveness of the measures implemented. Slightly higher ratings in the area of beliefs and attitudes also indicate a need to develop a safety culture based on operational discipline and goal orientation. Operational processes, such as communication and learning and development activities, also scored below average, suggesting insufficient mechanisms to support continuous improvement and knowledge sharing. Overall, the average rating of 1.6 (between levels 1 and 2 – see Fig. 1) confirms that the safety management system in the analysed period was characterised by low maturity, requiring reinforcement at both the strategic and operational levels.

Taking into account the results obtained during the safety culture audit in 2021, it was decided to implement measures in the company to improve this result and, above all, to increase safety. As part of the corporate governance overhaul, it was decided to clarify leadership roles in this area, standardise incident investigation and incorporate safety into the bonus system and promotion process. In 2023, the company conducted a media campaign on safety among employees and emphasised the importance of feedback from production employees. Operational activities were more focused on visualising and automating reporting and improving systems. The management of post-incident recommendations was standardised and the effectiveness of communication channels was improved. The year 2024 was characterised by the implementation and improvement of activities related to the implementation of safe practices and responsibility for safety at all levels of the company.

Table 2.
Security dimensions in company X

Dimension group	Safety dimensions	Years	
		2001	2004
Leadership	leadership engagement	2.5	2.4
	security policy, strategy, plan	1	2
	requirements, procedures, standards	2	2.4
	performance management – KPIs, reviews, PDCA, change management	1.5	2
Organisation	structure, assigned roles, responsibilities	1.5	3
	resources and potential	1.5	2.3
	awareness and motivation	1.3	2
	beliefs and attitudes – operational discipline, focus on task completion and goal achievement	1.5	2
Processes and activities	communication	1.5	2
	incident investigation (accidents, near misses)	2	3
	observations, audits, inspections	2	3.2
	learning and development	1	1

Source: Company X's own materials.

The CLEAR strategy was expanded in 2024 with the announcement of Operation Compass, which unites the entire operational organisation into a single team and guides it on the path to excellence based on employee engagement, effective leadership and continuous process improvement. Employee commitment is expressed in a positive attitude, openness to new ideas, identification with the organisation's goals, cooperation based on respect and a willingness to go beyond the call of duty. Effective leadership is understood as influence that does not result from coercion, but includes setting an example, making decisions based on reliable data, strengthening the team and inspiring others to work together towards the organisation's goals. The third element is the systematic improvement of processes, focused on customer satisfaction, strengthening the company's position, implementing best practices and using tools that support the achievement of the desired results. According to the Operation Compass strategy, these activities lead to effective management. An example of this is the Code of Conduct in place in the organisation, which is based on simple and transparent principles that support open communication, clear definition of goals, roles and responsibilities, and standardisation of processes to ensure consistent quality.

The most important operational measure to improve the safety culture was the implementation of behavioural observation. This was a process that involved all production foremen and production area managers. During the observation, a trained observer reacted to behaviours that were classified as unsafe. The second step was to talk to the observed employee in order to encourage reflection on the hazard and a commitment to correct behaviour in the future, without passing judgement. The final stage was anonymous reporting of non-compliance in the system for the purpose of analysing trends across the company. Approximately 1100 observations were recorded each month (see Fig. 2) and analysed. Examples (original spelling) included:

– The operator removed a rack with windows for repair during transport; the window fell out of the rack – the glass did not break. The reason was that the large window was in a short rack and had not been screwed to the rack.
– While picking up a pallet with a forklift, an employee hit another tall pallet, which almost fell over.
– The operator was transporting tall and narrow items in a rack in an upright position, posing a risk of the items falling over.

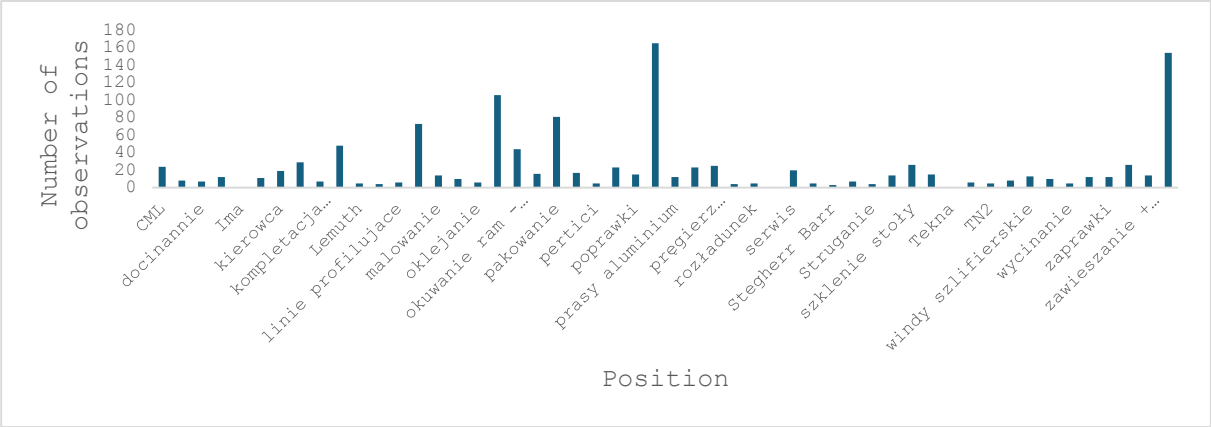

Figure 2. Number of behavioural observations per workstation – week 18.

Source: Company X's own materials.

The interventions implemented in the surveyed company resulted in a significant improvement in the values of most safety culture indicators in 2024 (Table 2). With the exception of the "leadership commitment" area, increases were recorded in all other areas. The greatest improvement was recorded in the leadership ($\Delta = 1.8$), which is reflected in the formalisation of guidelines. In the organisational area, the greatest progress was made in structure, roles and responsibilities related to the systematic conduct of mandatory behavioural observations. In the process area, incident investigation was significantly improved and observations, audits, inspections. At the same time, communication was improved, which increased risk awareness, transparency of actions and understanding of the interventions implemented among employees. The 2024 measurement yielded an absolute value = 2.28, it places the company between the second and third levels (see Figure 1), which is a consequence of targeted development activities and confirms the strengthening of organizational learning mechanisms in the area of occupational health and safety. The improvement in the actions of the company's employees has too translated into a measurable reduction in the accident rate (Fig. 3).

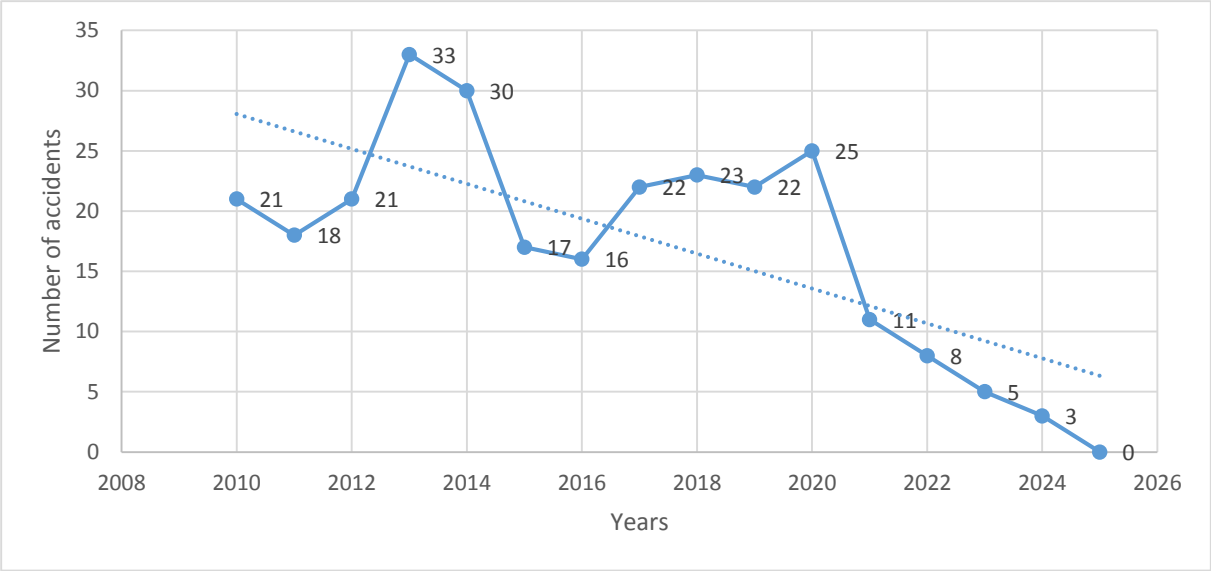

Figure 3. Number of accidents in the company in 2010-2025.

Source: Company X's own materials.

The company has also taken measures to strengthen the culture of safety and care for employees. These include, for example, regular meetings of leaders from all areas of the company, focused on coordinating initiatives, exchanging information and improving cooperation, with a particular focus on occupational safety, and the use of multi-channel communication to increase brand awareness and employee participation through regular messages on risk minimisation, information on incidents, and corrective and preventive measures (Facebook, LinkedIn, Daylight, dedicated internal application). Identified trends indicate that the systematic strengthening of the safety culture and employee care is reflected in employee evaluations, with further growth in indicators likely to be supported by maintaining a forum for cooperation between leaders and consistent, transparent communication of safety activities.

The research conducted has shown that the deliberate and consistent implementation of OHS management tools – from the formalisation of policies and roles, through systematic incident investigation and behavioural observation, to multi-channel communication and the integration of safety objectives with HR mechanisms – leads to a measurable increase in the maturity of the safety culture and a decrease in the accident rate. The results presented are confirmed by the literature, which consistently indicates that interventions based on behavioural observation of work and feedback (BBS) significantly reduce injuries and accidents (Tuncel et al., 2006; Krause et al., 1999). At the same time, research on the role of leadership and safety climate shows that it is the quality of everyday management practices, rather than declarations alone, that translates into the perception of safety as a priority in teams and into results in terms of compliance and participation (Christian et al., 2009; Zohar, Luria, 2010; Wu et al., 2008). The key mechanism for increasing maturity has been found to be the organisation's transition to a process of continuous improvement – a learning organisation. The literature shows that

a developed reporting system and reliable post-implementation investigations strengthen trust, communication and proactive identification of threats, and as a result reduce accident rates (Haas et al., 2020). Empirical reports also emphasise the role of communication quality and employee participation as key mechanisms for translating culture into behaviour (Naji et al., 2022), which was also highlighted in the research results.

The research showed that the complementary impact of situational factors (policies, role structures, standards), interactive factors (leadership, communication) and personal factors (attitudes, motivation) shapes the safety climate and culture, and their reinforcement – through BBS, incident learning, PDCA and integration with HR practices – translates into both safety indicators and operational results, and ultimately also financial results.

6. Conclusion

The literature indicates that organisations with a weak safety culture experience accidents more frequently, while those with a strong safety culture are more resilient (Clarke, 2006). As a result, safety culture measurement has become widespread as a tool for obtaining information about safety management practices and strategies in a company, enabling the identification of strengths and weaknesses as well as areas for improvement among employees and managers. The research presented in this paper has clear practical implications. Systematically raising health and safety standards not only reduces the likelihood of accidents, but also promotes job satisfaction by strengthening the sense of being noticed and appreciated by the employer and reducing stress related to health concerns. The benefits for employers are multifaceted: a high level of safety builds the organisation's reputation in the eyes of key stakeholders (customers, suppliers and employees), increases operational efficiency through greater process fluidity, which translates into productivity and product quality, and also strengthens employee commitment and loyalty. The regulatory dimension is also important: ensuring compliance with applicable regulations and standards reduces the risk of sanctions. At the same time, reducing accidents lowers direct and indirect costs, including employee absenteeism, recruitment and training of replacements, compensation payments, production downtime and damage repair costs.

The research results presented in the article should be interpreted with caution due to several limitations. Observations of behavior made by line employees may be prone to bias. In addition, the very large number of entries increases the risk of routine data entry, which may reduce the quality of the assessment. In subsequent assessment cycles, it is reasonable to introduce BBS quality controls, for example through observer rotation or random audits. Furthermore, incorporating safety targets into HR mechanisms may inadvertently encourage underreporting, which could affect the credibility of communication. In addition, the simultaneous

implementation of several initiatives may make it difficult to attribute effects to a specific tool. Given these limitations, the measurement system should be validated (e.g., by strengthening triangulation, prioritizing learning and development as a condition for maintaining results, implementing other indicators) in order to achieve increasingly better results leading to an improvement in the company's safety culture.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

MOTIVATION OF FEMALE MILITARY STUDENTS TO ENTER SERVICE IN UNIFORMED FORMATIONS

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Purpose: The aim of this article is to diagnose the level and determinants of motivation among women studying civilian programs at military universities to join uniformed services after graduation.
Design/methodology/approach: The study was based on a two-stage approach: the first step involved conducting a survey among female students, and the second was an expert panel with representatives of uniformed services, human resources, and labor market institutions. Based on the collected data, eleven key motivational factors were identified and subjected to structural analysis using the MICMAC method.
Findings: The results of the study allowed for the classification of motivational factors according to their strength of influence and interdependencies. Career advancement opportunities were identified as the key factor, while institutional support emerged as a determinant. The findings indicate that women's motivation to join uniformed services is shaped by complex relationships between individual and systemic factors, highlighting the need to develop a long-term and integrated system of institutional support.
Research limitations/implications: Despite the cognitive and practical value of the study, certain limitations should be acknowledged, as they may affect the interpretation and generalizability of the results. The research sample was limited to female students enrolled in civilian programs at a selected military university. While this group provides an important point of reference for analyzing potential female candidates for uniformed service, it does not cover the broader spectrum of women considering such a career path—for example, graduates of civilian universities, women with prior work experience, or those actively seeking employment in the public sector.
Practical and social implications: The results of this study provide practical guidance for institutions responsible for recruitment, personnel policy, and promotional activities related to service in uniformed formations—especially among women. These insights can serve as a foundation for developing more diverse and gender-sensitive recruitment strategies as well as institutional support systems.
Originality/value: The research conducted by the authors fills a gap in the literature. Research on women in the armed forces remains fragmented and primarily focuses on the physiological differences between men and women in service.
Keywords: motivation, uniformed services, military universities, gender, institutional support.
Category of the paper: Research paper.

1. Introduction

Since the emergence of scientific management, the effective motivation of individuals to pursue specific professions or work in particular sectors has been identified as one of the key challenges for both the theory and practice of human capital management (Chen, Hitt, 2021; Birnbaum, Somers, 2023). Numerous studies have explored the determinants of effective motivation and work engagement in the business sector (Sycheva et al., 2019; Korytko et al., 2021; Czerwińska-Lubaszczyk, Jankowiak, 2024, p. 14). More recently, researchers have increasingly turned their attention to the motivation for work in the public sector (Fernandes, Santinha, Forte, 2022; Al-Tkhayneh, Kot, Shestak, 2019; Serhan, Al Achy, Nicolas, 2018; Habánik, Martošová, Gullerová, 2018), including motivations for joining the military or other uniformed services (Evans, 2023; Rzepecka, 2022; Macovei, Argintaru, 2016).

Today, motivation to serve in uniformed formations holds strategic importance due to widespread staffing shortages across these services (Moczydłowska, 2024, p. 138). In light of the current geopolitical situation, it is crucial to effectively encourage young people—both men and women—to consider careers in uniformed services, whose fundamental mission is to ensure the safety and security of citizens and the state. While the motivation of men to join the military appears to be well-documented in the literature (Greaves, 2018), research on women's motivation remains fragmented (Bracken, 2021; Miller, 2018). Existing studies tend to focus on the physiological differences between men and women in service (Grier, 2024; O'Leary et al., 2023) or their differing responses to stress (Hourani et al., 2016).

Therefore, the aim of this article is to diagnose the level and determinants of motivation among women enrolled in civilian study programs at military universities to join uniformed services after graduation. To achieve this goal, an anonymous survey was conducted among female students at a selected military university. The next step involved an expert panel with 16 participants, including representatives of uniformed services, HR professionals, academics, and labor market institutions. The study contributes to a relatively underexplored area of public service motivation among women, with practical implications for recruitment policies and equality strategies in Poland.

2. Literature Review

Motivation is widely recognized as a psychological state that drives individuals to pursue desired goals, while also initiating, directing, and sustaining actions toward their achievement. It can be understood as a catalyst for action or a form of energy that enables goal-oriented behavior. The term motivation originates from the word motive, which refers to something that

prompts a person to act in a certain way or at least predisposes them to do so (Ihensekien, Joel, 2023, p. 34). Motivation is the process governing an individual's choice among various possible courses of action (Letkiewicz, Ortynskiy, 2022, p. 8). It is commonly accepted to distinguish between intrinsic and extrinsic motivation (Sitopu, Sitinjak, Marpaung, 2021, pp. 73-74). When a person performs an activity primarily for self-satisfaction or pleasure, their motivation is considered intrinsic. Conversely, if the motivation to complete a task is driven by the desire to obtain an external reward or approval, the individual is considered to be extrinsically motivated (Zheng, 2021, p. 4).

Work plays a fundamental role in every individual's life. When choosing a future profession, people are guided by various motives that reflect both their attitude toward a given occupation and their self-assessment of the ability to perform it (Sosnowska-Bielicz, 2021, p. 70). In light of the dynamic changes in the labor market, a shift in how young people approach career development is becoming increasingly apparent (Myszka-Strychalska, 2024, p. 124). The factors motivating individuals to pursue specific career paths vary by age and gender (Bartczak, Szymanowska, 2019, p. 133). Today, employers face a major challenge: understanding what motivates people to choose particular career directions. By identifying these factors, they will be better equipped to design motivational systems that attract the largest possible number of prospective candidates.

In Poland, there are eleven uniformed services in operation: the Internal Security Agency (ABW), the Intelligence Agency (AW), the Central Anti-Corruption Bureau (CBA), the State Fire Service (PSP), the Police, the Border Guard (SG), the Prison Service (SW), the Military Intelligence Service (SWW), the Military Counterintelligence Service (SKW), the Marshal's Guard (SM), and the State Protection Service (SOP). The nature of tasks assigned to these services results in a much stricter chain of command than that typically found in civilian labor relations (Moczydłowska, 2023, p. 31). Uniformed services are organizations characterized by a high level of formalization and hierarchy (Jabłońska-Wołoszyn, 2019, p. 27). Additional features commonly associated with these services include elitism, professionalism, uniforms, command structures, discipline, prestige, and readiness for duty. Service in such formations often requires a significant sacrifice of personal privileges and lifestyle changes (Knopp, 2021, p. 67).

In the face of growing challenges to national security, uniformed services such as the Police and the Border Guard are increasingly affected by high personnel turnover. These services must compete with the civilian labor market as well as with the military, which offers more attractive salaries and a wider range of social benefits. The factors motivating individuals to join uniformed services are multidimensional (Pákozdi, Bárdos, 2020, p. 62). They stem from individual needs, age or generational affiliation, and gender. Men who choose a career in uniformed services are often driven by different motives than women who aspire to become officers.

In recent years, a clear upward trend has been observed in the number of women joining uniformed services. According to data for 2024 provided by the Ministry of the Interior and Administration, the Polish Police currently employs 19.4 thousand female officers, accounting for 20% of the entire force. The Border Guard has 4.7 thousand women in service, while the State Fire Service employs 1.3 thousand female officers (https://www.gov.pl/). Being an officer entails high levels of commitment, both physical and mental effort, and constant readiness for duty. This state of permanent availability significantly impacts certain aspects of private life (Filaszkiewicz, Majer, 2023, p. 445). For a long time, public perception did not associate women with the role of uniformed officers. However, the traditionally male-dominated personnel model of hierarchical organizations is gradually evolving. Women are increasingly being appointed to command and leadership positions at various levels (Rybka, 2023, p. 91).

The situation of women in uniformed services is steadily improving, thanks to the dismantling of "weaker sex" stereotypes, the enhancement of anti-discrimination policies, and the implementation of equal opportunity strategies (Rudnicka, 2017, p. 252). Alongside the growing interest of women in uniformed service careers, their presence is also becoming more visible in military universities and in uniformed classes at secondary schools (Fijałkowska, Bieniek, 2018, p. 178).

Currently, young people in Poland who wish to develop skills in preparation for service to the state can choose from several universities and training centers. The Ministry of National Defense offers the most comprehensive education system, comprising five military universities: the Polish Naval Academy in Gdynia, the War Studies University in Warsaw, the Land Forces Military Academy in Wrocław, the Polish Air Force University in Dęblin, and the Military University of Technology in Warsaw. Each of these institutions offers both military and civilian study programs. These universities prepare students to perform tasks aligned with the mission of the armed forces, tailored to both current and potential future threats. Additionally, they serve as research and analytical centers supporting the processes of planning and programming the development of the Polish Armed Forces, including the implementation of state-of-the-art and technologically advanced equipment (Liberacki, 2018, p. 103).

Other uniformed services—including the Police, the State Fire Service, the Prison Service, and the Border Guard—also maintain their own higher education institutions and training centers (see Table 1).

Table 1.
Higher Education Institutions and Training Centers of Polish Uniformed Services

Service	Police	State Fire Service	Border Guard	Prison Service
Name of University	Police Academy in Szczytno	Fire Service Academy in Warsaw	Border Guard Higher School in Koszalin	Academy of Justice in Warsaw
Training Centers	Police Training Center in Legionowo	Central School of the State Fire Service in Częstochowa	Border Guard Training Center in Kętrzyn	
			Specialist Training Center of the Border Guard in Lubań	

Source: own elaboration.

Today, young people who wish to pursue a future career in uniformed services have a wide range of universities to choose from that can prepare them for such roles. However, it is common for a young person just beginning higher education to remain undecided about their future career path. Choosing a military study program means that the student simultaneously becomes an active-duty soldier. This entails completing two parallel curricula: a technical (engineering) program and a military training program. In addition, outside of academic classes, the student is subject to military discipline and regulations. Upon graduation, the student is guaranteed employment as a professional soldier with the rank of second lieutenant.

Military studies require a firm commitment to a specific career path—service in the Polish Armed Forces. An alternative for those who are not prepared to commit to military service but are interested in areas such as national security, broadly understood military logistics, computer science, mechanics, or mechanical engineering—or who wish to serve in one of the uniformed formations—is to pursue civilian studies at a military university. Civilian students follow only the technical curriculum and have no obligations to the Ministry of National Defense.

3. Methods

The aim of the study was to diagnose the level and determinants of motivation among female students enrolled in civilian programs at military universities to join uniformed services after graduation. The following research questions were formulated:

1. What proportion of female civilian students at military universities plan to enter uniformed service? How do they evaluate the attractiveness of uniformed services as potential employers?
2. What factors most strongly motivate female civilian students at military universities to join uniformed services?
3. What are the key challenges faced by women serving in uniformed formations? How do they perceive gender differences within these services?
4. What, in the opinion of the respondents, should be changed to increase women's motivation to join uniformed services?

The research process provided answers to the above questions. The study consisted of two stages and was conducted in the fourth quarter of 2024. The first stage involved quantitative research using the PAPI (Paper and Pencil Interview) technique among 80 female students from a selected military university. The sample was selected purposively. A proprietary questionnaire was used, which included both closed- and open-ended questions. Based on the results obtained, eleven factors influencing women's decisions to enter uniformed services were identified.

In the next stage, an expert panel was conducted with the participation of 16 individuals, including representatives of uniformed services, HR departments, academia, and labor market institutions. The panellists included uniformed services officers, soldiers, military academy staff, and authors of publications on management in the uniformed services. The factors identified in the quantitative stage were evaluated using a four-point scale:

0 – no influence,

1 – weak influence,

2 – moderate influence,

3 – strong influence.

The primary criterion for selecting factors was the frequency of their appearance in respondents' answers. The identification of relationships between the factors influencing the research area was made possible by having each expert complete an electronic version of the direct influence matrix (using the CAWI technique). A resulting matrix of mutual influences was created based on the individual matrices filled out by the experts. The values in the final matrix were determined based on the modal value (dominant score) of influence strength assessments assigned by the experts.

Subsequently, a structural analysis was conducted using the ISM (Interpretive Structural Modeling) method, which enables the identification of dependencies between individual factors. Structural analysis is a tool used to organize and analyze sets of elements with numerous interdependencies. Its application allows for determining mutual influences and relationships between factors, ultimately identifying the key variables (Nazarko, Wnorowski, Kononiuk, 2011, p. 15). The MICMAC software was used in the analytical process.

4. Results

The respondents answered questions regarding their motivation for choosing their field of study, career plans, perceptions of uniformed service, and the challenges women face within such formations.

One of the main reasons participants chose to study at a military university was the desire to link their future with the armed forces. Many also cited inspiration from family traditions. Pragmatic motivations were also present, such as acquiring professional competencies, job stability, and encouragement from peers.

When asked about their plans after graduation: 30% of the students declared an intention to join a uniformed service, 25% were undecided, 45% did not plan to pursue a career in such formations.

Among those intending to serve, the most frequently cited motivators were: the possibility of early retirement, job security, attractive salaries, and the prestige associated with uniformed service. Some respondents also emphasized the importance of additional social benefits.

Responses to the question regarding the attractiveness of uniformed service from the perspective of a young person entering the labor market were varied. Some students considered it highly attractive, while others were more reserved, indicating difficulty in making a clear assessment or viewing it rather negatively.

A key theme explored in the study was equal opportunity. The vast majority of participants believed that women have fewer career advancement opportunities compared to men in uniformed services. Respondents pointed to barriers related to promotions, trust from superiors, and entrenched stereotypes.

When asked how women could be better encouraged to join uniformed services, the most common suggestions included: organizing information campaigns showcasing positive examples of women in service, simplifying recruitment procedures, and adjusting physical and medical requirements to reflect realistic capabilities.

Finally, participants were asked to identify what they perceived as the greatest challenges for women entering uniformed service. The most frequently mentioned issues were: the need to constantly combat stereotypes, and the pressure to prove their worth in a male-dominated environment. Additional concerns included the physical demands of the job and difficult working conditions.

Based on the open-ended responses, 11 motivational factors influencing young women's decisions to join uniformed services were identified:

1. Promotion opportunities – PO.
2. Development opportunities – DO.
3. Service prestige – SP.
4. Employment stability – ES.
5. Self-fulfillment – SF.
6. Institutional support – IS.
7. Degree of gender stereotyping – GS.
8. Accessibility of recruitment processes – ARP.
9. Financial security – FS.
10. Physical and psychological demands – PPD.
11. Effectiveness of informational and promotional activities – EIPA.

These factors were evaluated by 16 experts. The resulting matrix was 11×11, meaning that experts were asked to assess 121 relationships between variables. In 37 cases, the dominant value was zero, indicating no relationship. In 35 cases, a weak relationship was found. In 34 cases, a moderate influence was identified. Strong relationships were observed in 15 cases.

Figure 1 illustrates the direct influence relationships among the motivational factors for women considering service in uniformed formations. Arrows represent the direction of influence, with their color and thickness indicating intensity. Red arrows denote the strongest direct influences. Notably, strong relationships were observed among promotion opportunities, development opportunities, and service prestige, highlighting their central role in the motivational structure.

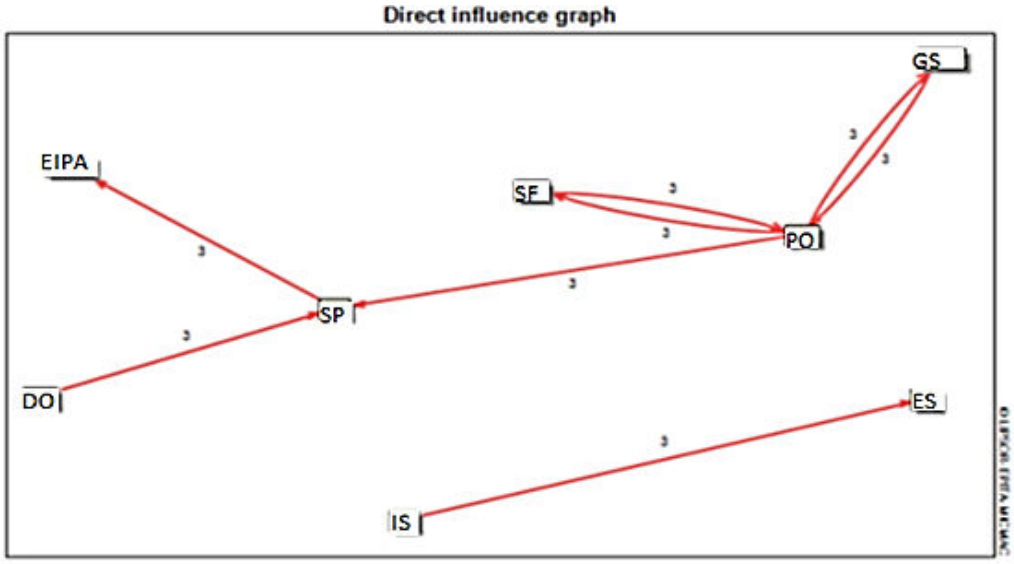
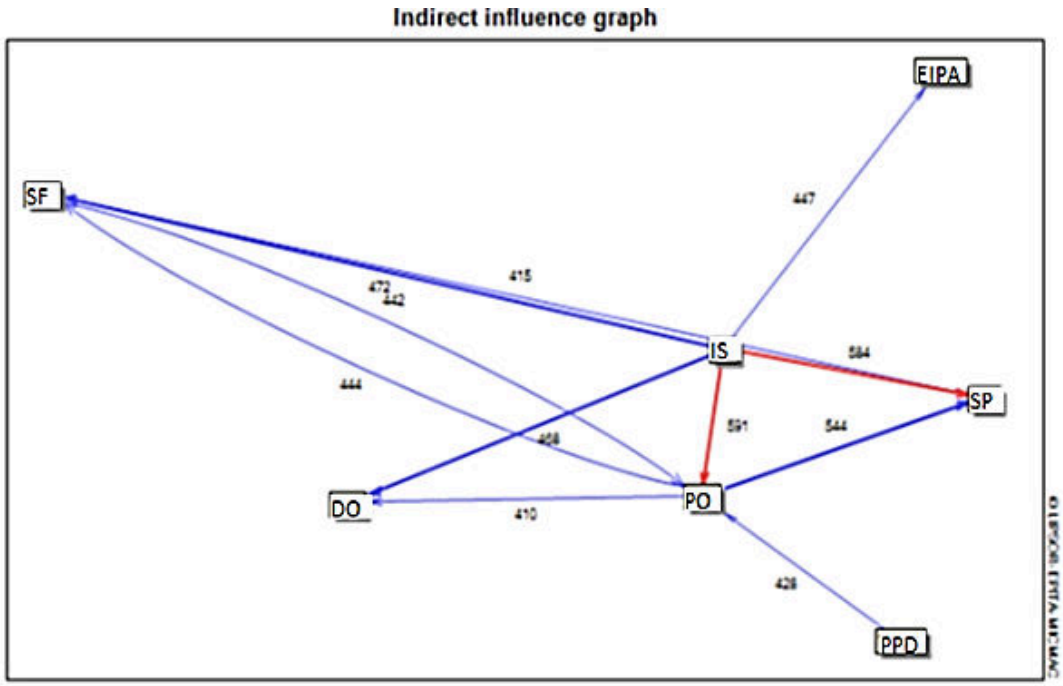


Figure 1. Direct influence graph.

Source: own elaboration using the MICMAC software.

Figure 2 illustrates the indirect influences between the analyzed factors. It highlights which variables act as intermediaries in transmitting influence among others. For example, institutional support (IS) plays the role of an initiating factor that, through other variables—such as development opportunities or financial security—indirectly affects service prestige or the motivation for self-fulfillment. The figure reveals deeper layers of interdependencies within the system.



— Moderate influences.
— Relatively strong influences.
— Strongest influences.

Figure 2. Indirect influence graph.

Source: own elaboration using the MICMAC software.

The graph analysis indicates that the most influential factors—those that exert strong influence on others while also being strongly influenced themselves—include:

- Promotion Opportunities (PO).
- Development Opportunities (DO).
- Service Prestige (SP).
- Self-Fulfillment (SF).
- Gender Stereotyping (GS).

A factor that exerts influence but is not influenced by others:

- Institutional Support (IS).

The most dependent factors are:

- Service Prestige (SP).
- Effectiveness of Informational and Promotional Activities (EIPA).

The distribution of structural analysis factors on the influence–dependence plane is presented in Figure 3.

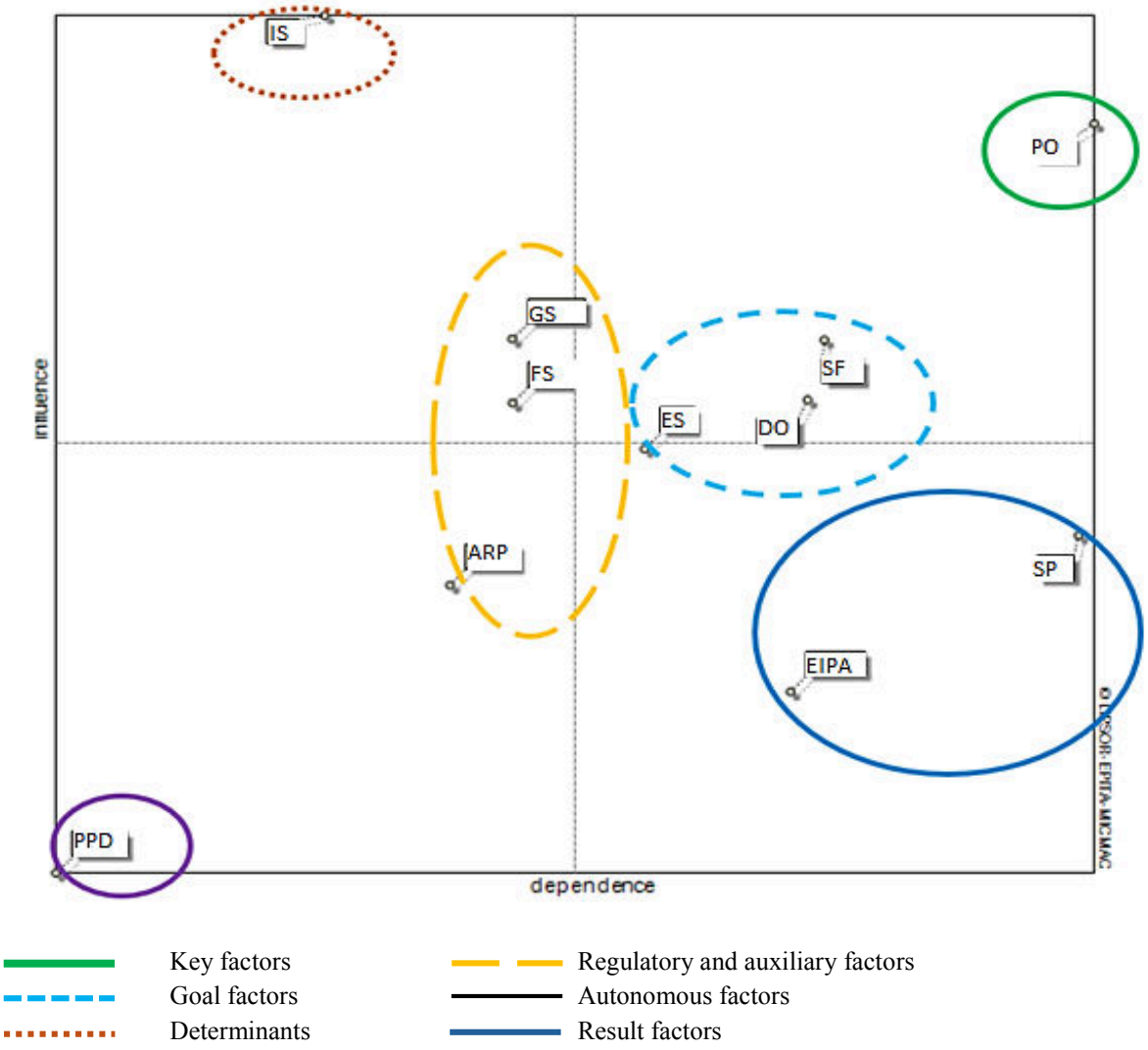


Figure 3. Classification of structural analysis factors based on direct influences, including potential influences.

Source: own elaboration using the MICMAC software.

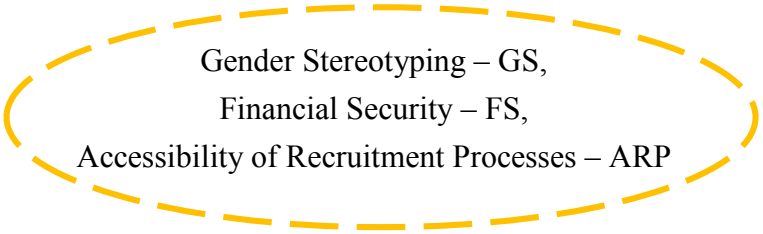
As part of the structural analysis, the factors were distributed on the influence–dependence plane using the MICMAC software. In the upper-right quadrant (high influence and high dependence), the key factor – promotion opportunities – is located. The upper-left quadrant represents determinants, which exert influence on the system but are relatively independent themselves, such as institutional support. The central and lower-right sections are dominated by goals and result factors, such as service prestige, self-fulfillment, or employment stability. The lower-left corner indicates autonomous factors, e.g., physical and psychological demands, which have limited systemic significance. As a result, six groups of factors were identified:

1. Key factors – combining high influence with high dependence:

Promotion Opportunities (PO)

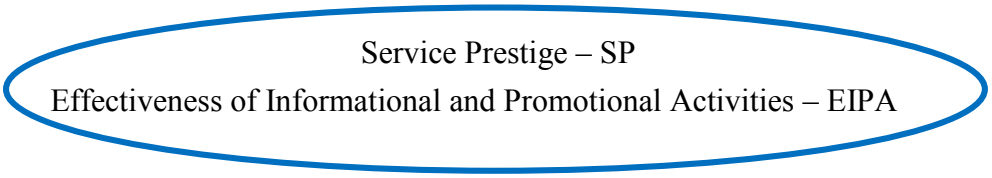
2. Determinants – exerting strong influence on the system, i.e., driving or inhibiting factors:

3. Regulatory and auxiliary factors – with medium or low influence, but potentially helpful in achieving strategic goals:

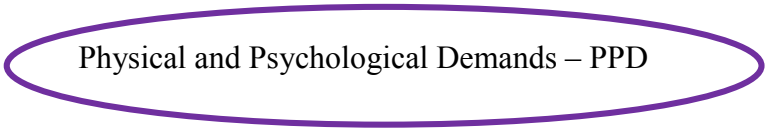


4. Goal factors – more subject to the influence of other factors than exerting influence themselves; they represent potential goals of the analyzed system:

5. Dependent/result factors – characterized by low influence and high dependence on other factors. They are particularly susceptible to changes in key and determinant factors:



6. Autonomous factors – having the least impact on changes occurring in the system as a whole:



The conducted analysis made it possible to identify the key determinants of motivation among women studying civilian programs at military universities to join uniformed services. The application of the MICMAC method allowed for the systematization of factors and the determination of their interrelations in terms of influence and dependence.

The factor with the greatest strategic significance is Promotion Opportunities (PO). It combines high influence with high dependence, meaning it not only affects other motivators but is also shaped by the systemic environment. Development Opportunities (DO) and Self-Fulfillment (SF) also play an important role in the motivational structure; however, they are more susceptible to the influence of external factors. Therefore, they are more likely to be considered system goals rather than drivers. Institutional Support (IS) was classified as the main determinant. It exerts a very strong influence while showing relatively low dependence, indicating its potential as a steering mechanism for the entire motivational system. Financial Security (FS), Accessibility of Recruitment Processes (ARP), and Gender Stereotyping (GS) were categorized as auxiliary factors, which do not determine the decision to enter service on their own but may facilitate or hinder it. Service Prestige (SP) and the Effectiveness of Informational and Promotional Activities (EIPA) are considered result factors, which are more of an outcome of how the system functions than a direct cause. However, they may influence recruitment decisions indirectly by shaping societal attitudes. Finally, Physical and Psychological Demands (PPD) were identified as an autonomous factor. Its role in the motivational model is marginal, which may indicate that it is more strongly related to individual physical predispositions than to systemic mechanisms.

5. Discussion

The results confirm that the motivation of women to pursue service in uniformed formations is multidimensional and dynamic. Its structure depends both on internal factors—such as the need for development or self-fulfillment—and on external ones, including institutional support and promotion policies. It is worth noting that soft factors, such as gender stereotypes or informational-promotional activities, although not key drivers, play a significant supporting role. Improving them may enhance the effectiveness of more decisive mechanisms.

A relatively surprising finding is the low significance of the Physical and Psychological Demands (PPD) factor. This may suggest that women considering service do not perceive physical limitations as a major barrier when choosing a professional path.

The results of this study are strongly supported by existing literature, which increases their credibility and allows for broader comparative conclusions. The identified key factor, Promotion Opportunities (PO), aligns with the findings of Mankowski et al. (2015), who, in a study on women's decisions to join the U.S. military, demonstrated that professional motivation—including qualification acquisition and promotion prospects—is one of the main determinants of enlistment. Similar conclusions were drawn by Judzińska (2023), who analyzed the careers of female officers in Poland. She emphasized that status-related motivators play a significant role in their engagement and in overcoming organizational barriers.

The factor of Institutional Support (IS) as the most influential determinant in the system is also reflected in the research by Pack (2023), who examined women's motivation in the Territorial Defence Forces. He observed that clear career paths, onboarding programs, and a supportive organizational environment are crucial for recruiting and retaining women in hierarchical structures.

Employment Stability (ES) and Self-Fulfillment (SF), as goal-related factors, also confirm findings from broader research on motivation in the public sector. These studies indicate that women often perceive public service as a way to realize personal values such as meaningful work, social responsibility, or life stability (Judzińska, 2023; Mankowski et al., 2015). These findings are further supported by Khraban (2024), who noted that women in uniformed services must reconcile professional identity with gender identity, and that systemic support helps them manage this balance. She also highlighted that hidden stereotypes toward women in uniformed structures still persist, which may hinder the full transition from formal equality to genuine professional acceptance.

In conclusion, the results of the study align with broader scientific trends showing that an effective equality policy in uniformed services cannot be limited to slogans and promotional campaigns. What is crucial is genuine institutional support, transparent promotion mechanisms, and opportunities for competence development. These elements form the foundation for sustainable female engagement in service and the development of modern, inclusive security structures.

6. Conclusions

The aim of the conducted study was to diagnose the level and conditions of motivation among women studying in civilian programs at military universities to join uniformed services after graduation. The use of the MICMAC program made it possible not only to identify key factors but also to analyze their mutual relationships and systemic importance. The results clearly indicate that motivation for service is the result of complex interactions between personal and institutional factors. Promotion opportunities, professional development, and structural support from the organization play a crucial role. In contrast, factors such as gender stereotypes or promotional activities, while important, are more supportive and secondary in nature.

Ultimately, the study confirms the need for a strategic approach to motivating women to serve in uniformed formations. Institutions should focus on building a long-term support system, realistic promotion pathways, and professional development opportunities, while simultaneously eliminating cultural and structural barriers. Only such an approach can

contribute to increasing the number of women entering service and ensuring their lasting engagement in the life of uniformed formations.

Despite the cognitive and practical value of the study, it is important to acknowledge its limitations, which may affect the interpretation and generalizability of the findings. First and foremost, the research sample was limited to female students in civilian programs at a selected military university. While this group constitutes a relevant reference point for analyzing potential candidates for uniformed service, it does not cover the wider spectrum of women considering such a career path—such as graduates of civilian universities, women with professional experience, or those actively seeking employment in the public sector.

Another limitation is the absence of a comparative analysis with the motivations of men in a similar context, which prevents the exploration of gender differences in the perception of uniformed service and its motivating factors.

Given the above, future research should involve a more diverse sample. It would also be valuable to introduce a comparative component, both between women and men, and between female candidates and women already serving. This would allow for the identification of variables related to professional experience and perceptual differences.

Longitudinal studies also seem justified, as they would allow tracking of changes in motivation and its structural determinants over time—from recruitment, through training, to the early years of service. Additional cognitive value could be provided by comparative international analyses that highlight the impact of cultural and institutional contexts on women's career decisions regarding service in uniformed formations.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

WIG REAL ESTATE INDEX – MORE A STOCK OR A REAL ESTATE?

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Purpose: The primary purpose of the paper is to verify if the WIG Real Estate index is determined by direct real estate market or the stock market.
Design/methodology/approach: The methodology is based on the Autoregressive Distributed Lag models, explaining quotations of the WIG Real Estate index. The independent variables represent influence of stock exchange (the WSE indexes), economy (monetary variables), real estate market (demand, supply and construction costs variables), and direct real estate prices (residential transaction prices). The time range of the data comprises 2007 Q2 - 2025 Q1.
Findings: The findings suggest that in the long-term these are WIBOR3M, value of mortgage loans and number of building permits that cause the WIG Real Estate index fluctuations. While in the short-term there is an influence of WIG index, WIBOR3M and number of building permits evident. The direction of the dependencies may be surprising though. Moreover, the study proves impact of government subsidy housing programs and COVID-19 on the index.
Research limitations/implications: The time series used applied make more in-depth analysis of impact of the GFC and the COVID-19 on the model infeasible. The future studies should expand the time span and depict the impacts more thoroughly. Furthermore, it would be desirable to verify if similar relationships between private real estate, public real estate and stocks hold in other CEE countries.
Practical implications: The results reflect character of relationships between securitized real estate, direct real estate and stocks. The findings of the study should be exploited by investors in portfolio management process.
Originality/value: The relationships between direct real estate, securitized real estate, stocks and economic variables are quite well documented in literature for the U.S., Western Europe and Asia. However, there are very few such publications for the CEE countries, including Poland. The paper aims to shed light on the topic with a use of more suited variables, longer time series and more robust methodology compared to previous studies. The article points out that long-term and short-term dependencies may differ from one another. Also, the external factors, that may distort the regular relationships described by the model, are counted in.
Keywords: securitized real estate, real estate stocks, relationships between real estate and stocks, Autoregressive Distributed Lag (ARDL).
Category of the paper: Research paper.

1. Introduction

The residential real estate nowadays not only fulfil the social function of a shelter but increasingly act as an individual assets class. The direct investments in residential real estate have become very popular among polish households in recent years. Nevertheless, the capital-intensity still limits availability of such savings allocation. However, securitized real estate is answer to this disadvantage. There is a vast amount of literature worldwide on the question, if the public real estate is more like private real estate or it should be regarded as regular securities. However, there are very few such publications for the CEE countries, including Poland. Because of lack of the Real Estate Investments Trusts (REITs) on polish financial market, we address this question to the WIG Real Estate Index quoted at the Warsaw Stock Exchange (WSE). In that context, the paper is an attempt to clarify if the index is more under pressure from housing market or stock market. For this purpose we extend previous research by Nowak (2020) and use variables that represent various impacts on the WIG Real Estate index: stock exchange (the WSE indexes), economic (monetary variables), real estate market (demand, supply and construction costs variables) and direct real estate prices (residential transaction prices). We formulate three research questions which are answered based on the built Autoregressive Distributed Lag models (ARDL).

We found that in the long-term these are WIBOR3M, the value of mortgage loans and number of building permits that cause the WIG Real Estate index fluctuations. While in the short-term there is an influence of WIG index, WIBOR3M and number of building permits evident. The direction of the dependencies are not always in line with stylized facts though. Moreover, we report indication of statistically significant impact of government subsidy housing programs and COVID-19 on the index.

The article consists of six main sections. In the introduction we provide context of the study, basics of time series and methodology used as well as general findings. In the next section the literature background of the study is presented, followed by the section devoted to selection of the variables. In the fourth section the ARDL model is introduced together with step by step procedure applied. The section five of results and discussion is divided into three sub-sections delineating the primary ARDL model and its modifications including impacts of government subsidy housing programs and COVID-19, respectively. The conclusions section includes findings, limitations and suggestions for further research.

2. Literature review

There are many papers which, based on econometric models, indicate the bounds between real estate (residential) market and stock market. Most of the studies imply that the markets, at least in some way, are integrated (Gokmenoglu, Hesami, 2019; Lin, Lin, 2011; Yousaf, Ali, 2020; Yunus, 2012). However, there are also records indicating that the two are segmented (Wilson, Okunev, 1996). The difference is actually crucial. Basically, considering real estate and stock markets as two separate, not cointegrated submarkets in the world of finance, can lead to the point that the two asset classes may be used to diversify investment portfolio. On the other hand, if the markets are closely integrated one should choose between the two assets, instead of mixing them in the investment strategy. Interestingly, the distinction between these two conditions very often is not straightforward, even for countries from one region. Lin and Fuerst (2014) noted linear cointegration of stock and property markets in Taiwan, only signs of fractional cointegration in Singapore and Hong Kong and no evidence of cointegration in China, Japan, Thailand, Malaysia, Indonesia and South Korea. The integration/segmentation can vary based on time perspective and level of real estate market under analysis. Su et al. (2019) concluded that in China the two markets are generally segmented in the short run but are integrated in the long run. Adcock, Hua and Huang (2013) revealed integration at the national level. However, in the case of property markets at the city level the segmentation was visible.

Moreover, the relationships between the two markets indicated in the empirical literature may be of a twofold character. First, as per the wealth effect, unexpected gains in stock market increase the amount of housing consumed by households. This means increased shares' prices raise the residential prices. On the flip side, the credit-price effect claims that housing prices' growth, through stimulation of economic activity, can in effect transform to stocks bull market. There are papers that affirm first (Coelho, Gomes, Ramos, 2023; Jud, Winkler, 2002; Kapopoulos, Siokis, 2005) as well as papers that acknowledge the second concept (Su et al., 2019; Yousaf, Ali, 2020). However, thirdly Bahmani-Oskooee and Ghodsi (2018) argued that at the state level in the US the causal effect is evidently bidirectional. Lou (2016) also attests that for the returns in the PIGS countries.

Many papers which are focused on studying relationships between stock and real estate are based on securitized real estate. The latter most of the time covers the Real Estate Investment Trusts (REITs). The reason for this, first and foremost, is easy access to data. The issue that arises here, is if the securitized real estate (REITs) are still more close to direct real estate or they can be treated as another class of regular securities? This can be answered in the context of aforementioned integration/ segmentation to the last two. Again, the empirical results are not homogeneous in that manner. Wilson and Okunev (1996) provided evidence that that securitized property markets and equity markets in the USA, the UK and Australia,

are segmented internationally. According to the study on Canadian time series, securitized property and stocks can be considered for diversification purposes in the short-run. However, this does not hold for the long-term perspective, since the fractional cointegration was detected (Assaf, 2006). Hoesli and Moreno (2007), based on the study of sixteen countries within years 1990-2004, found securitized real estate returns positively linked with stock and direct real estate returns, but negatively linked to bond returns. Based on the VECM model on returns in the U.S., the U.K. and Australia, Hoesli and Oikarinen (2012) asserted that in the long-term view, REIT market performance is much more closely related to the direct real estate market than to stock market. Nneji, Brooks and Ward (2013) found an interesting relationship regarding speculative bubbles i.e. stock market bubble works more heavily on the securitized real estate bubble, than that of direct property market does. Curiously enough, Kiohos, Babalos and Koulakiotis (2017) applied the ECM-ARFIMA methodology and similarly as for private real estate, provided support for the wealth effect (together with fractional integration) between stock and securitized real estate markets, in Germany and the UK. Wu and Wang (2024), with the use of Bootstrap Fourier Granger Causality in Quantiles test, found negative relationship between the stock price index and REITs' returns in the U.S. The paper of Olaleye and Ekemode (2014) is one example of the few in which quarterly time series of returns on the property listed stock, instead of REITs, are used against all share index. However, based on the integration with common/non-real estate stock in Nigeria, 1999-2011, they found real estate equity more like REITs. Moreover, upfront they denied integration of property listed stock to direct real estate market and returns of underlying direct real estate portfolio. Holcman and Prostejovská (2022) proved negative correlation between residential house price index and the Prague's all stock index in 2020. Liu et al. (2023) claimed that the Hong Kong REITs market consistently receives return and volatility spillover effects from the stock market and real estate market.

There are few polish studies regarding dependencies between direct/securitized real estate and stock market. Kołtuniak (2016a) based on polish data for 2005-2014, found evidence of a long-term co-integration and the credit-price effect between public and private real estate. Kołtuniak (2016b) applied wavelet analysis method and proved structural changes over the period 2004 Q4 and 2014 Q4. Ergo, no constant relationships in terms of both frequency and direction when it comes to the direct real estate, real estate company stocks and stock market indices in Poland. Noteworthy, Wolski (2018) based on the cross-sectional regression analysis, argued that rates of return on investments in real estate companies, quoted at the WSE, explain the price changes in the secondary housing market in Poland. Accordingly, Wolski (2020) using the Engle - Granger method on the secondary market cumulative average residential prices in seven largest voivodeship cities, found co-integration only with the WIG Real Estate index and no relationships with other three implemented the WSE's indexes.

The studies closest to ours are Cellmer, Bełej and Cichulska (2019) and Nowak (2020). Both of the articles are based on application of the VAR model and the Granger causality on differenced log time series. They express only short-term dependencies though, for periods 2008 Q1 - 2018 Q4 and 2007 Q2 - 2020 Q1 respectively. Cellmer, Bełej and Cichulska (2019) found that WIG index statistically significantly Granger-caused the residential cumulative transaction price at secondary market in seven main cities in Poland. They did not point out the opposite dependency. Noteworthily, Nowak (2020) revealed that cumulative prices of new residentials in ten secondary voivodeship cities as well as indexes WIG and WIG20, were affecting the WIG Real Estate index in a negative manner.

Regarding the explanatory variables being exploited, Serrano and Hoesli (2009) argued that not only economic but also financial and real estate variables shall be used to forecast securitized real estate returns. In the study returns of the REIT indexes were explained by two sets of variables. First, they used variables proposed by Chan, Hendershott and Sanders (1990), i.e. change in term structure, change in risk premium, expected inflation and its changes, unexpected inflation; and these deployed by Liu and Mei (1992), i.e. T-bill rate, yield spread (corporate bonds minus T-bill rate), stocks dividend yield and REITs capitalization rate. Then they input set of financial and real estate factors – total return stock index, 10-year total return government bond index and property prices indexes. They used Fractionally Integrated ECM model on data for the U.S., the U.K., and Australia and found that financial and real estate factors generally outperformed economic variables. In accordance with this approach, Akinsomi et al. (2016) pointed that monetary policy instruments, economy-wide and sentiment indicators are these which are the most efficient in predicting REITs returns. They made a use of inflation rate, the industrial production growth, the relative 3-month treasury bill, the lagged real US stock market returns, the S&P dividend price ratio, interest rate factor, the real REITs returns volatility, together with time series of sentiment and uncertainty indicators. The potential determinants of securitized real estate should also depend on the specific features of national economy and financial market. Arora, Killins and Gangineni (2019) next to REITs' characteristics, hired macroeconomic conditions, out of which GDP, inflation rate, exchange rate, and money supply turned to be significantly related to the returns of the REITs in Singapore, in the period 2004-2013. Cohen and Burinskas (2020; 2023) examined over a dozen Eurozone macroeconomic variables on the European listed real estate companies and REITs, with a use of dynamic linear model, Granger causality and the ARDL. Apart from the variables that have been mentioned so far, they found the relevant impact of time series reflecting supply side of real estate market (e.g. construction and residential building permits, the inflation of producers' prices). Wu and Wang (2024) added to the current state of knowledge, the positive impact of unemployment rate on REITs' returns.

Despite a fairly extensive literature on the determinants of private real estate in Poland, there is a deficiency with regard to papers on factors acting on the public real estate market. The reason might be that the latter is relatively underdeveloped, since no REITs are available

in Poland. Cellmer, Bełej and Cichulska (2019) focused on the one-to-one relationships between residential cumulative transaction price at secondary market in seven main cities in Poland, number of new residential premises handed over, the WIG index quotations and several macroeconomic variables (inflation, reference rate determined by the National Bank of Poland, average EUR/PLN exchange rate, GDP, unemployment rate, average gross nominal wage). Nowak (2020) hired cumulative average transaction price of new housing in ten voivodeship cities, the number of apartments with the official permit to inhabit, value and number of new mortgage loans and the WSE indexes: WIG, WIG20, WIG Real Estate.

In our study we follow the question stated in the title by Hoesli and Oikarinen (2012) - Are REITs real estate? However, considering the fact that on Polish financial market REITs are not available, we treat the WIG Real Estate index as the representative of securitized real estate. Then, we refer to the determinants of public real estate market and formulate the following first research question:

1. Which types of the explanatory variables influence the quotations of the WIG Real Estate index the most?

Based on the above literature analysis as well as taking into consideration the fact that the index is dominated by residential developing companies, we used four groups of variables: stock exchange (the WSE indexes), economic (monetary variables), real estate market (demand, supply and construction costs variables) and direct real estate prices (residential transaction prices).

At the beginning of XXI century Clayton and MacKinnon (2001) claimed, which we believe to be true by definition, that links between returns of REITs and bonds, stocks and unsecuritized real estate are of time-varying nature. Many authors acknowledge that by writing that the relationships among stocks, public and private real estate may be different in a long- and in a short-term (e.g. Assaf, 2006). This, to some point is a resultant of the exploited modelling approach. Many papers utilize the VAR, the VECM models or variants of the two. The first provides short-run estimations, while the second gives the long-run equilibrium and its short-run error corrections. The two approaches are based on the bi-directional dependencies between the employed variables. Unlike, instead of mutual relationships, we seek to verify impact of the particular independent variables on the WIG Real Estate index, in the long- and in the short-term. We use the ARDL model which helps to verify the one-side relationships in the two time frames. This brings on the second research question:

2. Is there evidence of different relationships among the dependent and independent variables in the long-term and in the short-term?

The aforementioned variations of the dependencies may be effects of changing conditions of the external environment. There may be many examples of such. However, there is a great amount of literature on the influence of shocks in the economy impacting public as well as on private real estate. Yuksel et al. (2017) prompted that the GFC and the European insolvency problems caused significant changes in cointegration between REITs and stock markets in ten

developed countries. Caporin, Gupta and Ravazzolo (2021) proved spillover effects from the US REITs on-to the equity market. Furthermore, they insisted that the contagion was stronger during the GFC and in the period of the European sovereign debt crisis. Ewing and Payne (2005) found that macroeconomic shocks (monetary policy, economic growth, and inflation) led to REITs returns in the U.S. being lower than expected returns. Many authors demonstrated impact of shocks on REITs' volatility. Ajmi et al. (2014) used the US Equity Market Uncertainty Index and the US Economic Policy Uncertainty Index, instead of employing stock and macroeconomic variables. They documented the US REITs conditional volatility being rather responsive to different historical shocks. In line with that, Hoesli, Johner and Kraiouchkina (2025) with a use of the GARCH models found synchronous volatility shocks of European listed real estate returns, across sectors and countries. However, they noted differences in magnitude, based on investigation of the GFC and the COVID-19 pandemic. There are also other studies expressing the substantial importance of financial stress on REIT market's volatility (Ozcelebi, Yoon, 2025) and returns (Armah, Amewu, 2024).

Lee (2020) shed light on possible different causes of unstable relationships. The paper insisted high variations of integration between REITs and stock market was attributed to economic conditions (1990 recession, start and then burst of the dotcom bubble, the GFC), but also to tax reforms. Lee and Chiang (2010) conjured the structural change noticed in the early 1990s as a reason for the fact that the U.S. REITs were more like stock during 1973-1993 period and more like private real estate in years 1994-2008.

In this context one may treat government housing subsidy programs as plausible cause of structural changes on direct real estate market, and also on securitized real estate afterwards. Egan and Bergin (2023) - based on a COSMO model of Irish economy - stated that, in the case of social and economic goals i.e. increase affordable housing availability, government housing programs may be preferable to an economy-wide stimulus. On the other hand, Hilber and Schöni (2022) insist that the programs may not always be effective to beneficiaries, in a desired way. We aim the two issues – economy shocks and government subsidy housing programs – as potential sources of external impacts that may distort the basic equilibrium relationships between the WIG Real Estate index and its explanatory variables. In that context we formulate the third research question:

3. Are there signs of external impact on the emerged dependencies, in the time range of the study?

We ascribe the external impact to government housing programs and the GFC and the COVID-19 pandemic. This selection stems from the time span of the data. In the time period of the study there were four government housing programs run in Poland, which are believed to have a great impact on the direct real estate market (Marona, Tomasik, 2023; Radzimski, 2014). Moreover, the time series under research start five quarters before the GFC took off, and end twenty quarters after the COVID-19 launched. This may provide us with a room for

potential checks, if the initially set dependencies were on pressure during these external impacts.

In our study, we follow the path set by Nowak (2020) and to lesser extent Cellmer, Bełej and Cichulska (2019). There are several advantages of our study over that ones. In the first place, we use broaden and more disciplined approach with longer time series and more suited variables. Furthermore, we deploy the ARDL model, rather than the VAR, which is suited to generate both the long- and short-run relationships. Last but not least, we also examine possible workings of external impacts on the dependencies (government housing programs, the GFC and the COVID-19).

3. Data and methodology

3.1. Selection of the variables and data characteristics

The dependent variable in the study represents fluctuations of the WIG Real Estate Index, which is quoted on the Warsaw Stock Exchange (WSE). The index is a total return index, thus its calculation takes into account both the prices of the included shares and income from dividends and subscription rights. The index is composed of companies classified in the real estate sector. As of the 8th of August 2025 there were 23 companies included in the index. The ten biggest companies comprise 96,14% of the index portfolio. Six out of the ten companies are focused entirely on developing business in residential sector (74.464% weight in the index). One company runs a development business in residential, office and retail real estate (6.452%). Two companies are mainly concentrated in commercial real estate but also invest in portfolio of apartments for rent (9.087%). There is only one company out of ten that is solely focused on commercial real estate (6.137%). On the one hand, composition of the index indicates its strong dependence on the economic situation in the residential market in Poland. On the other hand, fluctuation of the WIG Real Estate Index shall be also a product of present conditions on the WSE. In other words, the WIG Real Estate Index is located somewhere in between the housing market and the stock market. Taking this into account the study aims to verify what kind of determinants influence the index. The six types of variables that may impact the index are characterized in the Table 1.

Table 1.
Characteristics and descriptive statistics of time series applied in the study

Variables' characteristics	Time series	Variables' codes	Variables' roles	Unit	Min.	Max.	Mean	S.D.
Stock exchange variables	WIG Real Estate	WRE	Dependent variable	Quotation points	1237	6463	2443	1082
	WIG	WIG	Independent variable		24036	95953	53935	13423
	WIG Construction	WCO			1602	11686	4091	2278
	WIG Banks	WBA			2799	16030	7157	2272
Monetary variables	CPI inflation rate	CPI		p.p. (%)	-1.500	17.300	3.603	3.946
	WIBOR3M interest rate	W3M			0.210	7.210	3.509	2.043
Demand variables	Average salary	ASA		PLN	2644	8962	4621	1551
	Value of newly granted mortgages	MVA		bn PLN	6.169	28.148	13.170	4.520
Supply variable	Number of building permits for apartments	BPE		No.	29382	93295	57199	14934
Construction costs' variables	Price index of construction and assembly production	ICA		p.p. (%)	-2.000	14.800	2.907	4.081
	Production cost of an apartment	CPR		PLN per sq. m	2650	7612	4495	1021
Average transaction price of apartment	In 7 first tier voivodeships cities (primary market)	P7			5931	14347	8052	2337
	In 10 second tier voivodeships cities (primary market)	P10			3923	10675	5884	1835
	In 7 first tier voivodeships cities (secondary market)	S7			5445	13529	7581	2228
	In 10 second tier voivodeships cities (secondary market)	S10			3767	8793	4979	1476

Note: The time series of following variables represent value/numbers as of the end of the quarter: WRE, WIG, WCO, WBA, W3M. The time series of following variables represent cumulative value/numbers for the whole quarter: CPI, ASA, MVA, BPE, ICA, CPR, P7, P10, S7, S10. The sources of the time series are as follows: the Central Statistical Office (GUS) - CPI, ASA, BPE, ICA, CPR; the National Bank of Poland - P7, P10, S7, S10; The Warsaw Stock Exchange - WRE, WIG, WCO, WBA; the AMRON-SARFiN reports – MVA; the bankier.pl - W3M.

Source: Own elaboration.

The selection of explanatory variables was based in some way on the general classification provided by Serrano and Hoesli (2009). However, we also took into account local specifics, the nature of the explanatory variable (Real Estate stocks index, not REITs), and the data availability. As well as the fact that unlike the authors, we use time series of WIG Real Estate quotations rather than returns. Furthermore, we follow Cohen and Burinskas (2020; 2023) to some point, as we use determinants capturing particular facets of direct real estate market. Some of the applied variables were used by Cellmer, Bełej and Cichulska (2019) and Nowak (2020), however, we extend spectrum of the explanatory variables and scope of examined dependencies.

As far as the stock exchange variables are concerned, we included the WIG index together with two sectoral indexes, the WIG Construction and the WIG Banks. The first is the main index traded on the WSE, which includes all the stocks available on the market. Hence, this is the best mirror of current market conditions on the WSE. Another two indexes represent sectors closely connected to the residential market. The changes in the construction sector may affect the residential development branch by costs of construction and by that can work on profitability of housing projects. The impact of banking sector is twofold. Firstly, number and value of mortgage loans granted represent a vast part of a housing demand. Secondly, many residential projects are financed with bank loans. All the three indexes are income-based, meaning that their calculation takes into account both the prices of the shares and income from dividends and subscription rights.

The monetary group of independent variables includes CPI and WIBOR3M. It is well documented that real estate prices tend to follow dynamics of inflation and are even called an inflation hedge (Fehrle, 2023; Muckenhaupt, Hoesli, Zhu, 2025). Moreover, inflation triggers reactions from central bank regarding interest rates. The WIBOR3M variable represents time series of Warsaw Interbank Offer Rate for three months, which is the interest rate at which banks lend money to each other. The WIBOR3M is informally bound with reference interest rate set by Monetary Policy Council (Rada Polityki Pieniężnej). An increase / decrease of the reference interest rate causes, ceteris paribus, similar effect on the WIBOR3M. In that way, one should expect negative impact of WIBOR3M on stock market but also on residential market. Since in Poland interest rate of adjustable rate mortgages is equal to, most often, WIBOR3M plus a bank's margin. In that way variations of WIBOR3M reflect changes in the cost of mortgage repayment. Besides, oscillations of WIBOR3M also induce changes in households' borrowing power, which affects housing demand.

We also applied independent variables representing demand on residential market. The quarterly-cumulative average wage in Poland, on a monthly basis, reflects the ability of households to satisfy their housing needs. In the context of mortgage loans, the variable influences the borrowing power of polish households. The time series of the value of newly granted mortgages expresses households' ability to purchase housing. The last may be an outcome of various determinants e.g. households' financial situation, changes in the

mortgage repayment costs but also influence of legal acts or clauses of Recommendation S[1] of the Polish Financial Supervision Authority (Komisja Nadzoru Finansowego).

The number of building permits for apartments conveys the supply side of the housing market. One has to bear in mind that in the nomenclature of the Central Statistical Office (Główny Urząd Statystyczny) the word "apartment" relates to apartment as well as house.

The construction costs which cover the changes in the economic environment in which housing development companies operate, are carried by two variables. The price index of construction and assembly production gives the quarterly year-on-year dynamics of the costs bore by housing development companies. The production cost of an apartment variable represents a nominal expenditures of building one sq. m of a usable area of a residential building put into use in Poland.

The last four time series represent average transaction prices of one sq. m of brand new apartments and the ones sold on the secondary market. The variables are of a cumulative character, delineating two groups i.e. primary seven and secondary ten residential markets in Poland collectively. Most of the cities are the capitals of the sixteen polish voivodeships.

The variables' codes, units and basic descriptive statistics are presented in the Table 1. All the time series are quarterly data, however depending on the specificity, the method of their calculation may vary (details are provided in Table 1). The quotations of the WIG Real Estate index started in the second quarter of 2007, which limits the time range of the data to 2007 Q2 - 2025 Q1. The time span provides 72 periods. The data are of a nominal form as inflation rate was planned as a separate explanatory variable (this refers to variables W3M, ASA, MVA, ICA, CPR, P7, P10, S7, S10). Figure 1 presents oscillations of the variables used in the primary ARDL model.

[1] The Recommendation S, set by the Polish Financial Supervision Authority, concerns the scope of lending by banking sector in the mortgage loans segment in Poland.

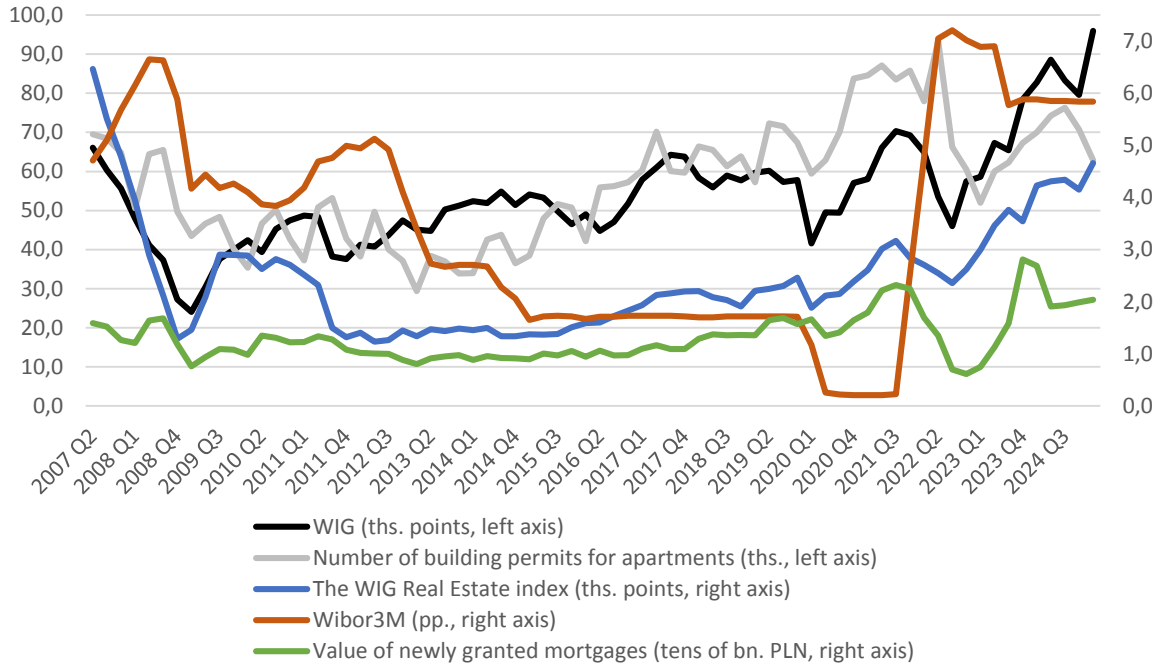

Figure 1. The oscillations of the variables used in the primary ARDL model.
Source: own elaboration.

3.2. Method

Many papers regarding the relationships between direct/securitized real estate and stocks are based on the VAR or VECM frameworks. The two allow to verify bidirectional dependencies. We chose the ARDL methodology (Pesaran, Shin, 1999; Pesaran, Shin, Smith, 2001) as we are looking for strictly examination of the impact of explanatory variables on the WIG Real Estate index alone. Moreover, the ARDL model enables to work out the long-term as well as the short-term relationships. Further, in the ARDL model one can exploit time series stationary at order [0] and at [1]. This broadens the range of potential independent variables as we use the raw time series in our study. The error-correction form of the ARDL model is conveyed by equation (1).

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \sum_{j=0}^{q} \gamma_j \Delta X_{t-j} + \delta_1 Y_{t-1} + \delta_2 X_{t-1} + u_t \quad (1)$$

where:

ΔY_t, ΔY_{t-i}, ΔX_{t-j} - dependent and explanatory variables on first-differenced time series,

Y_{t-1}, X_{t-1} – lagged dependent and explanatory variables on time series on levels,

α_0 – constant,

β_i, γ_j – coefficients indicating the short-run relationship between the dependent and explanatory variables,

δ_1 – a coefficient reflecting the speed of the adjustment process,

δ_2 – a coefficient indicating the long-run relationship between the dependent and explanatory variables,

u_t – error term.

The study was conducted in the STATA software. We pretty much followed the procedure provided by Kripfganz and Schneider (2023). The first step of the study involved verifying stationarity of particular variables, which was conducted with a use of the ADF test. Then, we formulated set of possible models, each including one explanatory variable from each type presented in Table 1. Hence, at the beginning each equation consisted of six independent variables. To avoid possible multicollinearity we formed the correlation matrices. If correlation with magnitude higher than 0.7 was detected, one variable was dismissed from the model. Subsequently, the ARDL models were built based on the remaining variables with number of lags served by the Bayesian (Schwarz) information criterion (BIC). We applied the Variance inflation factor (VIF) to inspect the magnitude of linkages between kept independent variables. Afterwards, we chose the best model out of the set of the basic ARDL models by using a three-step approach. First, as we seek for long- and short-run relationships, thereupon we dropped models with no cointegration indicated according to the Bounds test. Next, we dismissed models with inappropriate results of other postestimation tests: the Breusch-Godfrey test (autocorrelation); the White and the Breusch-Pagan tests (heteroskedasticity); the Jarque-Bera and the Shapiro-Wilk tests (normal distribution of residuals), Cumulative sum test for parameter stability (stability of the model). At that point, the primary ARDL model was chosen based on the magnitude of Adj. R^2.

The second part of the study includes examination of possible external impact on the established primary ARDL model. First, we verified if the four government subsidy housing programs influenced quotations of the WIG Real Estate index. These are: The Family on their own (Rodzina na Swoim), Apartment for young people (Mieszkanie dla Młodych), The Apartment plus (Mieszkanie plus), The Safe mortgage 2% (Bezpieczny kredyt 2%). If the programs improved the economic conditions in the residential market, they should also influence of stocks' prices of companies operating in this sector and the WIG Real Estate index. We formulated binary dummy variables for each of the programs, which take 1 in the quarters the programs took place in and 0 in remaining quarters. Also, we formed one time series for all the programs together, in the same way. Moreover, we formulated dummy variables by multiplying the binary dummies with each of the explanatory variables' time series. The dummy variables were input to the primary ARDL model according to the following scenarios: 1. the binary dummy alone; 2. the binary dummy and WIBOR3M dummy; 3. the binary dummy and value of the mortgages dummy; 4. the binary dummy, WIBOR3M dummy and value of the mortgages dummy; 5. the binary dummy and dummies of all explanatory variables. The time series of WIBOR3M and value of the mortgages reflect conditions of households' creditworthiness in order to purchase residential real estate. We decided to pay a special attention to dummy variables of the two time series, as three out of four government housing programs concerned subsidies in taking on mortgage loans (the scenarios 2, 3 and 4).

The impact of the GFC and the COVID-19 was estimated in similar approach. However, there are six scenarios of dummy variables' injections to the primary ARDL model, in each case: the binary dummy variable alone; the binary dummy and dummy of each of the explanatory variable separately (four scenarios); the binary dummy and dummies of all independent variables together.

We built independent model based on each of the dummy variables scenarios. We acknowledge the impact of the housing program/ the GFC/ the COVID-19 if the model passes postestimation tests (the Bounds test, the Breusch-Godfrey test, the White test, the Breusch-Pagan test, the Jarque-Bera, the Shapiro-Wilk test, Cumulative sum test for parameter stability) and coefficients of the dummy variables are statistically significant.

4. Results and discussion

The following section is divided into three parts. The first presents results of the regular ARDL model. The another two sub-sections serve models including impact of government housing subsidy programs and the COVID-19.

4.1. The primary ARDL model

Table 2 provides results of the ADF test, which works as a verification of the stationarity of the variables employed. Most of the variables are stationary at first differences, however few of them (i.e. CPI, MVA, PICA) are stationary on levels. In order to use all the variables, we chose the ARDL model as the study approach.

Table 2.
Results of the ADF stationarity test of time series applied in the study

Variable		**WRE**	**WIG**	**WCO**	**WBA**	**CPI**
Levels	Test statistic	-2.312	-0.650	-2.152	-0.764	-2.818*
First differences	Test statistic	-3.910***	-4.619***	-4.491***	-4.926***	-3.810***
Variable		**W3M**	**ASA**	**MVA**	**BPE**	**ICA**
Levels	Test statistic	-2.343	3.310	-3.511**	-2.032	-3.827***
First differences	Test statistic	-4.136***	-8.235***	-6.486***	-7.655***	-3.649***
Variable		**CPR**	**P7**	**P10**	**S7**	**S10**
Levels	Test statistic	1.011	2.349	4.010	1.350	2.431
First differences	Test statistic	-6.250***	-5.651***	-3.386**	-3.433**	-3.399**

Note: *p < 0.1; **p < 0.05; ***p < 0.01. The ADF test conducted with 1 lag.

Source: Own elaboration.

According to aforementioned methodology, initial models were predefined with six independent variables. In every model each type of variables stated in Table 1 was represented by only one explanatory variable. Table 3 brings on the correlation matrix for the primary ARDL model variables. The variables CPR and TS10 were dropped due to strong correlation (magnitude > 0.7). Accuracy of this method is proven by results of the VIF in Table 3. The numbers, well below 5.0, indicate a lack of strong relationships between the independent variables in the primary model.

Table 3.
The correlation matrix of the first choice independent variables and results of the variance inflation factor

Variable	WIG	W3M	MVA	BPE	CPR	TS10
WIG	1.0000					
W3M	0.0361	1.0000				
CVA	0.6463***	0.0210	1.0000			
BPE	0.5605***	-0.0544	0.6968***	1.0000		
CPR	0.7089***	0.2198*	0.5302***	0.4376***	1.0000	
TS10	0.7193***	0.3769***	0.6195***	0.6211***	0.9244***	1.0000
Variance inflation factor						
Variable	WIG	W3M	MVA	BPE	Mean	
VIF	1.79	1.01	2.39	2.05	1.81	

Note: *p < 0.1; **p < 0.05; ***p < 0.01.

Source: Own elaboration.

The primary ARDL model is presented in Table 4. The adj. R^2 is pretty high (0.7195). Also, the adjustment variable is statistically significant and negative. This works as confirmation of non-explosive pattern of the model, as in each quarter 23% of previous WRE move is corrected.

Three out of four long-run variables turned out to be significant. W3M represents short-term interest rate, which one might expect to be negative. This is proved for REITs returns in Japan, Hong Kong, Singapore and Malaysia (Liow, Yang, 2005), and for REITs prices in Japan by Ito (2016). On the other hand there is also quite a number of studies reporting opposite direction of the relationships e.g. Bouchouicha and Ftiti (2012), Chaudhry et al. (2022) regarding US REITs. According to stylized facts, increase of interest rates should effect, ceteris paribus, in stock market declines. Consistently, increased cost of mortgages should effect in lower sales and by that lower prices of real estate on both primary and secondary markets. However, one has to bear in mind that within the time span of the study there were four housing programs implemented by government in Poland. Three of them, i.e. Family on their own (Rodzina na Swoim), Apartment for young people (Mieszkanie dla Młodych), Safe mortgage 2% (Bezpieczny kredyt 2%), were dedicated to support households taking on mortgage loans. The time range of the study comprises of 72 periods, out of which only 9 quarters were these without any housing program running. Besides, within the Family on their own and the Safe mortgage 2% programs, the government subsidies were directly aimed at lowering the interest rate paid on mortgage loans. This might have skewed the WIBOR3M

default impact on residential market and on WIG Real Estate index as well. Another case is the fact that the study covers a very specific period of time. Firstly, in the sixth quarter of the study the Lehman Brothers went bankrupt and the GFC took off. Secondly, the first COVID-19 lockdown in Poland took place in the first quarter of 2020, which can be considered as the beginning of the pandemic's impact. Moreover, the surprisingly positive coefficient of W3M may be a result of factors which are not controlled for, in the model. An example of such may be an improvement of general financial conditions of polish households, which could inflate housing demand regardless of interest on mortgages. All in all, the external impacts on the WSE and on the residential market in Poland, and factors not included in the model may cause other than expected direction of influence of W3M on WRE (337.1872).

Also, the coefficient of MVA is other than expected i.e. negative. Again, it seems that the housing programs are first to be blamed for the fact that each additional PLN billion of sold mortgage loans decreases changes of WIG Real Estate by almost 116 points. This may be caused by the regulations of the programs. For instance, in three programs easing taking on mortgage loans, there were clauses setting maximum prices (either in PLN/ sq. m. or regarding total prices). Despite the conventional wisdom regarding the residential developers, next to the banking sectors, being main beneficiaries of the programs; such clauses might limit the developers' margin on the housing. Furthermore, the three housing programs, most of the time, were dedicated to both primary and secondary residential market. As residential developers drive the WIG Real Estate index the negative MVA suggests that the programs might have been more beneficiary to entities of secondary residential market. Moreover, the fourth program i.e. the Apartment plus (Mieszkanie plus) consisted in apartments being built by public authorities on public land, for rent or for rent with possible acquire in future. The last can be treated as the competition to private capital on residential market. Regardless the arguments, one would expect that the housing programs, in total positively influenced number of residential units sold. This should bring profits of residential developers as well as quotations of the WIG Real Estate index higher. However, another issue here is a specificity of the residential development process. The residential development act (Ustawa deweloperska) stands that when the agreement between residential developer and client is concluded the money from mortgage loan flow to the developer gradually, after each construction stage is finished. Hence, residential developers first bear the costs of construction and later receive (four to ten) instalments from the client's open escrow account. In that case, the value of mortgages may express promise of future profits burdened by today's costs, what can cause the WRE to fall. However, this should be true in a short-run. Unfortunately, in the primary model there is a lack of short-term MVA variable.

As expected, the coefficient of BPE variable is positive, which means that one additional building permit on residential real estate increases the WRE by 0.08 points. The coefficient of the WIG index is insignificant, insisting that there are no long-term relationships with WRE. Kołtuniak (2016b), in turn, proved causality between the WIG Real Estate index, the WIG index and the investment property fair value index but also unstable long-term dependencies at the same time.

As far as the short-term is concerned, coefficients of the variables DWREL1 and DWREL2 indicate trend continuation (0.2370 and 0.2226). A positive influence is also carried by DWIG and DWIGL3, 0.0286 and 0.0138 respectively. However, this contradicts findings of Nowak (2020) who reported negative short-term impact of indexes WIG and WIG20 on the WIG Real Estate. One should bear in mind that the study (Nowak, 2020) was based on time series that end in 2020 Q1. It essentially did not included the time of the COVID-19, what may impact the results. Naturally, one should expect the WRE to rather strongly follow short-run stock exchange (the WSE) conditions. This should be evident especially during stock market sharp overreactions, mostly in situations where systematic risk materializes. Nonetheless, literature on the impact of stock indexes on securitized real estate is ambiguous. One can find papers implying positive (on prices - Ito, 2016) and negative (on returns - Wu, Wang, 2024) effects on REITs.

Interestingly, statistically significant variables of WIBOR3M rate (DW3M and DW3ML2) are negative, -114.8398 and -311.9026. There is a clear difference of the Warsaw interbank offer rate's impact in the long- and short-term then. In the short-run the WRE responses to changes of W3M are consistent with economic theory. On the other hand, in the long-run the phrase "ceteris paribus" covers influence of all the external factors that may prevail and distort the standard relationships. Surprisingly, variables representing differenced time series of building permits (DBPE, DBPEL1) are negative (-0.0069 and -0.0084), what contradicts the long-term dependence. This, however, can be a result of the fact that in Poland there is still a problem of great amount of areas, within cities, which are not under local zoning plans. This means that residential developers often need to apply for land development conditions first, what may also make the process of obtaining the building permits more time consuming. The number of building permits is a derivative of a number of applications submitted few, usually 2-4 quarters before[2]. Therefore, the lag longer than just one quarter may be a reason of lack of positive coefficients in the short-term. Nowak (2020) noted lack of statistical significance of residential premises with permit to make use of, which is a close statistics to the building permits. It is worth to advert that Nowak (2020) obtained negative, so expected coefficients on value and number of mortgage loans handed over. In our study the MVA does not impact WRE in the short-run.

[2] However, the process may last even for few years in the case of opposition from the owners of neighboring parcels.

Differences in magnitude between individual variables are related to the time series values. Taking into account mean values of the variables (Table 1), in the long-run the strongest impact is contributed to building permits. Albeit, in the short-term these are lagged changes of the WIG index which weigh the most, which are insignificant in the long-term. The above means that answer to the first research question depends on the time-frame. Moreover, there is obvious change of WIBOR3M, which coefficients are according to the stylized facts in the short-term (negative) and opposite in the long-term (positive). The change is also evident when it comes to the building permits. The results directly indicate positive answer to the second research question. There are distinctions between long- and short-term relationships patterns, which again insist heavy impact of time frame on the obtained results.

The average transaction prices of apartments were dismissed from the model due to high correlation issue. For that reason we were unable to prove direct relationships between time series of securitized real estate and direct real estate, which is demonstrated in many aforementioned papers (e.g. Hoesli, Oikarinen, 2012; Kołtuniak, 2016a; Wolski, 2018, 2020).

Table 4.
The primary ARDL model explaining the differenced quotations of the WIG Real Estate

Independent variables	Coefficient	Std. Err.
Constant	-502.1992	139.6117***
Adjustment variable		
WREL1	-0.2278	0.0578***
Long-run variables		
WIG	0.0064	0.0126
W3M	337.1872	67.4224***
MVA	-115.9749	64.6887*
BPE	0.0793	0.0218***
Short-run variables		
DWREL1	0.2370	0.1029**
DWREL2	0.2226	0.1007**
DWIG	0.0286	0.0052***
DWIGL1	-0.0019	0.0061
DWIGL2	-0.0077	0.0057
DWIGL3	0.0138	0.0051***
DW3M	-114.8398	47.0447**
DW3ML1	42.1012	60.0075
DW3ML2	-311.9026	58.3945***
DBPE	-0.0070	0.0033**
DBPEL1	-0.0084	0.0031**
Adj. R^2	0.7195	

Note: *p < 0.1; **p < 0.05; ***p < 0.01. "D" at the beginning of variables' codes indicates first-differenced time series. "L" at the end of the variables' codes stands for lagged time series.

Source: Own elaboration.

Table 5 provides results of Bounds cointegration test. Results of the other postestimation tests, stored in table 6 and 7, indicate no autocorrelation (the Breusch-Godfrey test), heteroskedasticity (the White and the Breusch-Pagan tests) and normal distribution of residuals (the Jarque-Bera and the Shapiro-Wilk tests).

Table 5.
Results of the Bounds cointegration test (Case 3) of the primary ARDL model

p levels of critical values		10%		5%		1%		p-value	
Lower and upper bounds		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F-statistics	8.621***	2.475	3.720	2.956	4.341	4.054	5.735	0.000	0.000
t-statistics	-3.939*	-2.492	-3.581	-2.827	-3.963	-3.492	-4.708	0.003	0.052

Note: rejection of the null hypothesis of no long-run relationship at levels at *p < 0.1; **p < 0.05; ***p < 0.01.

Source: Own elaboration.

Table 6.
Results of the Breusch-Godfrey autocorrelation test of the primary ARDL model

Number of lags	chi2	df	Prob > chi2
1	0.002	1	0.9650*
2	1.198	2	0.5494*
3	1.701	3	0.6367*
4	2.028	4	0.7306*

Note: *p > 0.1; **p > 0.05; ***p > 0.01.

Source: Own elaboration.

Table 7.
Results of heteroskedasticity tests (the White and the Breusch-Pagan tests) and normality tests (the Jarque-Bera and the Shapiro-Wilk tests) of the primary ARDL model

The White test	The Breusch-Pagan test	The Jarque-Bera test	The Shapiro-Wilk W test
chi2(67)	F(16, 51)	chi(2)	z
68.00	1.02	1.463	0.104
Prob > chi2	Prob > F	Prob > chi2	Prob>z
0.4429*	0.4514*	0.4812*	0.45844*

Note: *p > 0.1; **p > 0.05; ***p > 0.01.

Source: Own elaboration.

We investigated the stability of the primary ARDL model with the Cumulative sum test for parameter stability. Based on the results provided by Table 8 the null hypothesis of no structural break stays on, in the case of both recursive as well as OLS statistics. This is also proved by Figure 2, both the recursive and the OLS cumulative sums stay within the 95% bands.

Table 8.
Results of the Cumulative sum tests for parameter stability of the primary ARDL model

Statistic	Test Statistic	1% Critical value	5% Critical value	10% Critical vale
Recursive	0.6825	1.1430	0.9479	0.850
OLS	0.4772	1.6276	1.3581	1.224

Note: *p > 0.1; **p > 0.05; ***p > 0.01.

Source: Own elaboration.

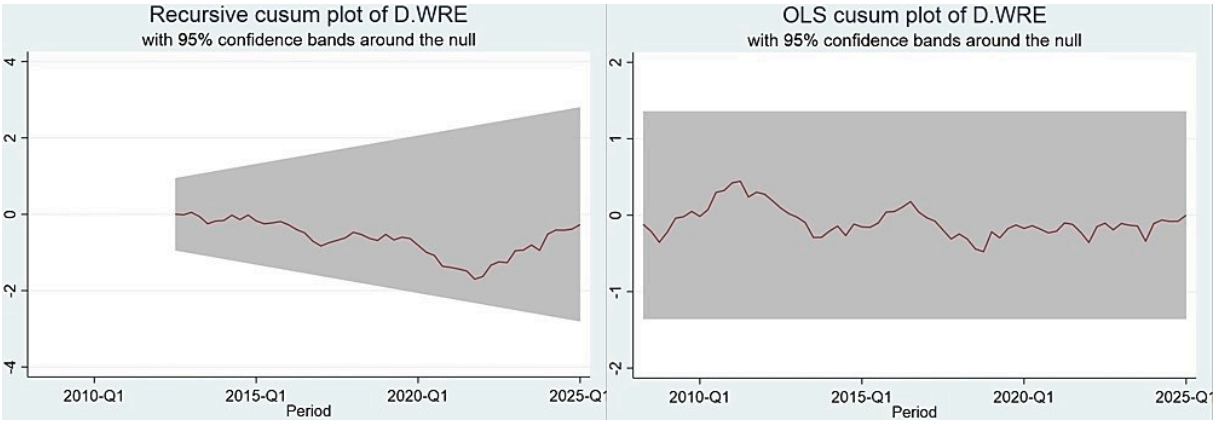

Figure 2. CUSUM test plots.

Source: Own elaboration.

The interpretation of the primary ARDL model, along with the ambiguous results of various studies recalled in this section, emphasize possible external impacts on the model that may result from the time span of the study, like economic situation, monetary, fiscal and even social policy (housing programs), and shocks arising from economic crises. In this context, and following the third research question, two major issues shall be examined: first, if the particular housing programs; second, if the GFC and the Covid-19; had impact on the WIG Real Estate.

4.2. The impact of government housing subsidy programs

As it was mentioned before, within the time span of the study (2007 Q2 – 2025 Q1) there were four government housing programs in Poland. Presenting the in-depth characteristics of the programs does not lie within the scope of the paper. However, short description may be crucial for understanding the impact they may have on residential market and on the WIG Real Estate index. The Family on their own (Rodzina na Swoim) housing program was aimed at young married couples and single parents and was in place in years 2007-2012. Under the program, the state paid half of the interest on the mortgage loan for the first eight years. The Apartment for young people (Mieszkanie dla Młodych) included subsidies for down payments while taking on the mortgage loan. The program was also dedicated to young adults and was running from 2014 to 2018. The Apartment plus (Mieszkanie plus) program which was in force from 2016 Q4 to 2023 Q2. The goal here was to build affordable rental apartments with the option of ownership in future. The Safe mortgage 2% (Bezpieczny kredyt 2%) housing program lasted only in two last quarters of 2023. According to this program young residential buyers could take on a mortgage loans with interest rate limited to 2% plus bank's margin. It is also worth to note that only people who did not own any residential real estate could become beneficiaries of all the four housing programs.

We formulated binary dummy variable of each housing program which take value 1 in the periods of running the program and 0 in others. We also formed such time series for all the programs altogether. Then, we formulated dummy variables as products of the binary dummy and two regular variables of the primary ARDL model i.e. W3M and MVA. Three out of four housing programs represent different kind of subsidies of mortgage loans. The variables W3M and MVA represent interbank interest rate and value of mortgage loans, thus they should reflect the impact of the programs the most. The verification was proceeded by adding the dummy variables to the primary ARDL model according to scenarios listed in the second column of Table 9. Again, the goal here was to specify a model with long- and short-term adjustments, so with detected cointegration.

Table 9.
List of housing programs dummy variables added to primary ARDL model in particular scenarios

No.	Variables added to primary ARDL model	Family on their own (RNS)	Apartment for young people (MDM)	Apartment plus (MPL)	Safe mortgage 2% (BK2)	Housing programs overall (HP)
1	Binary dummy	No cointegration	No cointegration	Cointegration	Cointegration, significant impact	No cointegration
2	Binary dummy, W3MDV	No cointegration	No cointegration	No cointegration	No cointegration	Cointegration, significant impact
3	Binary dummy, MVADV	No cointegration	No cointegration	No cointegration	No cointegration	Cointegration, significant impact
4	Binary dummy, W3MDV, MVADV	No cointegration	No cointegration	No cointegration	No cointegration	No cointegration
5	Binary dummy, all independent variables' DV	No cointegration	No cointegration	No cointegration	No cointegration	No cointegration

Source: Own elaboration.

The four models mirroring impact of housing programs, with cointegrated time series, are served in Table 10. There are moderate improvements of adj. R^2 in each of the four housing program models in comparison to the primary ARDL model.

In the case of the first model (MPL model) the dummy variable does not represent statistically significant impact on WRE. The coefficients of long-term as well as short-term variables are pretty close to these of the primary ARDL model.

As far as BK2 model is concerned coefficient of the DVBK2 indicates that the housing program Safe mortgage 2% took away almost 1053 points of WIG Real Estate index in last two quarters of 2023. Moreover, constant became negative and MVA became insignificant. The coefficients representing short-run variables changed only slightly.

When it comes to the HP1 model influence of W3M on WRE increased by 2,5 times (838.4225), however, the boost is totally limited by negative value of W3MHP1 (-582.8846). The variable DVHP1 imply considerable positive effect of consecutive housing programs on the real estate stock index (2159.086). Again, there are no major changes in the short-run adjustments.

In the HP2 model the MVA variable turned to be statistically insignificant. It seems like its impact is included in the dummy MVAHP2 which coefficient is about 60% higher (-184.2183). The binary dummy DVHP2 once more reflects major positive impact on WRE (2221.435). The coefficient of W3M declined by about 40%. In the short-term part of the equation one can notice magnitudes drop of coefficients of DW3M and DW3ML2 to -85.1855 and -231.4869. Also, the total influence of building permits rose by over 60%, primarily thanks to new significant variable (DBPEL2).

All things considered, there are signs of strong positive influence of all the four housing programs taken altogether (models HP1 and HP2), what is indicated by the binary dummies. However, the impact of the Safe mortgage 2% (BK2) program alone is negative. Nevertheless, one has to bear in mind that the program lasted only for six months. Therefore, in this case the long-term conclusions should be drawn with caution. Moreover, in the HP1 model, taking together coefficients of W3M and its dummies, the effect on WRE is weaker than in the primary ARDL model.

The results of the postestimation tests obtained for the four housing programs' models allow for their interpretation and are stored in the Tables 13-16.

Table 10.
The ARDL models with housing programs' dummy variables

MPL model			BK2 model			HP1 model			HP2 model		
Independent variables	**Coeff.**	**Std. Err.**	**Independent variables**	**Coeff.**	**Std. Err.**	**Inde-pendent variables**	**Coeff.**	**Std. Err.**	**Inde-pendent variables**	**Coeff.**	**Std. Err.**
Constant	-569.6563	147.4737***	Constant	542.9562	139.4298***	Constant	-745.9784	211.4558***	Constant	-637.0546	187.1444***
Adjustment variable			Adjustment variable			Adjustment variable			Adjustment variable		
WREL1	-0.2329	0.0575***	WREL1	-0.2510	0.0585***	WREL1	-0.2665	0.0559***	WREL1	-0.2551	0.0517***
Long-run variables			Long-run variables			Long-run variables			Long-run variables		
WIG	0.0060	0.0122	WIG	0.0046	0.0113	WIG	-0.0125	0.0135	WIG	-0.0179	0.0136
W3M	290.3875	70.0789***	W3M	354.3408	62.7145***	W3M	838.4225	200.3793***	W3M	200.5232	60.2713***
MVA	-137.5918	68.8840*	MVA	-76.9380	55.4024	MVA	-95.5225	49.2235*	MVA	83.9408	53.8413
BPE	0.0952	0.0269***	BPE	0.0708	0.0186***	BPE	0.0686	0.0163***	BPE	0.0710	0.0162***
DVMPL	-504.4125	389.9154	DVBK2	-1052.935	622.2718*	DVHP1	2159.086	833.3081**	DVHP2	2221.435	755.3445***
Short-run variables			Short-run variables			W3MHP1	-582.8846	207.0785***	MVAHP2	-184.2183	56.2601***
DWREL1	0.2261	0.1024**	DWREL1	0.2847	0.1051***	Short-run variables			Short-run variables		
DWREL2	0.2397	0.1008**	DWREL2	0.2579	0.1013**	DWREL1	0.2476	0.0969**	DWREL1	0.2848	0.0921***
DWIG	0.0293	0.0052***	DWIG	0.0286	0.0051***	DWREL2	0.2600	0.0955***	DWREL2	0.2093	0.0894**
DWIGL1	-0.0002	0.0062	DWIGL1	-0.0033	0.0060	DWIG	0.0312	0.0052***	DWIG	0.0325	0.0049***
DWIGL2	-0.0076	0.0057	DWIGL2	-0.0084	0.0056	DWIGL1	-0.0003	0.0058	DWIGL1	-0.0013	0.0055
DWIGL3	0.0130	0.0051**	DWIGL3	0.0147	0.0051***	DWIGL2	-0.0064	0.0054	DWIGL2	-0.0011	0.0054
DW3M	-110.9709	46.7773**	DW3M	-137.4579	48.2108***	DWIGL3	0.0138	0.0048***	DWIGL3	0.0148	0.0046***
DW3ML1	39.7792	59.5774	DW3ML1	30.9249	59.3776	DW3M	-88.7952	45.1443*	DW3M	-85.1855	42.6062*
DW3ML2	-306.565	58.0889***	DW3ML2	-294.4172	58.3654***	DW3ML1	38.5282	56.8925	DW3ML1	28.8920	54.2163
DBPE	-0.0093	0.0037**	DBPE	-0.0060	0.0033*	DW3ML2	-281.0384	58.8264***	DW3ML2	-231.4869	58.4887***
DBPEL1	-0.0101	0.0034**	DBPEL1	-0.0076	0.0031**	DBPE	-0.0068	0.0031**	DBPE	-0.0090	0.0031***
-	-	-	-	-	-	DBPEL1	-0.0087	0.0030***	DBPEL1	-0.0107	0.0030***
-	-	-	-	-	-	-	-	-	DBPEL2	-0.0057	0.0029*
Adj. R^2	0.7238		Adj. R^2	0.7289		Adj. R^2	0.7519		Adj. R^2	0.7805	

Note: *p < 0.1; **p < 0.05; ***p < 0.01. "MPL", "BK2" and "HP" at the end of the variables' codes stay for programs Apartment plus, Safe mortgage 2% and Housing programs overall, respectively.

Source: Own elaboration.

4.3. The impact of the GFC and the COVID-19

The impact of the GFC and the COVID-19 on the WIG Real Estate index was verified with a use of a similar procedure as in the case of the housing programs. The examined scenarios are presented in second column in Table 11. The cointegration and significant impact of the dummies were found only in the case no. 3 for COVID-19.

Table 11.
List of the GFC and the COVID-19 dummy variables added to primary ARDL model in particular scenarios

No.	Variables added to primary ARDL model	GFC	COVID-19
1	Binary dummy	No cointegration	No cointegration
2	Binary dummy, WIGDV	No cointegration	No cointegration
3	Binary dummy, W3MDV	No cointegration	Cointegration, significant impact
4	Binary dummy, MVADV	No cointegration	No cointegration
5	Binary dummy, BPEDV	No cointegration	No cointegration
6	Binary dummy, all independent variables' DV	No cointegration	No cointegration

Source: Own elaboration.

The COVID model is presented in Table 12. The Adj. R^2 has slightly improved (0.8098). The constant represents a positive number with over 40% higher magnitude than in the primary ARDL model. Curiously enough, WIG is significant and has a negative effect on WRE. One point increase of the WIG index quotation produces 0.0975 point decline in the WIG Real Estate index. W3M turned negative. But again, taking the coefficients of W3M (-520.9804) and W3COV (1061.206) together gives positive impact about 60% stronger than in the primary model. The binary dummy variable COV itself implies that starting 2020 Q1, in each quarter the Real Estate index was lower by 2,579.902 points. The MVA is positive, showing that every additional PLN 1 billion in newly granted mortgage loans increases WRE by 239.8643 points. The magnitude of the BPE decreased by a half.

There are no lags of independent variable in the short-term part of the model. All the four WIG differenced variables are significant and reflect 120% stronger total effect on WRE than in primary ARDL model, the direction stays the same though. When it comes to WIBOR, only changes lagged two periods are significant (DW3ML2). The coefficient is still negative and 20% lower than in regular model (-253.7385). Then again, taking it together with coefficient of emerged DW3COV (-222.4872) gives the slightly greater number. Also, there is an evidence of short term dependency of differenced WRE on changes of value of newly granted mortgages. The WRE changes in reverse direction than all of the four differenced MVA variables (the sum of coefficients stays at -137.0620). Joint influence of DBPE and DBPEL1 is little bit weaker but remains negative. The results of the postestimation tests for the COVID model are stored in the tables 13 – 16.

In the context of the GFC and the COVID-19, we also formulated two additional models to check if the time span alter the relationships between WIG Real Estate index and the set of explanatory variables of the primary ARDL model. First model was built on the time series for

a period 2009 Q1 – 2025 Q1, the second covered 2009 Q1 – 2019 Q4. However, in the both cases cointegration was not detected, so the models are not presented in the paper.

The impact of COVID-19 on economy and stock markets was negative at first. However, one shall recall the helicopter money and interest rates cuts as reactions of fiscal and monetary authorities, respectively. Then, expansion of inflation and its effect in elevated central bank rates later on, during restrictive monetary policy. All of this produced massive oscillations since 2020 on stock markets worldwide, also on the WSE. Eventually, the COVID model indicates the significant negative influence of the pandemic on WIG Real Estate index quotations in the long-term, conveyed by binary dummy (COV). Also, it pictures positive and negative impact of W3M's dummies in the long- (W3COV) and in the short-term (DW3COV), respectively.

Table 12.
The ARDL model with the COVID-19 dummy variables (the COVID model)

Independent variables	Coefficient	Std. Err.
Constant	719.3529	226.4888***
Adjustment variable		
WREL1	-0.2155	0.0528***
Long-run variables		
WIG	-0.0975	0.0309***
W3M	-520.9804	209.0767**
MVA	239.8643	81.3782***
BPE	0.0396	0.0175**
COV	-2579.902	843.969***
W3COV	1061.206	301.3015***
Short-run variables		
DWIG	0.0403	0.0051***
DWIGL1	0.0226	0.0048***
DWIGL2	0.0134	0.0046**
DWIGL3	0.0168	0.0042***
DW3M	-0.9187	66.5914
DW3ML1	42.6432	53.4153
DW3ML2	-253.7385	54.5753***
DMVA	-50.6590	12.6909***
DMVAL1	-31.9013	13.4205**
DMVAL2	-32.5153	9.9939***
DMVAL3	-21.9864	10.3504**
DBPE	-0.0038	0.0034
DBPEL1	-0.0090	0.0031***
DW3COV	-222.4872	83.4072**
Adj. R^2	0.8098	

Note: *p < 0.1; **p < 0.05; ***p < 0.01. "COV" at the end of the variables' codes indicate Covid-19 dummy variable.

Source: Own elaboration.

5. Conclusions

The study is based on the question if public real estate is more like private real estate or it should be treated as another class of securities. To examine that we verified impact on the WIG Real Estate index traded at the WSE, of variables representing stock exchange (the WSE indexes), economic (monetary variables), real estate market (demand, supply and construction costs variables), and direct real estate prices (residential transaction prices). Our findings insist that basically in the short-run the path of WIG Real Estate index is set by macroeconomic variables, real estate variables and the mostly by the WIG index. However, in the long-run the WIG index coefficient turns insignificant. This incline that the WIG Real Estate index captures the current stock market situation and follows its short-term shocks. While in the long-term view it traces the macroeconomic and sector based conditions. We also found that there is a statistically significant impact of government subsidy housing programs as well as the COVID-19 on the index.

The main limitation of the study springs from time range of available time series. The time frame is imposed by the quotations of the WIG Real Estate index which set out in 2007 Q2. This made more in-depth analysis of impact of the GFC on the model infeasible. Moreover, the data end in 2025 Q1, what again leave us with insufficient number of quarters to build reliable model starting at the beginning COVID-19. However, this constraint can be overcome in time.

The results indicate linkages between direct real estate market and stock market with the WIG Real Estate index. The implied character (direction and magnitude) of the relationships can be of service to investment portfolio management. The findings can be useful for investors building their portfolios with direct real estate, securitized real estate and stocks.

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Appendix

Table 13.
Results of the Bounds cointegration test (Case 3) for models with dummy variables (housing programs, the COVID-19)

p levels of critical values		10%		5%		1%		p-value	
MPL model									
Lower and upper bounds		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F-statistics	7.592***	2.306	3.580	2.736	4.150	3.716	5.430	0.000	0.001
t-statistics	-4.049*	-2.482	-3.774	-2.820	-4.167	-3.491	-4.936	0.002	0.062
BK2 model									
F-statistics	7.894***	2.306	3.580	2.736	4.150	3.716	5.430	0.000	0.000
t-statistics	-4.288**	-2.482	-3.774	-2.820	-4.167	-3.491	-4.936	0.001	0.040
HP1 model									
F-statistics	8.197***	2.184	3.478	2.579	4.013	3.476	5.214	0.000	0.000
t-statistics	-4.761**	-2.473	-3.945	-2.814	-4.348	-3.490	-5.138	0.000	0.022
HP2 model									
F-statistics	10.045***	2.178	3.483	2.572	4.020	3.469	5.228	0.000	0.000
t-statistics	-4.933**	-2.466	-3.935	-2.808	-4.340	-3.486	-5.134	0.000	0.015
COVID model									
F-statistics	12.070***	2.164	3.491	2.558	4.034	3.455	5.256	0.000	0.000
t-statistics	-4.083*	-2.451	-3.914	-2.796	-4.323	-3.479	-5.126	0.002	0.076

Note: rejection of the null hypothesis of no long-run relationship at levels at *p < 0.1; **p < 0.05; ***p < 0.01.

Source: Own elaboration.

Table 14.
Results of the Breusch-Godfrey autocorrelation test for models with dummy variables (housing programs, the COVID-19)

Number of lags	chi2	df	Prob > chi2	Number of lags	chi2	df	Prob > chi2
MPL model				**BK2 model**			
1	0.030	1	0.8632*	1	0.022	1	0.8809*
2	2.526	2	0.2828*	2	0.548	2	0.7603*
3	3.367	3	0.3384*	3	1.108	3	0.7750*
4	4.252	4	0.3729*	4	1.473	4	0.8315*
HP1 model				**HP2 model**			
1	0.014	1	0.9042*	1	0.136	1	0.7123*
2	0.850	2	0.6539*	2	1.206	2	0.5471*
3	1.660	3	0.6458*	3	1.232	3	0.7453*
4	1.979	4	0.7397*	4	1.490	4	0.8283*
COVID model				-			
1	2.631	1	0.1048*	-	-	-	-
2	4.358	2	0.1132*	-	-	-	-
3	8.572	3	0.0356***	-	-	-	-
4	8.666	4	0.0700**	-	-	-	-

Note: *p > 0.1; **p > 0.05; ***p > 0.01.

Source: Own elaboration.

Table 15.
Results of heteroskedasticity tests (the White and the Breusch-Pagan tests) and normality tests (The Jarque-Bera and The Shapiro-Wilk tests) for models with dummy variables (housing programs, the COVID-19)

The White test	The Breusch-Pagan test	The Jarque-Bera test	The Shapiro-Wilk W test
MPL model			
chi2(67)	F(17, 50)	chi(2)	z
68.00	1.03	2.859	0.604
Prob > chi2	Prob > F	Prob > chi2	Prob>z
0.4429*	0.4431*	0.2394*	0.27303*
BK2 model			
chi2(67)	F(17, 50)	chi(2)	z
68.00	0.61	1.684	0.544
Prob > chi2	Prob > F	Prob > chi2	Prob>z
0.4429*	0.8695*	0.4308*	0.29337*
HP1 model			
chi2(67)	F(18, 49)	chi(2)	z
68.0	0.47	1.867	0.329
Prob > chi2	Prob > F	Prob > chi2	Prob>z
0.4429*	0.9573*	0.3931*	0.37116**
HP2 model			
chi2(67)	F(19, 48)	chi(2)	z
68.0	0.57	1.97	0.205
Prob > chi2	Prob > F	Prob > chi2	Prob>z
0.4429*	0.9096*	0.3734*	0.41883*
COVID model			
chi2(67)	F(21, 46)	chi(2)	z
68.0	0.78	0.6131	0.485
Prob > chi2	Prob > F	Prob > chi2	Prob>z
0.4429*	0.7226*	0.736*	0.3138*

Note: *p > 0.1; **p > 0.05; ***p > 0.01.

Source: Own elaboration.

Table 16.
Results of the Cumulative sum tests for parameter stability for models with dummy variables (housing programs, the COVID-19)[3]

Statistic	Test Statistic	1% Critical value	5% Critical value	10% Critical vale
MPL model				
Recursive	0.3470	1.1430	0.9479	0.850
OLS	0.5504	1.6276	1.3581	1.224
BK2 model				
Recursive	0.0584	1.1430	0.9479	0.850
OLS	0.4862	1.6276	1.3581	1.224
HP1 model				
Recursive	0.7218	1.1430	0.9479	0.850
OLS	0.6209	1.6276	1.3581	1.224
HP2 model				
Recursive	0.6090	1.1430	0.9479	0.850
OLS	0.5385	1.6276	1.3581	1.224
COVID model				
Recursive	0.1640	1.1430	0.9479	0.850
OLS	0.3250	1.6276	1.3581	1.224

Note: *p > 0.1; **p > 0.05; ***p > 0.01.

Source: Own elaboration.

[3] Graphs of Cumulative sum tests for parameter stability are available from author at a reasonable request.

SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

LEGAL WAYS TO REDUCE THE EFFECTS OF LATE PAYMENTS ON THE OPERATIONS OF ENTERPRISES IN POLAND

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Purpose: The aim of the publication is to analyse a problem of late payments on the European Union market and in Poland, analyse the solutions that are available to entrepreneurs in the event of a difficult financial situation, assess the scope of their application in practice and find solutions to reduce the negative effects of delays.
Design/methodology/approach: The conducted research used an analysis of domestic and foreign literature concerning finances, law, methods of protecting against risk. Data on the problem of late payments in the activities of entrepreneurs in Poland and selected European Union countries were obtained and analysed. As part of the conducted works, the following research hypotheses were raised: In Poland and Europe, there is a problem with delayed payments. Failure to pay by the contractor on time has negative consequences for the company's finances. These effects can be minimized thanks to the risk mitigation tools used.
Findings: Research would show that entrepreneurs are particularly often unable to meet their financial obligations on time. These delays in Poland amount to over 40 days, more than average in EU. Late payment affects the financial result of enterprises and their financial liquidity. However, business practice and legislation have developed instruments that can significantly reduce the negative effects of late payment or fully compensate for them.
Research limitations: Limitations in the research concerned the lack of access to entrepreneurs' financial data and actual payment dates, as this is often an element of entrepreneurial secrecy and its competitive advantage.
Originality/value: The content of the study confirms that the problem of late payments occurs in Poland and Europe. The article indicates possible legal instruments for minimizing this risk and protecting against it. The paper is dedicated to people dealing with financial and organisation management.
Keywords: late payment risk, payment security, terms of payment, receivables, obligations.
Category of the paper: Research paper.

1. Introduction

The Polish economy based on the freedom of economic activity has been developing since 1989, when significant political changes took place. These changes consisted, in particular, in indicating the right of ownership as the basic right vested in entities operating in Poland. The economy was based on the fundamental principle of freedom of economic activity. This resulted in an avalanche increase in the number of entities conducting this activity to over 4.9 million entities at the end of 2022. These entities operate in various branches of the economy, produce, sell, and provide services. This is associated with the emergence of liabilities on this account. Statistical studies show that liabilities resulting from the sale of goods and services of entrepreneurs are constantly growing. Despite many legal regulations in this area, the average payment term in commercial transactions in Poland in 2019-2022 was 57.5 days. Entrepreneurs are also late with payments to their contractors. The average deadline for late payment of an invoice in Poland in 2019-2022 is 53 days, while in Germany in the same period this period is only 10.5 days. This means that it is necessary to analyse the available instruments that will limit delayed payments or protect companies against the risk of non-payment from the counterparty.

2. Business risk

Every company operating on the market is exposed to risk. It concerns many aspects of the functioning of the business. The concept of risk is defined in various ways and in different aspects. Differences in the interpretation of this term are manifested in such issues as the relationship between risk and uncertainty, the types of deviations that arise – unidirectional, multidirectional, the object of reference, the possibility of measurement by applying the theory of probability. Table 1 contains a selection of definitions of uncertainty presented in the literature.

Table 1.
Summary of selected definitions of uncertainty

Definition of uncertainty
The possibility of deviations from the expected state, which cannot be measured, because the theory of probability cannot be applied (F. Knight)
Immeasurable uncertainty to which statistical measures cannot be applied (O. Lange)
State of mind, measured by the degree of faith (I. Pfeffer)
An immanent feature of reality, resulting from: a large number of complex and changing subjects; the significant relationship between them and the environment; limited ability of people to control the factors shaping reality (K. and T. Jajuga)
Condition – a situation characterized by the lack of full knowledge of the parameters of the intended project and their distributions in a set of alternative events (E. Kulwicki)

Cont. table 1.

Uncertainty manifests itself in mistakes made and assessments of future events; it is immeasurable; its results cannot be predicted; occurs in long periods (E. Hołowska)
It is the beginning of many human reflections and considerations and an inseparable element of decision-making processes (S. Nahotko)
Its source is the complexity and dynamism of the situation and the mental processes of the decision-maker

Source: Own study based on: Kaczmarek, pp. 11 ff.

The first definitions of the concepts of risk and uncertainty were found in the work of F.H. Knight (Knight, pp. 19-20). According to this author, risk means the possibility of deviation from the expected or planned state, which can be calculated using the calculus of probability, while uncertainty occurs when such a possibility cannot be assessed more precisely, because it is not possible to use the theory of probability.

Representatives of the defensive trend treat risk as a negative phenomenon – a source of losses that should be taken into account in the company's operations (Gup, p. 355); the danger of negative deviation from the target (Brühwiler, p. 40); the threat of a decrease in profit (Sahl, p. 292).

In insurance science, risk is defined as the possibility of a specific event, accident or random damage. The term risk is identified here with any danger threatening the facilities in question or persons referred to as fortuitous events. The theory of decision-making under conditions of uncertainty and risk is based on the assumption of quantification. R.D. Luce and H. Raiffy distinguish three types of decisions that can be made (Jędralska, p. 51):

- under conditions of certainty - if it is known that a particular action leads to,
- to this and not another result,
- in risk conditions – when the action leads to an outcome from a certain set of possible outcomes, each of which has a probability of occurrence known to the decision-making entity,

Under conditions of uncertainty – we do not know the distribution of the probability of achieving the goal.

A similar concept of risk and uncertainty is presented by R.L. Ackoff, who distinguishes areas of certainty, risk and uncertainty in the area of decision-making. Uncertainty as to the final result of an action is the cause of entrepreneurial behavior, because the set of possible results includes expected and undesirable actions. Achieving the most desirable effect often presents a significant difficulty that must be overcome. In this way, uncertainty gives rise to entrepreneurship and the entrepreneur struggling with uncertainty, i.e. fighting against adversity for a result that would give him maximum satisfaction (Grzybowski, p. 22).

The concepts presented above show that the risk is, on the one hand, the result of the uncertainty experienced by the decision-making entity, and on the other hand, it depends on the amount of capital involved in the implementation of the decision. Risk is a function of uncertainty, and this function is a simple relationship: the greater the extent of uncertainty, the greater the risk, and vice versa – as unspecified and uncertain factors decrease, so does risk.

It follows that there is no risk where there is no uncertainty and where some capital has not been involved. It is obvious that the risk increases with the amount of capital employed. It should also be noted that since the main attribute of risk is uncertainty, the value of risk will also be significantly affected by time. This means that as the time horizon of predictions increases, their uncertainty will increase.

The literature distinguishes many types of risks to which enterprises are exposed. Figure 1 schematically presents the most important of these risks. It is obvious that each company is different, among other things, in terms of finance, organization, subject of activity, industry, size, scope of activity, number of customers, rules of cooperation. Therefore, it may happen that not all risks will occur in a specific company. It may also be that there will be additional risks in a particular company.

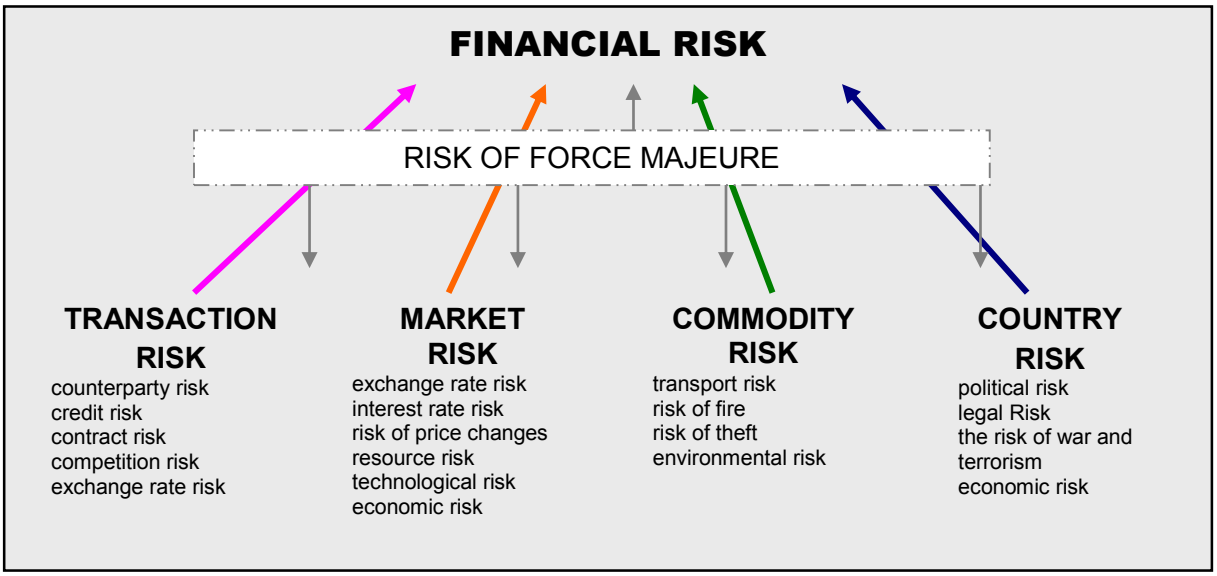

Figure 1. Financial risk in trading activities.

Figure 1 shows that business risk can be divided into transactional, market, commodity and country risks. Transaction risk refers to all events causing the partner to fail to meet the obligations undertaken in the concluded agreement. Market risk includes the risk of changes in the value of market instruments such as the exchange rate, interest rate, prices of raw materials, production materials and changes caused by the development of technology and the economic situation on the markets. Commodity risk consists in the danger of loss or damage to goods, changes in their quantity, quality and commercial condition, and the areas of its occurrence are related to the storage and transport of goods. Country risk is a fairly broad concept that may be related to political issues in a given country or the economic situation and the economic and legal conditions for doing business.

Undoubtedly, one of the biggest risks faced by entrepreneurs is the risk of delayed payment by the partner to whom the company sells goods or services.

3. Risk of delayed payments on the European Union market and in Polish enterprises

The risk of late payments consists in the inability of the debtor to fail to perform a monetary obligation on time. Unfortunately, this risk affects all entrepreneurs and is quite common on the European Union market. Figure 2 presents the average payment terms in selected EU countries in 2019-2023.

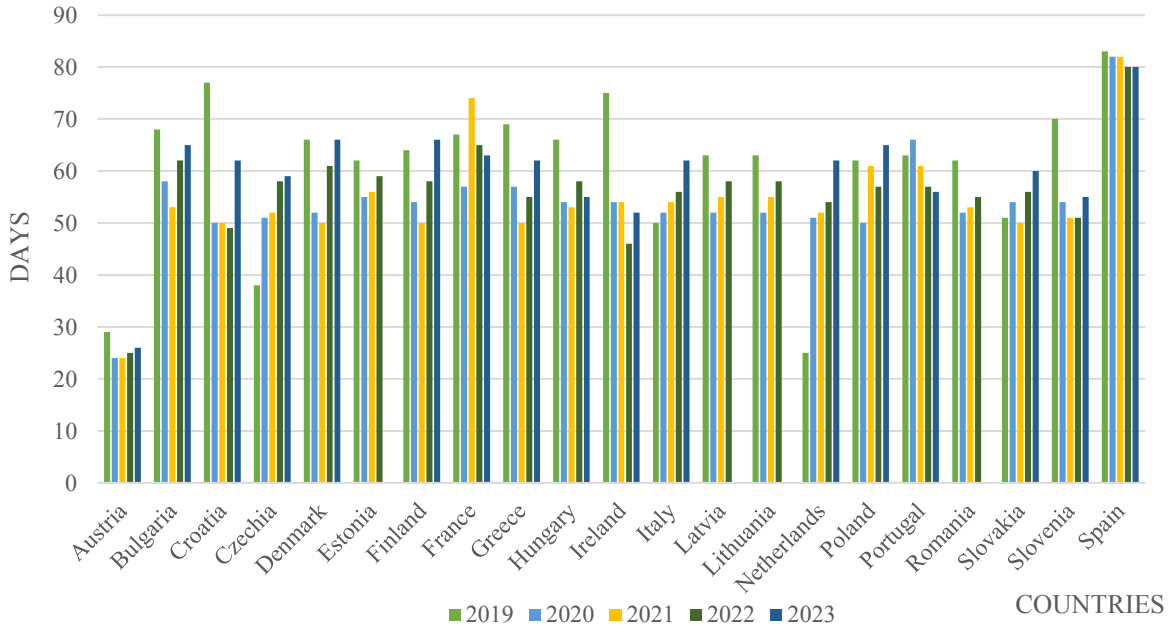

Figure 2. Average payment period in number of days in selected European countries, years 2019-2023, B2B.

Source: own elaboration based on EU Payment Observatory, 2024 Luxembourg: European Innovation Council and SMEs Executive Agency (EISMEA), Sector I-02-2 - Competitiveness and Internationalisation, Unit I-02 - SMP / SME Pillar, Internal Market and Support to Standardisation.

The data presented in the figure 2 show that average payment terms in EU countries are long. They are about 50 days. However, in some countries these deadlines exceed even 80 days (Spain), and in some entrepreneurs wait for payment for a short time (e.g. Austria – less than 30 days). In addition, worryingly, in almost all EU countries, payment terms increased in the last audited period, i.e. in 2022-2023. In Poland, it has increased from 57 to 65 days, in Greece from 55 to 62. This period has been slightly shortened only in France and Portugal

It needs to be clarified that each day of waiting for payment in business activity means crediting its contractor and incurring the costs of this financing by the seller/supplier. This, of course, has an impact on the situation of the company granting trade credit. It usually increases the company's operating costs and reduces the result of operations.

Statistics on delays in payment for commercial transactions are also worrying for entrepreneurs. Data for Polish and German countries are presented in Figure 3.

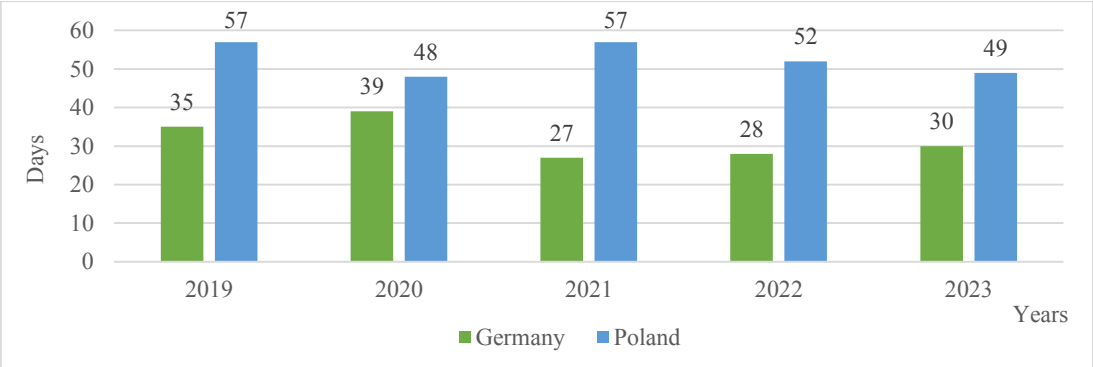

Figure 3. Average payment period in number of days in selected European countries, years 2019-2023, B2B.

Source: own elaboration based on EU Payment Observatory, 2024 Luxembourg: European Innovation Council and SMEs Executive Agency (EISMEA), Sector I-02-2 - Competitiveness and Internationalisation, Unit I-02 - SMP / SME Pillar, Internal Market and Support to Standardisation, Germany Corporate Payment Survey 2023: On the way back to the bad old time, https://www.coface.com/news-economy-and-insights/on-the-way-back-to-bad-old-times-in-2023-s-germany-payment-survey, 30.05.2025.

Figure 3 shows that the average time of late payment in Poland has been decreasing in the last three years and in 2023 it amounted to 49 days. In Germany, this period has been extended to 30 days in the same period. However, it is still shorter than in Poland. Delays in payment for goods and services are particularly difficult for entrepreneurs, because this deadline is unexpected by them and they usually have no impact on its length. Entrepreneurs set payment deadlines and they are usually the result of an agreement/consensus. Therefore, the entrepreneur has the opportunity to prepare to grant a loan to his contractor. Unfortunately, in the case of delays in payment, entrepreneurs are surprised by the lack of payment. This means that they are forced to look for financing themselves to pay their contractors.

The data presented in Figure 4 are also worrying.

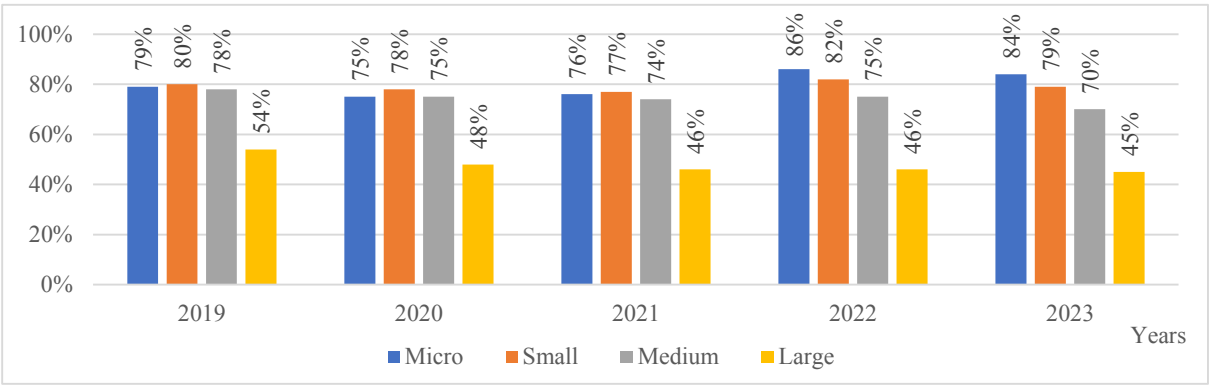

Figure 4. Average payment period in number of days in selected European countries, years 2019-2023, B2B.

Source: own elaboration based on EU Payment Observatory, 2024 Luxembourg: European Innovation Council and SMEs Executive Agency (EISMEA), Sector I-02-2 - Competitiveness and Internationalisation, Unit I-02 - SMP / SME Pillar.

Figure 4 shows that the greatest risk of late payments in Poland is linked with cooperation with large entrepreneurs, and the lowest with small and medium-sized enterprises. The presented chart clearly shows that, for example, in 2023, only 45% of large companies paid their liabilities resulting from commercial transactions on time, while at the same time, 84% of micro-entrepreneurs paid their liabilities in accordance with the contract. This creates a greater risk, because usually transactions made by large entrepreneurs are of higher values than those made with micro or small companies.

All these data confirm that it is necessary to support entrepreneurs in various fields to ensure that the effects of delays in payment of business activity are minimized.

4. Counteracting excessive delays in commercial transactions

In business practice and law, there are many instruments that limit losses related to late payments.

One of the best instruments to minimise the effects of excessive delays in payment and to counteract such delays are the provisions of the Act on Counteracting Excessive Delays in Commercial Transactions. This act introduces maximum payment terms in B2B transactions, stating that they cannot exceed 60 days. An exception to this rule is a situation in which the parties to the agreement have expressly agreed on a different deadline, and the creditor is not a micro-, small-, or medium-sized entrepreneur and setting a longer term is not grossly unfair to the creditor. The payment deadline in transactions in which the debtor is a public entity may not exceed 30 days. In addition, the Act introduces the principle that in each case of delay in payment of an invoice, the creditor who has fulfilled his obligation is entitled to statutory interest for delay in commercial transactions and, without a separate request, compensation for the recovery of receivables, which amounts to EUR 40 (transaction up to PLN 5,000), EUR 70 (transaction from PLN 5,000 to PLN 50,000), and EUR 100 (transaction over PLN 50,000). Unreliable debtors are therefore aware of the additional costs associated with failure to pay their liabilities on time. These costs will often exceed the value of a possible bank loan. The value of interest for delay in commercial transactions and compensation is therefore intended to encourage contractors to pay their liabilities on time.

Table 2 shows that the value of interest on liabilities in commercial transactions was constant in the years 2016-2017. This is similar in the case of statutory interest for late payment, which can be applied to any delay in payment. In Poland, there are no other legal regulations regarding interest on late payments to energy companies. However, they may introduce contractual interest in contracts, different from those provided for by the legislator. However, the condition for their introduction is the consent of the con-tractor. The list clearly shows that the amount of interest in commercial transactions is much higher than the statutory interest for

delay. This is a nod from the legislator to entrepreneurs who can apply this interest in settlements with unreliable debtors, but they do not have to. On the other hand, a significant increase in interest is noticeable in 2022–2023, when in Poland, according to the Central Statistical Office of Polish, the year-on-year price increase was greater than 18%.

Table 2.
Statutory interest for delay in commercial transactions (p.a.) in Poland

Period	Statutory Interest for Delay in Commercial Transactions p.a.	Statutory Interest for Delay p.a.
2016	9,50%	7%
2017	9,50%	7%
2018	9,50%	7%
2019	9,50%	7%
1 January–30 June 2020	11,50%	6%
30 June–31 December 2020	10,10%	5,6%
1 January–31 December 2021	10,10%	6%
1 January–30 June 2022	11,75%	7,75%
1.July–31 December 2022	16,00%	12,5%
2023	16,75%	11,5%
2024	15,75%	11,25%
2025	15,75%	10,75%

Source: own study.

The second instrument introduced in Polish legislation aimed at encouraging debtors to pay their liabilities on time are the provisions of the procedure before courts in civil cases. According to the wording of the Polish Code of Civil Procedure, the court will issue an order for payment in order for payment to proceed if the facts justifying the pursued claim are proven by a bill attached to the statement of claim accepted by the debtor, a request for payment by the debtor and a written statement of the debtor on the recogni-tion of the debt, and on the basis of an agreement attached to the statement of claim, proof of mutual non-monetary performance, proof of delivery of an invoice or bill to the debtor, and if the plaintiff seeks payment of a monetary benefit under the Act on Counteracting Excessive Delays in Commercial Transactions (Piaskowska, 2024; Zieliński, 2024). Such a prohibition on payment is a security and the creditor may seize a bank account, a claim, or establish a mortgage on its basis even before the final conclusion of the court dispute (Piaskowska, 2024; Manowska, 2022; Koecher, et al., 2015). This, in turn, will allow enforcement of the debt when the case is over.

5. Tax solutions

Another instrument that reduces the negative effects of late payment is the so-called bad debt relief, which is provided for in the Polish tax law. This instrument allows for the recovery of tax on unpaid revenue invoices. An entrepreneur can use this institution when he is a taxpayer of value added tax or income tax (PIT and CIT). The possibility of using these solutions is

provided for in the Goods and Services Tax (VAT) Act, the Corporate Income Tax Act and the Corporate Income Tax Act.

In the case of VAT, this relief consists in the possibility of adjusting the tax base and the tax due on the supply of goods or services in the case of receivables whose uncollectibility has been substantiated. The adjustment also applies to the tax base and the amount of tax attributable to the part of the amount of the receivable, the uncollectibility of which has been substantiated. The legislator has assumed that a bad debt is when it has not been settled or disposed of in any form within 90 days from the date of expiry of the payment deadline specified in the agreement or invoice. In order to take advantage of the relief, you must be a registered active VAT taxpayer and no more than 3 years have elapsed from the date of issue of the invoice documenting the receivable, counting from the end of the year in which it was issued. This relief allows you to recover VAT, for example. Unfortunately, in the event of non-payment, the principal amount will have to be applied to the court (Article 89a of the VAT Act).

The provisions of the VAT Act also provide for a domestic sanction for a debtor who has not paid the amount due under an invoice documenting the supply of goods or services in the territory of the country within 90 days from the date of expiry of the payment deadline specified in the contract or on the invoice. He is obliged to correct the deducted amount of tax resulting from this invoice in the settlement for the period in which the 90th day has elapsed from the date of expiry of the payment deadline specified in the agreement or in the invoice (Article 89b of the VAT Act).

In income taxes, the mechanism of the relief is very similar to that in VAT. However, it has minor differences. The creditor may reduce the tax base by the amount resulting from invoices (bills) and contracts that have not been paid for 90 days from the expiry of the payment deadline. However, here the relief is included in the annual tax return. In addition, the legislator requires that additional conditions be met jointly, i.e. the debtor as at the last day of the month preceding the month in which the tax return is filed, cannot be in the course of restructuring, bankruptcy or liquidation proceedings, and no more than 2 years have passed since the end of the calendar year in which the invoice was issued or the agreement was concluded. The debtor, on the other hand, if the creditor has taken advantage of the relief, is obliged to show the value of the relief as his income.

6. Joint enforcement of claims by creditors

Polish law also provides for two specific proceedings, i.e. bankruptcy and restructuring proceedings, which are aimed at joint enforcement of claims against an insolvent debtor, with the outcome of the proceedings being different. In the first case, the goal is to satisfy creditors in the best possible way and liquidate the debtor. On the other hand, restructuring

proceedings are aimed at avoiding the debtor's declaration of bankruptcy by enabling him to restructure by concluding an arrangement with creditors, and in the case of reorganization proceedings – also by carrying out remedial actions, while securing the legitimate rights of creditors (Article 3 of the Restructuring Proceedings Act).

Both laws currently cover insolvent entrepreneurs. On the other hand, the Restructuring Law may also be applied to entrepreneurs threatened with insolvency (Restructuring Law, Art. 1). It should be noted that solutions similar to those in Poland are regulated by the legislator of European countries and the law in force in the United States of America (Renssen, 2017, p. 20). The Act considers an entrepreneur to be insolvent who has lost the ability to pay his monetary obligations, whereby a debtor is presumed to have lost the ability to meet its monetary obligations due if the delay in payment exceeds three months. At a case of a debtor who is a legal person or an organizational unit without legal personality, which is granted legal capacity by a separate statute, is also insolvent if its financial liabilities exceed the value of its assets, and this state of affairs persists for a period exceeding twenty-four months.

First of all, it is worth noting that each creditor may file a petition for the debtor's bankruptcy or for its restructuring. Polish law has adopted the principle of the primacy of restructuring law. This means that if several applications for restructuring or bankruptcy of a given debtor are submitted, the possibility of restructuring will always be considered first. This means that Polish law gives debtors a chance to negotiate with creditors in order to determine the repayment of their liabilities in a multilateral manner. Only if such a possibility is not used by the parties, the bankruptcy procedure will be conducted.

Table 3 presents legal possibilities that can be used by entrepreneurs in the event of losing the ability to settle due liabilities or when there is a threat of such difficulties.

Table 3.
Types and objectives of proceedings concerning insolvent entrepreneurs

Bankruptcy proceedings	
May be carried out by insolvent entrepreneurs	**Objectives of the procedure**
	The proceedings should be conducted in such a way that the claims of creditors can be satisfied to the greatest extent possible and, if reasonable considerations allow, the debtor's existing business is preserved.
Restructuring proceedings	
may be carried out by entrepreneurs: – Insolvent, – Threatened with insolvency.	**General Purpose**
	Avoiding the debtor's bankruptcy by: 1. allowing it to restructure by concluding an arrangement with creditors, 2. and, in the case of sanation proceedings, also by carrying out remedial actions, securing the legitimate rights of creditors.
Types of restructuring proceedings	
Procedure for approval of the arrangement	1) enables the conclusion of an arrangement as a result of the debtor's own collection of creditors' votes without the participation of the court, 2) may be conducted if the sum of disputed claims entitling to vote on the arrangement does not exceed 15% of the sum of claims entitling to vote on the arrangement.

Cont. table 3.

Accelerated arrangement proceedings	1) enables the debtor to conclude an arrangement after the list of claims has been drawn up and approved in a simplified manner, 2) may be conducted if the sum of disputed claims entitling to vote on the arrangement does not exceed 15% of the sum of claims entitling to vote on the arrangement.
Arrangement proceedings	1) enables the debtor to conclude an arrangement after the list of claims has been drawn up and approved, 2) may be conducted if the sum of disputed claims entitling to vote on the arrangement exceeds 15% of the total amount of claims entitling to vote on the arrangement.
Remedial proceedings	It enables the debtor to carry out remedial actions and conclude an arrangement after the list of receivables has been prepared and approved. **Remedial actions** are legal and factual actions, which aim to improve the economic situation of the debtor and are aimed at restoring the debtor's ability to perform its obligations, while protecting it from enforcement.

Source: In-house analysis based on the Bankruptcy Law and the Restructuring Law.

Table 3 shows that both creditors and debtors in Poland have a choice between procedures concerning the principles of debt recovery/repayment of liabilities. All proceedings listed in the table are conducted under the control of the court with the participation of a specially appointed entity, i.e. a restructuring advisor, who supports debtors and creditors in conducting the proceedings. In some cases, he takes over the management of the debtor's assets, and in some cases supervises his activities.

Statistical data show that currently restructuring proceedings in Poland are constantly replacing bankruptcies in terms of numbers.

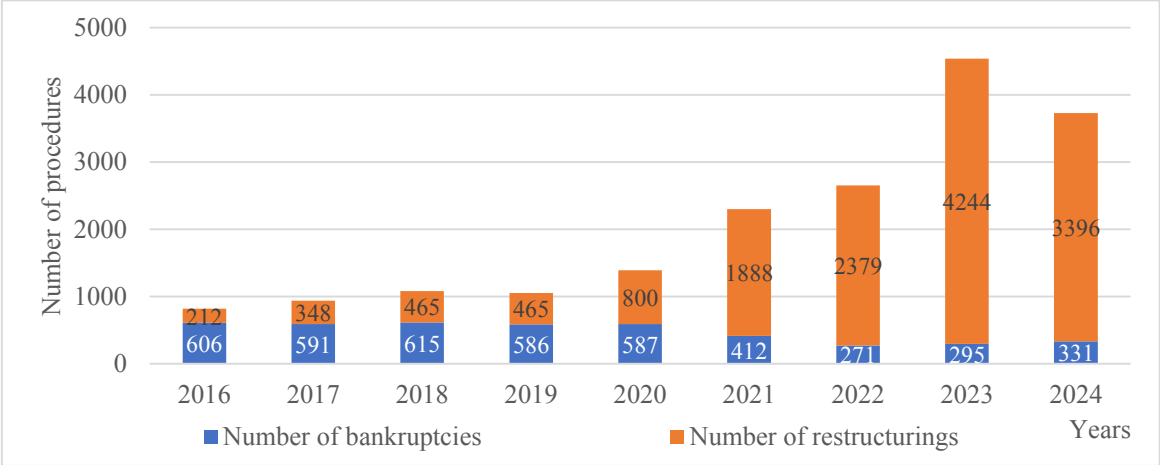

Figure 5. Number of initiated bankruptcies and restructurings in Poland in 2016-2024.

Source: own elaboration based on: https://www.coig.com.pl/2024-upadlosci-firm_wrzesien.php, 30.05.2025.

Figure 5 presents a collective number of initiated bankruptcy and restructuring proceedings. The list clearly shows that Polish entrepreneurs are facing financial problems, as the number of proceedings increased steadily in 2016-2023, with a slight decrease compared to the previous year in 2024. So far, the record year in terms of the number of restructuring proceedings was 2024, in which 4244 proceedings were initiated. The data also clearly show that restructuring proceedings are much more popular.

7. Pursuing claims before the court and securing receivables

Another instrument to support the creditor is specifically court procedures related to commercial proceedings regulated in the Polish Code of Civil Procedure, the court will issue an order for payment in order for payment to proceed if the facts justifying the pursued claim are proven by a bill attached to the statement of claim accepted by the debtor, a request for payment by the debtor and a written statement of the debtor on the recognition of the debt, and on the basis of an agreement attached to the statement of claim, proof of mutual non-monetary performance, proof of delivery of an invoice or bill to the debtor, and if the plaintiff seeks payment of a monetary benefit under the Act on Counteracting Excessive Delays in Commercial Transactions (Piaskowska, 2024). Such a prohibition on payment is a security and the creditor may seize a bank account, a claim, or establish a mortgage on its basis even before the final conclusion of the court dispute (Piaskowska, 2024; Manowska, 2022). This, in turn, will allow enforcement of the debt when the case is over.

In addition, in any case before a civil court in Poland, the creditor may demand security for his claim until the final conclusion of the proceedings. This is particularly important because court proceedings in Poland take a relatively long time. Data from the Ministry of Justice show a steady increase in the length of proceedings from a few months in 2011 to a dozen or so in 2023.

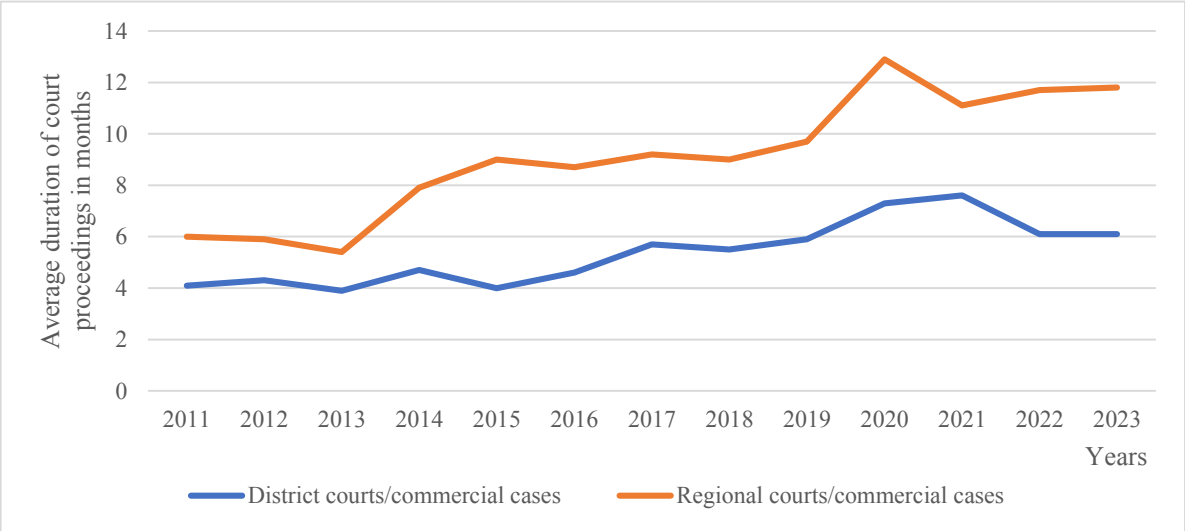

Figure 6. Average duration of court proceedings in months.

Source: own study based on data from the Ministry of Justice of the Republic of Poland.

The data presented in the figure 6 shows disturbing information for creditors that they wait longer for the resolution of their case from year to year. It is also worth noting that the presented data indicate the average duration of the proceedings. These data contain information on the duration of both simple proceedings such as the issuance of a payment order, as well as complex, long-term proceedings involving many witnesses and experts. In addition, the data

presents the duration of the investigation only before one instance. In the event of an appeal by the parties against the judgment, these periods are significantly extended, even up to several years or even longer.

These data confirm how important it is for the creditor to be able to secure its interests during the course of court proceedings, so that effective enforcement can be carried out after the dispute is over.

Polish law provides such instruments. As mentioned, in any civil case, including commercial one, security may be requested. The court establishes such injunctions, in justified cases, even before the commencement of the trial (filing of the lawsuit). Security may include, for example, attachment of the debtor's bank accounts, establishment of a mortgage, prohibition on the sale of a specific item, etc. The choice of the method of security depends on the creditor's choice and the court's decision.

It is also worth mentioning that there are economic information offices in Poland that collect information on unreliable debtors. Their activity will not guarantee the recovery of the receivables, but it may reduce the risk of concluding an agreement with an unreliable partner. These entities have the right to collect data on natural persons, including consumers and other entities that do not pay their due liabilities. The offices operate on the basis of the Act on the provision of economic information and exchange of economic data. Thanks to the provisions of this act, energy companies can enter their customers on the debtors' lists in these offices when the receivables are due, at least 30 days have passed from the date of sending the request to the debtor, and the debtor has not paid the debt within the deadline specified in the summons. In the case of consumers, an arrears of PLN 200 (approx. EUR 46) is sufficient, while in the case of entrepreneurs and other entities it is PLN 500 (ap-prox. EUR 116). Placing the debtor on such a list usually makes it difficult to obtain sources of financing (loans, credits, leasing, etc.). This is a significant impediment for the person/entity that finds itself there.

8. Conclusions

The research has shown that there is a risk of late payments in the European Union countries and in Poland. Payment terms are relatively long, and in addition, contractors do not pay their obligations on time. It leads to a deterioration of the economic situation of sellers/suppliers, because they are forced to credit their contractors. Despite the occurrence of these negative behaviours, there are instruments that in some cases compensate the entrepreneur for losses related to late payments. Such instruments are interest for delay in commercial transactions and the compensation for recovery of receivables due with them. In addition, entrepreneurs can report unreliable contractors to economic information offices, thanks to which unreliable debtors are eliminated from the market. In the case of a court dispute, which in Poland may last

several years, it is also possible to secure creditors' claims, so that the dishonest debtor does not get rid of his assets during court proceedings. All the instruments described in the article are used by entrepreneurs in the situation of overdue debt. It should therefore be emphasized that the proper fight against transaction risk begins from the moment of concluding the agreement with the client. At this stage, you can check the contractor, predict appropriate bakes and then use them. The instruments described in the article will be used only if none of the risk mitigation tools in the case of a specific counterparty has prevented the occurrence of arrears.

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SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

ANALYSIS OF THE ACCURACY OF SELECTED TECHNICAL INDICATORS ON THE EXAMPLE OF INVESTMENTS IN AMERICAN SECTORAL ETF FUNDS IN THE YEARS 1998-2025 FOR THE DAILY INTERVAL

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Purpose: This study evaluates the effectiveness of technical analysis indicators compared to a buy-and-hold strategy for US sector ETFs from 1998 to 2025 using a daily timeframe. It also investigates the relationship between trade frequency and achieved returns.
Design/methodology/approach: The research examines five technical indicators—Relative Strength Index (RSI), Commodity Channel Index (CCI), Williams Percent Range (W%R), DeMarker (DM), and Stochastic Oscillator—applied to 11 ETFs tracking major US industry indices. Two hypotheses were tested: H1, that technical strategies yield higher average annual returns than buy-and-hold, and H2, that trade frequency strongly correlates with returns. Daily closing prices were analyzed, with statistical significance assessed via one-way ANOVA and normality tested using the Shapiro-Wilk test with Lilliefors correction. Spearman's rank correlation coefficient was used to evaluate trade frequency and returns.
Findings: The Stochastic Oscillator outperformed buy-and-hold in 45.45% of cases, achieving a 6.29% average annual return compared to 6.01% for buy-and-hold. RSI yielded the lowest returns at 2.46%. A moderate correlation (Spearman's coefficient 0.42) was found between trade frequency and returns, rejecting H2.
Research limitations/implications: Limitations include shorter data periods for XLC and XLRE funds and limited high-frequency data availability. Future research could explore lower timeframes or alternative indicators.
Practical implications: Stochastic Oscillator-based strategies may enhance returns in specific sectors, offering actionable insights for investors.
Originality/value: This study addresses a research gap by combining multiple technical indicators for sector-specific ETF trading, challenging efficient market theory assumptions.
Keywords: ETFs, technical analysis, Stochastic Oscillator, buy-and-hold, sector investing.
Category of the paper: Research paper.

1. Introduction

In recent years, passive ETFs (Exchange-Traded Funds) have gained popularity, mainly due to their high level of diversification and the ability to directly invest in instruments that track the performance of a stock market index (Madhavan, 2017). Compared to actively managed funds, ETFs, in addition to their broad diversification capabilities, are also characterized by low operating costs, which translates into lower fees for investors than in the case of traditional funds, and higher liquidity, because, unlike actively managed funds, they are not valued only once a day (Mitrenga, 2013). The above-mentioned features confirm that ETFs are generally considered instruments worth investing in for the long term (Mazumder, 2014). Therefore, determining the best timing to start and end an investment seems important from the perspective of both researchers and investors.

Technical analysis indicators are tools commonly used in many markets to determine investment entry and exit points. The purpose of these indicators is to predict price movements based on historical patterns and trends (Sokolov Germanov, 2023). Previous research indicates that these indicators are also applicable to the ETF market. For example, strategies based on the RSI indicator achieved accuracy exceeding 80% and enabled annual returns close to 24%, while strategies combining various indicators and machine learning methods achieved accuracy of 75-83.6% (Özbayoğlu, Umur Erkut, 2010). In contrast, simple strategies based on moving averages generated accuracy of approximately 54% (Bollapragada, Savin, Kerbache, 2013). Research also indicates that moving averages and the MACD, along with momentum used as a volatility filter, can generate returns as much as 79% higher than the buy-and-hold strategy (Cohen, 2020). These results suggest that strategies based on technical analysis can also provide profitable trading signals in the ETF market (Metghalchi, Cloninger, Niroomand 2023). It is worth noting, however, that most of existing research focuses on ETFs that represent broad markets, not individual industries, and technical indicators have been most often used individually. Therefore, there is a lack of clear evidence demonstrating the validity of strategies based on a combination of technical indicators, especially in relation to individual industries. This represents a significant research gap, which, if filled, could expand knowledge about the practical application of technical analysis in ETF investments.

The aim of the study is to determine whether selected technical analysis indicators yield higher rates of return than a buy-and-hold strategy, and whether the number of trades executed by investors is related to the resulting rates of return. The study was conducted using ETFs that track the performance of major US industry indices based on the daily timeframe, commonly used in long-term investments. Therefore, the following research hypotheses were tested:

- **H_1**: The use of investment strategies based on technical analysis indicators allows for obtaining higher average annual rates of return than the use of the "buy and hold" strategy in the case of sector ETFs on the US market for the daily timeframe.

– **H_2**: There is a strong relationship between the number of trades and the returns obtained from investing in US sector ETFs using technical indicator strategies in the daily time frame.

The proposed research problem is situated within the context of three important economic theories:

– efficient markets theory – by analyzing whether technical strategies can outperform the passive approach postulated by this concept (Fama, 1970),
– portfolio theory – through the subject of research, which is highly diversified ETF funds, and in the context of searching for strategies that can improve portfolio efficiency (Markowitz, 1952),
– the theory of adaptive markets – which assumes that market efficiency changes over time depending on conditions and the adaptation of participants – by examining whether technical strategies can be more effective in specific market conditions, e.g., for a specific sector (Lo, 2004).

The article consists of six parts. The introduction outlines the context of the study, identifies the research gap, and defines the objective and hypothesis. The second part provides a literature review on the accuracy of technical oscillators as a basis for investment decision-making. The third part describes the research methodology and assumptions. The fourth part presents the results obtained in the study. The fifth part contains conclusions, a discussion of the results of other studies, a description of the research limitations, and suggestions for future research directions. The final part provides information on the funding sources for the article.

2. Review on the accuracy of technical oscillators as a basis for making investment decisions.

A review of the literature concerning the accuracy or effectiveness of technical oscillators indicates significant variability in results, which depends both on the type of instruments analyzed and on the adopted research methodology. The studies can be divided into groups encompassing strategies integrating oscillators with machine learning models, classical oscillators applied to indices and ETFs of developed markets, analyses of domestic indices, as well as simplified binary systems and low-frequency investment strategies. Such a division allows for comparison of results, identification of conditions for the effectiveness of particular tools, and presentation of the conclusions formulated so far regarding the use of oscillators in different market contexts.

Deep, A., Shirvani, A., Monico, C., Rachev, S., and Fabozzi, F.J. (2025) conducted research on the use of machine learning in price forecasting in financial markets. The authors focused on the integration of classical technical indicators with Random Forest Regression (RFR)

models in the context of high-frequency trading. The subject of analysis was minute-level data for the SPY ETF, a highly liquid instrument reflecting the performance of the S&P 500 index. The aim of the study was to assess whether the addition of technical indicators, such as the RSI oscillator, Bollinger Bands, EMA moving averages, or Fibonacci retracements, could increase the effectiveness of price forecasts and improve the risk–return trade-off under conditions of elevated market volatility. Methodologically, the study relied on comparative analysis of RFR model results with different sets of input variables. The authors performed a feature importance analysis, juxtaposing basic price data (opening, high, low, closing prices) with technical indicators. In addition, advanced measures of investment strategy performance evaluation were introduced, such as the Rachev ratio or the profit–loss ratio, which allowed for a more comprehensive assessment of model quality than using returns alone. The key benchmark was a buy-and-hold strategy. The results indicated that classical technical indicators had limited predictive value, and that raw price data played the most important role in forecasts. Although models enhanced with indicators achieved better risk-adjusted performance measures (with Rachev ratios ranging from 0.919 to 0.961), they consistently underperformed compared to the simple buy-and-hold strategy, generating returns in the range of -2.4% to -3.9%. The authors emphasized that the findings are consistent with the weak form of the efficient market hypothesis, since the applied models were not able to consistently generate abnormal returns.

Similar research was conducted by Macchiarulo, A. (2018), who attempted to compare the effectiveness of methods based on machine learning and technical analysis in the context of predicting stock market movements and generating excess returns. The analysis was based on historical data covering the period from January 1995 to December 2005, which were used to train machine learning models such as neural networks and support vector machines (SVM). These forecasts were then applied in investment strategies from January 2006 to December 2016, during which their effectiveness was tested in real market conditions. The analysis was referenced against the performance of the SPDR S&P 500 ETF, which served as a benchmark. The study made extensive use of various statistical tools, including paired-sample t-tests, which were used to assess whether the results obtained with machine learning methods differed significantly from those achieved with traditional technical analysis indicators, such as moving averages or oscillators. Particular attention was paid to market conditions, as the study covered both bull and bear markets, allowing for assessment of the resilience and adaptability of the applied methods in different phases of the business cycle. The results indicate that, in the analyzed period, the machine learning model achieved a higher average monthly return (1.19%) compared to the average return of the S&P 500 index (0.48%). Particularly noteworthy is the observation that among technical indicators, oscillators played a key role. For example, indicators such as the parabolic SAR or the Rate of Change (ROC) showed high effectiveness in predicting trend reversals and generating trading signals. These findings suggest that integrating oscillators with machine learning models can significantly enhance the effectiveness of predictive systems and trading strategies, supporting investors in achieving better returns at an acceptable level of risk.

Other studies focusing exclusively on classical oscillators analyzed their effectiveness compared to a buy-and-hold strategy in international markets. Cohen, G. and Cabiri, E. (2015) compared the performance of a buy-and-hold strategy with results obtained from applying selected, popular oscillators of technical analysis to various indices representing key global markets—DJI, FTSE100, Nikkei 225, and TA100—over the period 2007-2012. The aim of the analysis was to determine whether technical analysis tools are able to systematically generate higher returns than a buy-and-hold strategy under different market conditions. The results indicate that among the analyzed oscillators, the Relative Strength Index (RSI) achieved the best results, outperforming returns from the DJIA, FTSE100, and Nikkei 225 indices in five out of six years studied. The only exception was the Israeli TA100 index, which proved to be more effective than all analyzed oscillators, including RSI. The second-best performer was the MACD (Moving Average Convergence/Divergence) oscillator, which outperformed the buy-and-hold strategy for the Nikkei 225 index and ranked second relative to TA100. The analysis also showed that in bear market conditions, the RSI and MACD oscillators generally performed better than passive strategies, whereas in bull markets their effectiveness was lower compared to buy-and-hold.

In a subsequent study, Cohen, G. (2020) conducted a detailed analysis of the effectiveness of popular technical oscillators in ETF trading, covering the period 1999-2018. The author examined whether standard settings of these tools, as well as their modifications and combinations, could outperform the buy-and-hold strategy. To this end, daily data were used for six of the most popular U.S. ETFs, including SPY, QQQ, IWM, XLF, XLK, and XLI. The methodology relied on programmatic implementation of oscillators such as RSI, Stochastics, MACD, CCI, CMF, and Bollinger Bands. After initially applying the settings recommended by their creators, the author modified and optimized them to maximize the profit ratio—the ratio of gross profit to gross loss. In addition, the study tested combinations of various oscillators to determine whether their combination could improve results. The results showed that the most effective tools were the CCI and Bollinger Bands, with CCI performing better on more volatile ETFs (XLF and XLK), while Bollinger Bands were more effective on less volatile funds such as IWM and XLI. A particularly favorable outcome was obtained for the strategy combining RSI and Chaikin Money Flow, which generated positive returns in all analyzed ETFs and significantly outperformed the buy-and-hold strategy by as much as 79% in the case of ETF XLF. Importantly, none of the tested tools outperformed the buy-and-hold strategy in the case of ETF QQQ. The study confirms that certain technical solutions can improve results in ETF trading, although their effectiveness varies depending on the characteristics of the instrument and market conditions. As the author emphasized, the findings may have significant implications for traders using algorithmic strategies based on technical oscillators, highlighting the necessity of adjusting settings and tools to the specificity of a given ETF and market.

At the same time, research by Trembiński, M. and Stawska, J. (2021) showed that in European conditions, oscillators and indicator-based trading systems can also outperform passive strategies, provided that parameters are properly selected. The authors conducted a study aimed at evaluating the effectiveness of trading systems based on technical analysis tools on the German DAX index in the years 2015-2020. The analysis included six different strategies based on indicators and oscillators such as moving averages, ADX, MACD, Parabolic SAR, RSI, Bollinger Bands, Ichimoku Kinko Hyo, Donchian Channel, CCI, and Keltner Channel. All trades were executed on the Meta Trader 4 platform, and the strategy was evaluated using portfolio performance measures such as the Sharpe ratio and the Managed Account Ratio (MAR). The study compared the effectiveness of the selected trading systems with a passive buy-and-hold strategy, i.e., long-term passive investing. The results showed that most of the analyzed systems achieved positive returns, and their effectiveness largely depended on the appropriate selection of indicator and oscillator parameters. It turned out that four out of six tested strategies were more effective than the passive strategy already by the end of 2019, and by the end of the first quarter of 2020 all strategies had shown an advantage. Furthermore, the study confirmed that technical analysis tools can be useful in investment practice, enabling not only profit generation but also loss limitation during unfavorable market periods. The findings suggest that although the effectiveness of systems based on technical analysis depends on proper parameter selection and strategy choice, their use can significantly improve investment results compared to passive investing. At the same time, the authors emphasized that further optimization and development of indicator parameters can further increase the effectiveness of these systems.

Naved, M. and Srivastava, P. (2015), in turn, conducted a study aimed at evaluating the effectiveness of three of the most popular oscillators used in technical analysis on the financial market, namely: the Stochastic Oscillator, RSI (Relative Strength Index), and Commodity Channel Index (CCI). The analysis covered the period from 2004 to 2014 and focused on the S&P CNX Nifty 50 index, representing the Indian stock market. The study applied various methods of testing trading strategies based on signals generated by the selected oscillators. The results indicate that among the considered oscillators, the CCI demonstrated the highest profitability in the analyzed period. The CCI-based strategy generated 7012 profit points, which was 9.52% higher than the buy-and-hold strategy in the same period. The strategy produced a total of 182 trades, of which 88 were profitable and 94 unprofitable, resulting in an accuracy rate of 48.35%. Importantly, the study analyzed time horizons ranging from 7 to 21 days, enabling a detailed assessment of indicator performance in different time configurations. For CCI, the 21-day period proved to be the most beneficial, with higher profits than other oscillators. The study therefore shows that the appropriate selection of technical indicator parameters—in this case, the CCI period length—can significantly affect the effectiveness of investment strategies.

The work of Jiménez-Preciado, A.L., Cruz-Aké, S., and Santillán-Salgado, R.J. (2021) shows that even simple binary systems using selected oscillators can provide an advantage over passive strategies under different market conditions. The authors developed a binary trading system intended for algorithmic trading in a low-frequency environment. To identify buy and sell signals, two popular technical analysis indicators were applied: Bollinger Bands and Williams Percent Range. The constructed model was then empirically verified, and its results were compared with a buy-and-hold strategy serving as the benchmark. The aim of the study was to demonstrate that the developed system can generate profits even in conditions of a downward trend and high volatility, as well as after accounting for brokerage commissions. The study was conducted for three ETFs: SPY (SPDR S&P500), DUST (Direxion Daily Gold Miners Index Bear 2x Shares), and EDZ (Emerging Markets Direxion Daily MSCI Emerging Markets Bear 3X Shares). The idea of using ETFs was to reflect stock market results of different economic sectors (including indices, metals, and emerging markets in this case). The data covered the period from January 2018 to March 2020, including two training years and the first quarter of 2020, when high market volatility was observed due to the COVID-19 pandemic and falling oil prices. The results indicate that this system made it possible to achieve positive returns, even under conditions of sharp market declines. Importantly, after accounting for brokerage commissions (on average 0.25%), the system still showed higher returns than holding ETF units. The study confirms that the use of Bollinger Bands and Williams Percent Range in a binary system can improve investment performance, reducing potential losses and generating profits under various market conditions. As the authors emphasized, these results are relevant for investors and traders seeking effective methods of analysis and automation of investment decisions in stock and ETF markets.

Attention should also be paid to the study by Paik, C.K., Choi, J., and Vaquero, I.U. (2024). This study aimed to examine whether it is possible to achieve above-average investment results without the need for complex analytical tools, dynamic portfolio rebalancing, or advanced technological infrastructure required by high-frequency trading strategies. Within the framework of the study, the DeepSignal algorithm was developed, based on two technical oscillators - the stochastic oscillator and the Williams Percent Range - and applied to tests on two ETFs: SPY, reflecting the S&P 500 index (a developed market), and EWY, tracking the MSCI Korea index (an emerging market). The authors did not apply portfolio rebalancing, limiting the number of trades to an average of one per month, which allowed for significant reduction of operating costs. The simulation results showed that even with such a simplified approach, the strategy delivered stable and clearly better performance than the buy-and-hold strategy, with a very low maximum drawdown (–1.0%) and a high signal accuracy rate. The authors argue that this approach not only allows effective responses to market volatility but also constitutes a real alternative for investors seeking simple, low-cost, and effective investment solutions. The study also makes an important methodological contribution to the literature, highlighting the potential of simple technical signals in long-term asset allocation in the ETF market.

The literature analysis indicates that the effectiveness of technical oscillators compared to the buy-and-hold strategy is varied and largely dependent on the characteristics of the instrument, market volatility, the adopted time horizon, and indicator parameters. Despite the lack of conclusive empirical evidence confirming the systematic superiority of technical oscillators over passive strategies, they remain an important component of technical analysis, supporting the investment decision-making process.

3. Research methodology and assumptions

The research was conducted based on data from December 23, 1998, to June 30, 2025, except for the XLC and XLRE funds, which were established later. For the XLC fund, the beginning of the research period was June 20, 2018, and for the XLRE fund, October 9, 2015. The beginning of the research period was determined by the beginning of each fund's market listing. The research period ended at the end of the last full month preceding the commencement of the analysis. Daily closing prices were used for the study, as they are most commonly used in long-term investments and have the greatest informative value. The study included eleven ETFs representing major industries. Each fund reflects the performance of companies from a specific sector within the S&P 500 index, enabling the analysis of diverse sector conditions. Most of the selected funds have been listed since the late 1990s, allowing for a long-term analysis. The parameters of each fund are presented in Table 1.

Table 1.
Parameters of ETF funds selected for the study

ETF fund name	ETF ticker	Industry	Beginning of the research period	End of the research period
Materials Select Sector SPDR Fund	XLB	Raw materials and supplies	1998-12-23	2025-06-30
Communication Services Select Sector SPDR Fund	XLC	Telecommunication	2018-06-20	2025-06-30
Energy Select Sector SPDR Fund	XLE	Power engineering	1998-12-23	2025-06-30
Financial Select Sector SPDR Fund	XLF	Finances	1998-12-23	2025-06-30
Industrial Select Sector SPDR Fund	XLI	Industry	1998-12-23	2025-06-30
Technology Select Sector SPDR Fund	XLK	Information technologies	1998-12-23	2025-06-30
Consumer Staples Select Sector SPDR Fund	XLP	Basic consumer products	1998-12-23	2025-06-30
Real Estate Select Sector SPDR Fund	XLRE	Real estate	2015-10-09	2025-06-30
Utilities Select Sector SPDR Fund	XLU	Utility supply	1998-12-23	2025-06-30
Health Care Select Sector SPDR Fund	XLV	Health care	1998-12-23	2025-06-30
Consumer Discretionary Select Sector SPDR Fund	XLY	Discretionary consumer products	1998-12-23	2025-06-30

Source: own study.

The analysis used oscillators frequently used by investors, i.e., indicators allowing the identification of oversold and overbought levels (Brown, 1999), such as: Relative Strength Index (RSI), Commodity Channel Index (CCI), Williams Percent Range (W%R), DE Marker (DM) and Stochastic Oscillator (ST).

The Relative Strength Index is an indicator developed by Welles Wilder that compares the upward and downward movements of closing prices over a given period (Wilder, 1978) – see formula 1.

$$RSI = 100 - \frac{100}{1+RS} \text{Where} RS = \left(\frac{a}{b}\right) \quad (1)$$

where:
a – average value of the closing price increase for the analyzed period,
b – average value of the closing price decline in the analyzed period.

The indicator ranges from 0 to 100. Values above 70 (and above 80 in the conservative variant) indicate an overbought market and are a signal to open a short position or close a long position. Values below 30 (below 20 in the conservative variant) indicate an oversold market and are a signal to open a long position or close a short position (Panerai, Vachhani, Chaudhury, 2021).

The Commodity Channel Index is an indicator developed by Donald Lambert that measures the difference between the current and average prices for a given period (Lambert, 1983) – see formula 2.

$$CCI = \frac{1}{0{,}015} * \frac{CT - SMA(CT)}{\sigma(CT)} \text{Where} CT = \frac{C_{max} + C_{min} + C_z}{3} \quad (2)$$

where:
CT – typical rate,
C_{max} – maximum rate,
C_{min} – minimum rate,
C_z – closing price,
SMA – simple moving average,
σ – mean standard deviation.

The CCI does not have a strict range. Values below -100 indicate oversold conditions and are a signal to take a long position or close short, while values above 100 suggest overbought conditions, which are a signal to take a short position or close long (Maitah et al., 2016).

The Williams Percent Range (W%R) is an indicator developed by Larry Williams. The W%R is derived by dividing the current closing price by the high over n periods by the low over n periods. This result is then multiplied by 100 (Williams, 1979). The W%R is calculated using Formula 3.

$$\%R = \frac{C_z - C_{max}}{C_{max} - C_{min}} * 100 \tag{3}$$

where:
C_z – current closing rate,
C_{max} – maximum rate from n periods,
C_{min} – minimum rate from n periods.

The Williams Percent Range oscillator ranges from -100 to 0. Values close to -100 indicate an oversold zone, while values close to 0 indicate an overbought zone. A buy signal is generated when the oscillator reaches values below -80, while a sell signal is generated when they are above -20 (Williams, 1979).

DeMarker (DM), an indicator developed by Tom DeMark, compares periods in which maximum prices are reached with a selected period (DeMark, 1994) – see formula 4.

$$DeM = \frac{SMA\ (DeMax,O)}{SMA\ (DeMax,O)+SMA\ (DeMin,O)}\text{; where}$$
$$DeMax = H\ (i) - H\ (i-1)\text{if}\ H\ (i) > H\ (i-1)\text{or}$$
$$DeMax = 0\text{; if}\ H\ (i) =< H\ (i-1) \tag{14}$$
$$\text{DeMin} = \text{L (i} - 1) - \text{L (i)}\textbf{if}\text{L (i)} < \text{L (i} - 1),$$
$$\text{DeMin} = 0\textbf{if}\text{L (i)} >= \text{L (i} - 1)$$

where:
H(i) – maximum rate of the current period,
L(i) – minimum rate of the current period,
H(i – 1) – maximum rate of the previous period,
L(i – 1) – minimum rate of the previous period,
SMA – simple moving average,
O – number of periods for which the indicator value was calculated.

The oscillator ranges from 0 to 1. Values above 0.7 indicate an overbought market and signal a short or close a long position. Values below 0.3 indicate an oversold market and signal a long or close a short position (Lane, 1984).

The Stochastic Oscillator, developed by George Lane, consists of two lines: %K and %D. The %K line is the main oscillator line, and the %D line is a three-period moving average of the %K line (Lane, 1984). The method for calculating the %K line of the stochastic oscillator is presented in Formula 5.

$$ST = \frac{C_z - C_{min}}{C_{max} - C_{min}} * 100 \tag{5}$$

where:
C_z – current closing rate,
C_{max} – maximum rate from n periods,
C_{min} – minimum rate from n periods.

Both the %K and %D lines take values from 0 to 100. Values of the %K lines above 0.9 indicate an overbought market and are a signal to open a short position or close a long position. Values below 0.1 indicate an oversold market and are a signal to open a long position or close a short position (Damayanti, 2020).

The study was conducted using the time series analysis method, and the statistical significance of the obtained results was confirmed using one-way ANOVA analysis, and the normality of the distributions of return rates and the annual number of transactions was checked using the Shapiro-Wilk test with Lilliefors correction, which is designed for time series with small sample sizes (Öztuna et al., 2006). The research procedure consisted of the following stages:

1. Obtaining daily closing prices for individual ETF funds from www.investing.com (Investing, 24.07.2025) and processing them in the indicated research periods.
2. Calculation of the values of individual oscillators for each fund in the adopted research periods.
3. Determining overbought and oversold zones in accordance with the methodology for calculating individual indicators and determining transaction signals.
4. Simulations of buy and sell transactions in ETF shares were conducted based on signals generated by individual indicators. If a buy signal was not followed by a sell signal by the end of the research period, the transaction was closed on the last trading day.
5. Calculation of rates of return for the "buy and hold" strategy and for a strategy that includes the purchase and sale of shares in individual funds, and a cross-sectional analysis of the results obtained.
6. To examine the relationship between the average annual number of transactions using individual oscillators and the average annual rates of return for each fund, the Spearman rank correlation coefficient was chosen for the analysis, as the hypothesis of normality in the distribution of the average annual number of transactions was rejected.
7. Conducting statistical tests using one-way ANOVA analysis to confirm which of the obtained results are statistically significant.

Overall, the study analyzed daily closing prices of 11 sector ETFs from 1998 to 2025 (with shorter periods for XLC and XLRE). Popular oscillators (RSI, CCI, W%R, DM, ST) were used to generate buy and sell signals, and results were compared with a buy-and-hold strategy. Simulated trades, rate of returns, and the relationship between trading frequency and performance (Spearman correlation) were examined. Statistical significance was assessed with one-way ANOVA, and normality was tested using the Shapiro–Wilk test with Lilliefors correction.

4. Research results

The rates of return obtained using the classic “buy and hold” strategy and strategies using technical indicators are presented in Table 2.

Table 2.
Comparison of rates of return achieved using buy-and-hold strategies and strategies using technical indicators

ETF ticker	Buy and hold	RSI (20/80)	CCI (-100/100)	W%R (-100/0)	DM (0.3/0.7)	ST (10/90)
XLB	5.53%	2.76%	5.37%	6.64%	4.46%	8.88%
XLC	10.21%	-2.33%	7.60%	5.90%	3.98%	6.44%
XLE	5.03%	6.41%	4.61%	4.61%	4.77%	6.83%
XLF	3.85%	0.39%	7.27%	3.02%	2.36%	5.13%
XLI	7.14%	1.78%	6.17%	5.64%	4.42%	6.17%
XLK	8.01%	0.91%	4.94%	2.64%	2.29%	4.74%
XLP	4.21%	3.91%	2.91%	4.29%	3.67%	4.27%
XLRE	3.32%	2.57%	4.85%	2.22%	5.04%	5.72%
XLU	3.89%	5.24%	3.53%	2.92%	1.51%	4.89%
XLV	6.49%	3.88%	5.80%	5.07%	1.34%	7.53%
XLY	8.40%	1.51%	5.96%	3.34%	5.25%	8.56%
Mean	**6.01%**	**2.46%**	**5.36%**	**4.21%**	**3.55%**	**6.29%**
the lowest rate of return for the examined fund				the highest rate of return for the examined fund		

Source: own study.

The "buy and hold" strategy produced the highest rates of return for three of the eleven ETFs examined (27.27% of the total). The strategy based on the stochastic oscillator as a signal indicator demonstrated the highest accuracy, generating the highest rates of return in five of the eleven cases (45.45%). The strategy using the stochastic oscillator also generated the highest average rate of return (6.29%), which exceeded the rate achieved by the "buy and hold" strategy by 0.29 percentage points. The strategy using signals generated by the RSI indicator achieved the worst returns. In over half of the cases (54.54%), this strategy generated the lowest rates of return, with the average annual rate of return being just 2.46% (a whopping 3.55 percentage points lower) than the "buy and hold" strategy. In the case of the XLC fund, it even generated a negative result (-2.33%), which may indicate the limited usefulness of this indicator in the analyzed period or its inadequacy to the specific nature of the given sector. The results indicate that for most indicators, the rates of return were lower than for a "buy and hold" strategy. Using the example of a strategy based on the stochastic oscillator, it is worth noting that properly constructed technical strategies can outperform traditional passive approaches in terms of generated returns.

To provide a more comprehensive comparison of rate of returns, we calculated average rates of return obtained by using technical indicators as a signal source, highlighting the differences between the two approaches. A comparison of rates of return obtained by using the "buy and hold" strategy and average rates of return for technical strategies is presented in Table 3.

Table 3.
Comparison of Buy-and-Hold Returns and Average Returns for Technical Strategies

ETF ticker	Buy and hold	Technical indicators	Difference [in pp]	Higher rate of return
XLB	5.53%	8.88%	3.35 pp	Technical indicators
XLC	10.21%	4.65%	5.55 pp	Buy and hold
XLE	5.03%	5.56%	0.53 pp	Technical indicators
XLF	3.85%	4.32%	0.47 pp	Technical indicators
XLI	7.14%	5.13%	2.01 pp	Buy and hold
XLK	8.01%	3.39%	4.62 pp	Buy and hold
XLP	4.21%	3.84%	0.37 pp	Buy and hold
XLRE	3.32%	4.16%	0.85 pp	Technical indicators
XLU	3.89%	3.84%	0.05 pp	Buy and hold
XLV	6.49%	5.20%	1.29 pp	Buy and hold
XLY	8.40%	5.60%	2.80 pp	Buy and hold
Mean	**6.01%**	**4.96%**	**1.05 pp**	**Buy and hold**
lower rate of return for the examined fund			higher rate of return for the examined fund	

Source: own study.

According to the above table, the "buy and hold" strategy generated higher rates of return than technical strategies in seven cases (63.63% of the total). The average rate of return for the passive strategy was 6.01%, while the average for technical strategies reached 4.96%, representing a 1.05 percentage point advantage in favor of the "buy and hold" approach. In particular, the rates of return for the XLC, XLK, XLI, and XLY funds proved significantly higher for this strategy, with differences ranging from 2.01 percentage points to 5.55 percentage points. Funds representing the information technology (XLK), communications (XLC), and consumer goods (XLY) sectors demonstrated a clear advantage for the passive strategy, which may indicate greater stability and long-term growth potential for these sectors. Funds representing the raw materials and real estate sectors (XLB, XLRE) responded better to technical signals. The higher accuracy of the buy-and-hold strategy in most cases may be due to its ability to capitalize on long-term uptrends, while technical strategies may be more susceptible to false signals in conditions of increased volatility – see Figure 1.

Figure 1. Comparison of the volatility of XLB and XLK funds.

Source: own study.

Two funds were selected for comparison, where the passive approach was most dominant (XLK – a 4.62 percentage point surplus) and technical strategies (XLB – a 3.35 percentage point higher rate of return). The XLC fund was excluded from the comparison because it was only listed in 2018.

Given the varying accuracy of technical strategies, it is also reasonable to examine whether the number of transactions may be a factor in determining rates of return. Table 4 presents the number of open and closed transactions executed within each technical strategy.

Table 4.

Number of transactions executed within individual technical strategies

ETF ticker	RSI (20/80)	CCI (-100/100)	W%R (-100/0)	DM (0.3/0.7)	ST (10/90)
XLB	27	182	190	93	102
XLC	6	44	42	21	29
XLE	28	179	177	87	96
XLF	23	179	183	86	89
XLI	27	177	180	81	104
XLK	22	174	165	77	97
XLP	23	165	179	80	91
XLRE	10	68	68	35	32
XLU	29	179	170	78	79
XLV	26	176	177	82	93
XLY	20	184	171	77	104
Mean	**21.91**	**155.18**	**154.73**	**72.45**	**83.27**

Source: own study.

The number of transactions for individual technical strategies varies, but it's worth noting that the lowest values for the XLC and XLRE funds result from their shorter research period. To maintain data comparability, the average annual number of transactions was calculated for each of the indicators studied – see Table 5.

Table 5.
Average annual number of transactions executed within individual technical strategies

ETF fund	RSI (20/80)	CCI (-100/100)	W%R (-100/0)	DM (0.3/0.7)	ST (10/90)
XLB	1.02	6.86	7.16	3.51	3.85
XLC	0.85	6.26	5.97	2.99	4.12
XLE	1.06	6.75	6.67	3.28	3.62
XLF	0.87	6.75	6.90	3.24	3.36
XLI	1.02	6.67	6.79	3.05	3.92
XLK	0.83	6.56	6.22	2.90	3.66
XLP	0.87	6.22	6.75	3.02	3.43
XLRE	1.03	6.99	6.99	3.60	3.29
XLU	1.09	6.75	6.41	2.94	2.98
XLV	0.98	6.64	6.67	3.09	3.51
XLY	0.75	6.94	6.45	2.90	3.92
Mean	**0.94**	**6.67**	**6.64**	**3.14**	**3.60**

Source: own study.

Of the five technical indicators analyzed, three groups can be distinguished: those with a high number of signals (CCI – 6.67 and W%R – 6.64), moderate ones (ST – 3.60 and DM 3.14), and the RSI indicator, for which the number of transactions was the lowest (only 0.94). It is also worth noting the relative stability of results between the analyzed funds. The values of the average annual number of transactions for individual funds are relatively consistent, suggesting that the characteristics of the technical indicators dominate the specificity of the analyzed sectors in terms of signal frequency. Next, based on data on the average annual number of transactions executed within individual strategies and the corresponding rates of return, after checking the distributions using Shapiro-Wilk tests with the Lillefors correction and finding that the distribution of the number of transactions was not close to normal, the Spearman rank correlation coefficient was calculated. The obtained coefficient value was 0.42, which indicates a moderate level of dependence between the variables examined (Evans, 1996) – the rates of return are moderately dependent on the number of transactions made within individual strategies.

5. Conclusions and Discussion

Based on the analysis, we rejected hypothesis H1, which states that the use of investment strategies based on technical analysis indicators allows for higher average annual rates of return than the use of a "buy-and-hold" strategy for sector ETFs on the US market for the daily

timeframe. However, the results of the study indicate that there are individual indicators that allow for higher rates of return than the "buy-and-hold" strategy.

Hypothesis H2 which states that there is a strong relationship between the number of transactions and the rates of return obtained from investing in US sector ETFs using strategies based on technical indicators, should also be rejected in the case of the daily timeframe, as the discussed relationship is at a moderate level (the Spearman rank correlation coefficient was 0.42).

The research conducted allowed us to draw the following conclusions:

- C1: Of all the oscillators examined, the highest average annual rates of return were recorded for the Stochastic Oscillator.
- C2: The index and technical analysis yielded higher average rates of return for industries such as raw materials, energy, finance, and real estate. Except for the raw materials industry, the difference in rates of return did not exceed 1 percentage point.
- C3: The average annual number of transactions made using individual oscillators varies. The Commodity Channel Index recorded the most, with 6.67 pairs of buy and sell signals. The Relative Strength Index recorded the fewest, with less than one pair (0.94).
- C4: The level of correlation between the average annual number of transactions executed on the basis of signals generated by oscillators and the average annual rate of return measured by the Spearman rank correlation coefficient is 0.42, which indicates a weak level of correlation between the variables examined.

The results of the conducted study indicate that, overall, investment strategies based on technical oscillators do not outperform the “buy-and-hold” strategy for sector ETFs on the U.S. market in the daily timeframe, which is consistent with the findings presented in the literature. The research by Deep et al. (2025) and Cohen (2015, 2020) demonstrated that classical technical indicators have limited predictive value and, in many cases, yield results lower than the passive strategy. At the same time, the literature emphasizes that some oscillators can outperform buy-and-hold under certain conditions, which is reflected in our study – the Stochastic Oscillator achieved the highest average annual returns among the examined indicators. Further results of the study confirm the dependence of oscillator effectiveness on the characteristics of the instrument and the market. In our research, higher returns were achieved in the materials, energy, financial, and real estate sectors, which aligns with the observations of Cohen (2020) and Trembiński & Stawska (2021), highlighting the necessity of adjusting indicator parameters to the characteristics of the instrument. The observed differences in the effectiveness of strategies across sectors, as well as their dependence on market volatility and the number of transactions, can be interpreted in light of the Adaptive Market Hypothesis – the results indicate that the effectiveness of investment strategies varies according to market conditions and sector characteristics, reflecting the adaptive behavior of market participants. The analysis of the number of trades revealed a moderate correlation (0.42) between the number of signals and the rate of return, which is also supported by the literature – more frequent signals

generated by oscillators, such as the CCI, do not necessarily translate into higher investment performance (Naved, Srivastava, 2015; Cohen, 2020). In conclusion, the study results confirm the observations from the literature: technical oscillators can support the investment decision-making process and, in certain situations, improve investment outcomes; however, their effectiveness is variable, depending on the instrument, the market, the indicator parameters, and market conditions, and systematic outperformance of the passive strategy is not consistently achievable.

The main limitation of the conducted study was the length of the research period (XLC and XLRE funds were established in later years), determined by the period of existence of individual ETF funds and the availability of data - especially high frequency. Considering potential future research directions, it seems worthwhile to repeat the study, considering different, primarily lower, time frames. The study could also be repeated using other, lesser-known oscillators, a different group of indicators, such as trend or volume indicators, or a different method of interpreting the signals generated by the indicators. Another interesting concept seems to repeat the study in the coming years while maintaining the same parameters and incorporating a larger dataset. It would also be worthwhile to explore combining multiple indicators, applying machine learning techniques, or testing the strategies in non-US markets.

Acknowledgements

Supported by funds from the Ministry of Science under the "Regional Excellence Initiative" Program.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

TECHNOLOGY ASSESSMENT IN THE FIELD OF TRANSPORT AND LOGISTICS IN THE SILESIAN VOIVODSHIP

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Purpose: In the contemporary era, metropolitan areas and regions are confronted with a plethora of challenges in the realm of transportation and logistics management. This assertion is substantiated by a variety of technological solutions that facilitate the streamlining of processes, the mitigation of the deleterious environmental impact of these activities, and the enhancement of people's living standards. These technologies have been extensively discussed in the literature; however, their analysis within the context of specific regions remains underdeveloped. Due to this fact, the aim of the article was to provide recommendations for identified technologies in the area of transport and logistics in the Silesian Voivodeship.
Design/methodology/approach: The paper assesses 18 technologies in the area of transport and logistics in the Silesia Voivodeship, assigning them to four categories. The assessment was based on three criteria: the effectiveness of the technologies, the market age of the technologies, and their impact on the technological landscape. The analyses employed an expert survey, incorporating a technology assessment questionnaire.
Findings: The analyses identified six sets of technologies in the area of transport and logistics in the Silesia Voivodeship, differentiated in terms of their importance and level of use and further development. Recommendations were provided for each identified set of technologies.
Research limitations/implications: The research is concentrated within one voivodeship. The subsequent expansion of these enterprises into other regions and countries represents a promising avenue for further research. Furthermore, subsequent research endeavours will seek to refine the focus of the technologies under scrutiny.
Originality/value: Application of a technology appraisal methodology in the field of transport and logistics for the Silesian Voivodeship.
Keywords: transport and logistics, technology assessment, storage technologies, information technologies, transport technologies.
Category of the paper: research paper.

1. Introduction

Cities can't function without well-organized transport and logistics processes (Kauf, 2016a). These processes are related to the implementation of cargo, people, energy, and accompanying information flows within the city's logistics system while maintaining the assumed goals, including minimizing flow costs and improving the quality of life in the city (Jefimowaitė, Vienažindienė, 2022; Płaczek, 2011). At the same time, trends such as urbanization, changes in human behavior (e.g., increased mobility, development of e-commerce sales), and rising expectations regarding the quality of life are making transport and logistics aspects a major problem in cities and regions around the world (Alarcón et al., 2023; Kauf, 2016b). Unfortunately, these processes, in addition to their basic and necessary role, also generate a number of negative effects related to environmental pollution (air, soil, water), noise, increased congestion, accidents, infrastructure occupancy, and social exclusion (Mężyk, Zamkowska, 2016; Szołtysek, Twaróg, 2012). Therefore, the challenge for logistics is to minimize the identified problems and shape flows consistent with the concept of sustainable development, which assumes the harmonious development of regional social, economic, and environmental conditions, contributing to improved quality of life in the indefinite future (Sobol, 2017).

In response to constant changes, new societal needs, and emerging problems and challenges, support for transport and logistics activities through various solutions that improve the functioning of cities is becoming increasingly important (Bondar et al., 2022). Consequently, there is a growing global demand for new, often innovative, technologies in the field of city logistics (Winkowska et al., 2019; Szpilko et al., 2020; Dąbrowska et al., 2023). The concept of technology is broad and ambiguous in the extant literature. Its multifaceted nature is evident in its perception through various lenses, including machines, equipment, tools, materials, and products, collectively termed 'artefacts'. Additionally, it is interpreted through the lens of science and knowledge in its broadest sense, encompassing know-how, patents, tacit knowledge, and skills. Furthermore, techniques and methods, along with activities and processes, are intricately woven into the fabric of production methods (Bielińska-Dudzic in 2020). The term 'technology' itself is derived from the Greek 'technology', signifying the systematic treatment of an art or craft. One of the more fundamental definitions is that proposed by Dosi et al. (1990), which states that technology constitutes a collection of elements of practical and theoretical knowledge, the ability to apply it (i.e. know-how), methods, procedures and physical devices that utilise this knowledge. There is a widespread consensus among both management theorists and practitioners regarding the role of technology. Changes resulting from the technological race are becoming commonplace, even necessary. Consequently, the choice of technology, the timing of its introduction or withdrawal, are becoming key issues in technology management, and even management in general (Chyba, 2016). Awareness of the

need for technology development has become widespread, as evidenced by international and national programs supporting technology development and the activities of scientific research and development institutions. Given the growing demand for innovative technologies and the developed technology market, technology analysis and assessment seem essential. Their goals include characterizing and examining the technologies in use, determining their potential, and defining directions for development. Technology analysis and assessment enable the identification of strengths and weaknesses of technological activities, identifying opportunities for increasing competitive advantage through appropriate technology use, and identifying available technologies that could be applied to improve processes (Halicka, 2016).

In contemporary urban and regional contexts, a diverse array of technologies is employed for the management of freight, human mobility, and the dissemination of information. However, it is important to note that the level of support for technologies varies across different cities and regions. The technologies employed, the extent of their implementation, and the trajectories of their evolution are subject to variation. Therefore, in reference to the presented research problem, the aim of the article is to provide recommendations for identified technologies in the area of transport and logistics in the Silesian Voivodeship. The present study adopted three research questions in relation to the formulated aim of the paper:

1. What is the set of technologies used in the area of transport and logistics in urban and regional transport and logistics systems?
2. How to assess technologies in the area of transport and logistics in cities and regions?
3. What is the level of development of technologies in the field of transport and logistics in the Silesia Voivodeship?

It is important to note that the majority of research on technology assessment methods is of a universal nature, whereas the analyses conducted for the Silesian Province serve as a case study. The selection of the province for analysis is dictated by the research conducted by the authors as part of the Translog Transport and Logistics Observatory established in the Silesian Province. The observatory was established as part of the network of Regional Specialised Observatories in the Process of Entrepreneurial Discovery (SO RIS in PPO). The primary objective of the Observatory is to monitor global trends in urban logistics and to combine expert knowledge in order to improve it in the Silesian Province. It is evident that the research problem addressed in this paper is congruent with the tasks that have been undertaken by the Observatory.

In order to achieve the objective and answer the research questions, a literature review was conducted, focusing on the identification of technologies supporting transport and logistics in urban and regional systems. This is outlined in section 2 of the paper. The subsequent section will address the methodology of the research. Its use allowed us to obtain research results on technology assessment in the Silesian Voivodeship. These results were used to formulate recommendations. These findings are elucidated in Section 4, entitled "Results and Discussion". The paper concludes with a series of final conclusions.

2. Technologies in the field of transport and logistics – theoretical background

The flows realised in urban and regional transport and logistics systems involve different flows, the main ones being material goods (raw materials, materials, semi-finished products, spare parts, finished products), people and information. These flows necessitate the utilisation of technologies that facilitate their realisation and concurrently provide support, thereby enhancing efficiency, effectiveness, and stakeholder satisfaction.

The main subsystem requiring technology support is freight transport, which, by virtue of its complementary nature, constitutes the basis of all economic activity. The responsibility attributed to the concept of regional development is twofold: firstly, in terms of the development of individual economic branches, and secondly, in terms of the development of regions. Consequently, it is imperative to direct attention towards technological advancements that will facilitate the establishment of a contemporary and pioneering transportation system that is both environmentally sustainable and socially inclusive. It is evident that a number of the technologies are associated with multi- and intermodal transport. This perspective is consistent with the assertions made in strategic documents that underscore the significance of these modes of transportation. For instance, the White Paper (Transport Commission, 2011) and the Strategy for Sustainable Transport Development to 2030 (2019). The evolution of multi-modal and intermodal transportation has enabled the integration of transport policy assumptions with the principles of sustainable development. This integration has facilitated the development of eco-friendly transportation solutions that are less energy-intensive and generate lower external costs. The foundation for intermodal transportation is the establishment of contemporary solutions for the transhipment of intermodal loading units (containers, swap bodies, semi-trailers, or bimodal trailers), encompassing both vertical (lo-lo) and horizontal (ro-ro) transhipment technologies. A notable example of this is Modalohr. The implementation of these and other solutions pertaining to inter-branch transshipment is contingent upon the integration of technologies that are underpinned by novel advancements in the domain of rail wagons, road transport modalities, and infrastructure at transshipment terminals. The field of freight transport is heavily reliant on contemporary technologies, which have facilitated the development of various means of transport and loading facilities across different modes. Other technologies of particular importance include those related to autonomous vehicles and drones. There is a general trend related to the significant interest in these types of solutions due to their innovation, reduced human resource commitment and their relationship to 'last mile' transport. In particular, the use of electric and low-emission vans, freight trams, delivery bicycles, and other vehicles powered by alternative propulsion sources has attracted significant attention in recent research (see Taniguchi et al., 2014; Bellandi et al., 2014; Iwan et al., 2018; Kauf, 2016b; Taniguchi et al., 2020). A significant challenge in the domain of freight transport

pertains to the delivery of parcels, a phenomenon concomitant with the rapid expansion of e-commerce. This issue is further compounded by the intricate dynamics of 'last mile' transport flows. In such circumstances, both logistics companies and city and regional managers face a considerable challenge in organising sustainable parcel flows (Heitz, Beziat, 2016; Montwiłł et al., 2021; Nathnail et al., 2016). Examples include the development of alternative delivery and collection points based on locations other than the customer's home (e.g. a shop or gas station) (Vural, Aktepe, 2022); and the development of parcel vending machines (Taniguchi et al., Recent studies have explored the potential of drones in the context of parcel delivery (Müller et al., 2019), the development of urban and regional consolidation or distribution centres (Taniguchi et al., 2020; Pan et al., 2015; Serafini et al., 2018; Chen, Pan, 2015), the utilisation of alternative modes of transport (e.g. delivery bicycles) (Pan et al., 2015), and the development of the concept of crowdshipping (based on the idea of crowdsourcing, which involves the use of so-called crowd potential) (Taniguchi et al., 2020; Serafini et al., 2018).

The domain of passenger transport is another area that necessitates the integration and implementation of contemporary technologies for both individual and collective transportation. The utilisation of public collective transport is identified as a significant factor in reducing road transport and, consequently, reducing external transport costs and balancing passenger flows. It is asserted that a number of solutions are poised to contribute to this phenomenon, including, but not limited to, the implementation of a city card system (Grad et al., 2013; Jaroszyński, Chłąd, 2015), the establishment of a dynamic (real) passenger information system (Grad et al., 2013; Kiba-Janiak, 2012), and the introduction of dedicated bus lanes, along with the incorporation of smaller buses that operate at a higher frequency than standard buses (Kiba-Janiak, 2012). In the pursuit of diminishing the prevalence of road transport modes, alternative solutions have been proposed. These include the facilitation of multimodal travel through the implementation of micromobility options, such as urban bicycle and scooter systems, as well as the promotion of car-sharing and car-pooling initiatives. Additionally, the introduction of incentives to encourage the utilisation of public transportation has been mooted (Kiba-Janiak, 2012; Szołtysek, 2016; Jaroszyński, Chłąd, 2015). The primary focus is on the development and enhancement of railway infrastructure, including both linear and point-based facilities, which serve as a robust alternative to road transportation. Additionally, there is a strong impetus to transition to more environmentally sustainable rolling stock, such as electric vehicles or hydrogen-powered buses. Concurrently, there is a necessity to develop infrastructure dedicated to these types of vehicles, including car parks, repair points and charging stations (Iwan et al., 2018). A significant amount of attention has been dedicated to autonomous vehicles and their utilisation in passenger transportation, emphasising the potential environmental, societal and economic benefits. These benefits encompass enhanced safety, reduced congestion and optimised traffic flow, as well as augmented mobility for individuals with disabilities or for the elderly (Future Industry Platform, 2025). Furthermore, the introduction of multi-level and

collision-free intersections and traffic lights to regulate traffic, thereby enhancing transport safety, as well as the construction of underground or multi-storey car parks, are proposed as effective solutions (Stawasz, 2015). The development of collective public transport, both rail and road, as well as the aforementioned micromobility, additionally requires the construction of sites that will allow multimodality of travel. As posited by (Cichosz, 2015; Bul, 2017; Kauf, 2012), the following measures are primarily recommended: the construction of interchanges, the creation of infrastructure that facilitates the combination of cycling with public transport (e.g. B&R), and the establishment of infrastructure that enables the integration of trips by private vehicles with public transport (e.g. P&R).

The implementation of transport and logistics processes is widely supported by developed information technologies. Of particular note is the Internet of Things (IoT), a term defined as a modular method of integrating various sensors with all information and communication technologies (Blicharz, 2023). Alternatively, the IoT can be viewed as a totality of smart objects that can respond to the environment and process information, subsequently relaying it to other objects and users (Rot, 2017). A fundamental function of the Internet of Things (IoT) is the aggregation of data from multiple sources and the management of critical resources, including water, energy, transportation, waste, and public safety, to name a few (Balicka, 2023). The utilisation of collected data has the potential to enhance transparency in local government activities, to raise residents' awareness of their city's state, and to stimulate their desire to participate in municipal activities (Baraniewicz-Kotasińska, 2017). In the context of logistics, the Internet of Things (IoT) is being used extensively in the creation of an intelligent transport system, including through smart roads, car parks, bicycle systems, vehicles, street lighting, public transport, and real-time traffic management (Szum, 2021). Its application is also evident in the domain of waste management (Bondar et al., 2023). The utilisation of the Internet of Things (IoT) is evident in the Intelligent Transport Systems (ITS) under development. These technologies encompass a wide range of disciplines, including telecommunications, information technology, automation, and measurement, in addition to management techniques. These are applied to the domain of transport with the objective of safeguarding the lives of traffic participants, enhancing transport efficiency, and protecting environmental resources (Dembińska et al., 2018). ITS are applications that link data collection, communication, data mining, machine learning, artificial intelligence and database management (Tomaszewska, 2022). The objective of these initiatives is to furnish services pertaining to diverse modes of transport and traffic management, thereby enabling varied users to be more informed. Furthermore, these initiatives aspire to facilitate a safer, more coordinated and more intelligent utilisation of transport networks (Wojewódzka-Król, Rolbiecki, 2018). The present moment marks the current vanguard of artificial intelligence in the domain of transport and logistics operations. AI algorithms have the capacity to analyse vast quantities of data, including vehicle location, road condition, weather conditions and demand patterns, thereby determining optimal routes and minimising delivery times. This has been demonstrated to result in fuel savings,

reduced CO2 emissions and enhanced customer service. Furthermore, AI algorithms have the capacity to analyse data from sensors mounted on vehicles and machines, with the objective of predicting and preventing breakdowns before they occur (Envio Group, 2024). The AI technologies utilised are concomitantly associated with a plethora of mobile applications and digital platforms dedicated to residents or property owners (Jąderko et al., 2016), or the creation of an environment for the sharing of resources and the facilitation of customer integration (Strojna et al., 2022). Moreover, the utilisation of information technology, machine learning algorithms and the concept of the Internet of Things (IoT) constitutes the primary foundation for the development of contemporary solutions within the domain of waste logistics (Marques et al., 2019; Lewicki, 2018). The development of transport, both freight and passenger transport, also requires the support of automatic identification systems and data capture techniques (Automatic identification and data capture). The utilisation of automatic identification and data capture technologies facilitates the provision of real-time visibility at the point of shipment, the prediction of delivery times, and the explanation of delayed deliveries and much more (Rusek, Pniewski, 2016).

Warehouses represent a pivotal component within the framework of supply chains. In addition to their traditional function of inventory storage, they have expanded their operations to encompass a range of value-added services, including packaging, wrapping, and co-packing. The broad spectrum of tasks undertaken by warehouses has led to an increased focus on strategies to enhance competitiveness through process optimisation or cost reduction. The predominant trend observed in warehouses pertains to the automation and robotisation of their operations. For instance, in the context of automated high-bay warehouses, stacker cranes are assuming the function previously performed by forklift operators. The rapid and safe movement of loads, along with the optimisation of warehouse space utilisation, has been demonstrated (Grabowy, Wielgosz, 2018). Mobile robots serve as a prime illustration of the integration of robotics within warehouse environments. These devices facilitate the movement of inventory within the warehouse environment, enabling the efficient transportation of storage units between specific locations. Mobile robots can be categorised into two distinct classifications: AMR and AGV (Jardzioch, 2020). AGV technology is predicated on the utilisation of unmanned transport vehicles, which are engineered to convey objects along a designated route (Bednarz, 2018; Surma, 2020). AMR robots can be regarded as a more advanced iteration of AGVs. These devices are equipped with scanners, cameras, and sensors that facilitate the acquisition of comprehensive real-time environmental data. In the possession of such information, the robot is capable of navigating the storage area autonomously and reacting to a changing environment or emerging obstacles (Jardzioch, 2020). Another illustration of this phenomenon is provided by Amazon's experimentation with the utilisation of the Digit humanoid robot in the context of picking processes. The integration of unmanned aerial vehicles, more commonly referred to as drones, into warehouse operations is a recent development. These devices can facilitate hall inspections or warehouse rack surveys,

and are also used in inventory management. Their ability to maintain a stationary position in the air affords them a wide field of vision, thus enabling them to facilitate the work of warehouse personnel. This assistance may take the form of indicating safe routes or assisting in the manoeuvring of trolleys in confined spaces. The utilisation of drones in the context of stock taking has been demonstrated to contribute to the elimination of errors, the optimisation of time and financial resources, and the enhancement of safety measures for personnel and stored goods (Mecalux, 2021). In the context of warehouse operations, product picking represents a critical procedural element. In this area, the employment of a range of technologies, including Pick by Light, Pick by Point, Pick by Voice, Pick by Frame, Pick by Watch, and Pick by Vision, has been observed (Wróbel, Zbadyński, 2018). The latter is a particularly innovative technology, augmented by augmented reality (AR) (Rusek, Pniewski, 2017). Robots specialising in packaging, such as FANUC, which is equipped with sensors and vision systems to locate packages, packaged products, and put-away locations, also demonstrate proficiency in the realm of picking. It facilitates the accurate and precise packaging without damage to products (Jardzioch, 2020). In considering warehouse technology, the development of sustainable or green warehouses is a salient consideration, with environmentally friendly solutions assuming particular importance. The utilisation of compressors for heat recovery, light-emitting diodes, air destratification and warehouse automation represent merely a subset of the numerous solutions that yield environmental benefits (Mardeusz, 2021). Green warehouses employ a range of techniques and strategies to minimise waste production and energy consumption, motivated by environmental concerns. These principles are integral to the concept of green logistics, which emphasises the mitigation of the carbon footprint and the effective management of resources (Mecalux, 2022).

3. Methodology

In conducting the research to answer the research questions posed in the Introduction, the authors adopted the research methodology shown in Figure 1. It consists of four main phases.

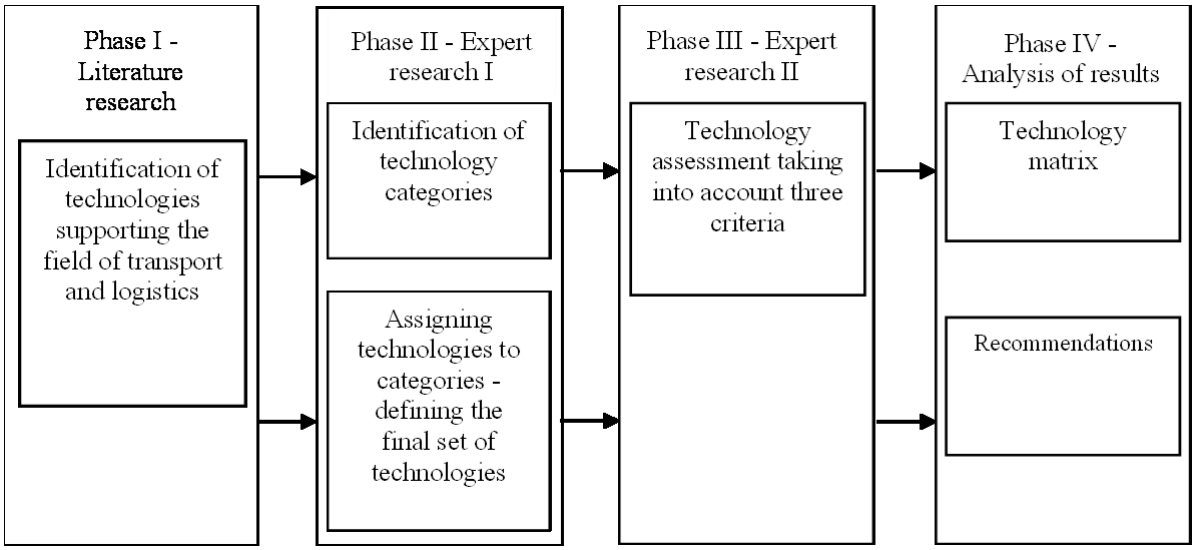

Figure 1. Research methodology.

Source: own work.

In the initial phase of the research, the authors of the study proposed a preliminary list of technologies, based on a thorough literature review. These processes encompassed all aspects of transport and logistics within the systems of cities and regions. In the second stage, a preliminary round of expert research was conducted. The study involved ten experts from both scientific and business practice backgrounds. The research was conducted through a series of interviews and discussions. The objective of the present study was to organise and group the technologies identified during the literature research stage within the adopted categories and to finally validate them. The result of the research conducted at this stage was the preparation of a questionnaire containing a list of technologies organised into four categories. This questionnaire, administered during the third stage of the research, was presented to the experts for their evaluation. Given that the technology assessment pertained to the Silesian Voivodship, the experts were drawn from this specific region. Pursuant to the assumptions that had been made, the technologies were analysed in accordance with the three criteria that are presented in Table 1.

Table 1.
Technology assessment criteria in the field of transport and logistics

Technology assessment criterion	**Technology - description**
Effectiveness	• base (core) technologies - widely used and available in the sector. Their possession is a necessary, but generally insufficient condition for achieving or maintaining a high competitive position; • key technologies - which are the basis for the competitiveness of the activities carried out; their perfect mastery is a key success factor; • experimental technologies - have little use, are in the early stages of development; they are, however, promising to become key technologies in the future and are therefore also protected from competition.

Cont. table 1.

Market age	• introduction phase - characterised by high uncertainty, research intensity, little application but high development potential. It may be experimental, there may be few or no competitors in the market. The research intensity of the technology is high, aiming to improve the technology and demonstrate its potential benefits; • growth and popularity phase - the technology is characterised by average uncertainty, emphasis on applications, thereby gaining wider acceptance, and demand grows rapidly. The technology is refined and improved and new competitors enter the market. Over time, improved, it can become a key technology, characterised by high efficiency, understood as the ability to reduce costs, create high quality and thus generate profits; • maturity phase - the technology is characterised by low uncertainty, reduced costs and reduced investment; it becomes more standardised and widely used. It has already reached the maximum level of its technological capabilities. The market becomes more saturated and competition more intense. Profits are often lower than in the growth phase; • decline phase - the technology becomes obsolete and is replaced by a new technology with greater competitive value.
Impact on the technological landscape	• niche technology - associated with a narrow, selected area or audience. Has less competition due to a small market of customers; • critical technology - brings an element of innovation with significant potential to the market, or contributes to reducing or preventing strategic dependencies; • disruptive technology - is a new, emerging technology that significantly changes a particular market or industry and, over time, unexpectedly displaces an existing technology. A disruptive technology replaces an established process, product or technology after some time, giving rise to a new way of doing things for consumers or businesses. This can lead to a number of benefits, including lower prices, better service quality and greater competition, and thus revolutionise the industry. In some cases, disruptive technology can even create other markets (e.g. smartphones, which have helped to develop mobile banking); • deep-tech - is characterised by a high degree of uncertainty about their actual technological feasibility at the start of development. As a result, there is a high level of specific R&D efforts up to implementation. There is also a high level of market risk in the early stages of technology development, as the products associated with the technology are very novel and it is often unclear how systems integrators and end customers will react to these adaptations.

Source: compiled from: Chyba, 2016; Halicka, 2016; https://www.focus.pl/artykul/disruptive-technology-czyli-technologie-ktore-zmieniaja-nasze-zycie, 16.05.2025; Regulation (EU) 2024/795 of the European Parliament and of the Council of 29 February 2024 on the establishment of the Strategic Technology Platform for Europe (STEP), https://eur-lex.europa.eu/legal-content/PL/ALL/?uri=CELEX%3A32024R0795, 16.05.2025.

Taking into account the criteria presented in Table 1, each identified technology in the area of transport and logistics in the Silesian Voivodeship was assigned to a relevant technology group by the experts. On this basis, in the last (fourth) stage of the study, two matrixes were prepared to analyse the technologies. Each matrix is a combination of two criteria:

- matrix I - the criterion of efficiency and market age of the technology,
- matrix II - criterion of effectiveness and influence on the technological landscape.

On the basis of the results obtained, the importance and level of development of individual technologies in the area of transport and logistics in the Silesian Voivodeship was indicated, and recommendations were made for their further development.

4. Results and discussion

In accordance with the adopted methodology, the initial phase of the research involved the identification of a range of technologies that facilitate transport and logistics activities in urban and regional contexts. In the second phase of the research, which was conducted in conjunction with experts, four categories were identified, to which the technologies identified during the literature research stage were assigned. The categories encompassed in this study were: passenger transport, freight transport, information flows and warehousing. It is imperative to emphasise that the identified categories are a consequence of the type of flow streams that occur in transport and logistics, and the principal logistical tasks that accompany cities and regions. The extensive range of technologies identified through a comprehensive literature review was then subjected to a more detailed analysis, with the valuable input of experts in the field. The objective of the exercise was to organise, complete and ultimately classify each technology into one of four categories. This process yielded a total of 18 technologies, with five technologies identified for each of the first three areas and three technologies identified for the storage-related area. The list in question is presented in Table 2.

Table 2.
List of identified technologies

Item	Technology area	List of technologies
1	Technologies for freight transport	Technologies for intermodal transport (T1) Technologies for autonomous vehicles and unmanned aerial vehicles (T2) Technologies for low-emission means of transport (T3) Modern technologies for last mile transport (T4) Other technologies for last mile transport (T5)
2	Technologies for passenger transport	Technologies for collective transport (O1) Autonomous vehicles technologies for passenger transport (O2) Technologies for micromobility (O3) Technologies for parking systems (O4) Technologies for integrated transport (O5)
3	Information technology	Intelligent Transport Systems (I1) IoT technologies for logistics and transport (I2) Artificial intelligence, virtual and augmented reality in logistics (I3) Web and mobile technologies for transport and logistics (I4) Other identification and tracking technologies for transport and logistics (I5)
4	Warehouse technologies	Warehouse process automation technologies (M1) Robotics technologies for warehouse processes (M2) Green warehouse technologies (M3)

Source: own work.

The technologies listed in Table 2, in accordance with the adopted methodology, were subjected to expert assessment. As a result, within the first category 'technologies for freight transport', the following were distinguished:

- in terms of efficiency criterion - three key technologies and two experimental technologies;
- in terms of market age - two technologies in the market launch phase and three technologies in the growth phase;
- in terms of impact on the technological landscape - one niche technology, one critical technology and three breakthrough technologies.

Within the second category 'technologies for passenger transport', the following were identified:

- in terms of performance criteria - two core technologies, two key technologies and one experimental technology;
- in terms of market age - one technology in the launch phase, two in the growth phase and two in the maturity phase;
- in terms of impact on the technological landscape, all technologies were considered critical.

Within the third category 'information technology', the following were identified:

- in terms of performance criteria - one core technology, two key technologies and two experimental technologies;
- in terms of market age - two technologies in the launch phase, two in the growth phase and one in the maturity phase;
- in terms of impact on the technological landscape - three technologies were identified as critical and two as disruptive.

Within the fourth category 'technologies for storage', the following were identified:

- in terms of efficiency criteria - two critical technologies and one experimental technology;
- in terms of market age - one technology in the market launch phase and two technologies in the growth phase;
- in terms of impact on the technological landscape - two critical technologies and one breakthrough technology.

Consequently, within the domain of transport and logistics, three core technologies, nine critical technologies and six experimental technologies were identified. With regard to the market's age, it is evident that six technologies are in the introduction phase, nine are in the growth phase, and three are in the maturity phase. In accordance with the initial two criteria of technology assessment in the Silesian Voivodship, namely effectiveness and market age, the technologies in question were examined and subsequently arranged in the form of a matrix, as illustrated in Figure 2.

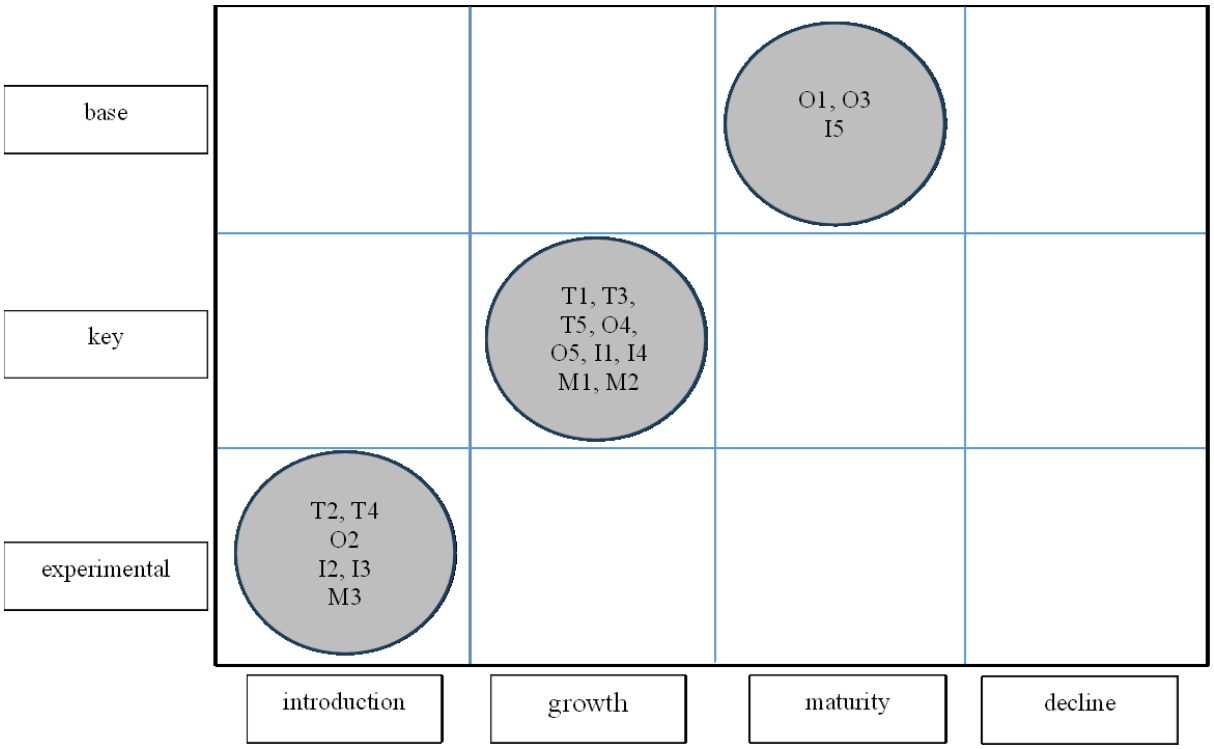

Figure 2. Assessment of transport and logistics technologies in terms of efficiency and market age. Source: own elaboration.

As demonstrated in Figure 2, within the domain of transport and logistics in the Silesian Voivodeship, three technologies were identified as being in the basic maturity phase. The technologies in question are as follows: technologies for public transport (O1), micromobility technologies (O3) and identification and tracking technologies (I5). These technologies have a strong presence in the market, are extensively utilised, and are characterised by their predictability and standardisation. While the possession of these territories is imperative for the efficient operation of transport and logistics within the province, it does not ensure a competitive edge in this domain. As part of a series of key technologies that are undergoing rapid development, seven technologies have been identified in the area of transport and logistics in the Silesian Voivodeship. The following technologies are to be considered: technologies for intermodal transport (T1), technologies for low-emission means of transport (T3), other technologies for last mile transport (T5), technologies for parking systems (O4), technologies for integrated transport (O5), intelligent transport systems (I1), web and mobile technologies for transport and logistics (I4), technologies for automation of warehouse processes (M1), technologies for robotisation of warehouse processes (M2). The aforementioned technologies are instrumental in ensuring competitiveness in the domain of transport and logistics within the Silesian Voivodeship. It is imperative for the advancement of this domain that these competencies are proficiently attained, as they are distinguished by an average degree of uncertainty and recognised as a pivotal success factor, thus prompting the pursuit of their implementation. These products are readily accepted, and their use contributes to a number of advantages in terms of both cost and quality. Six experimental technologies are

currently in the introduction phase. The technologies in question are as follows: technologies for autonomous vehicles and unmanned aerial vehicles (T2), cutting-edge technologies for last-mile transport (T4), technologies for autonomous vehicles in passenger transport (O2), IoT technologies for logistics and transport (I2), artificial intelligence, virtual and augmented reality in logistics (I3), technologies for green warehouses (M3). The technologies previously mentioned are characterised by a relatively high degree of uncertainty and have only limited application in the present day. These solutions represent a state-of-the-art, pioneering approach, and their usability is currently under investigation. It is widely acknowledged that they possess considerable potential and represent a significant opportunity for the future development of the Silesian Voivodeship. Concurrently, it is emphasised that the acceptance of these solutions in practice is uncertain (e.g. extensive use of crowdsourcing).

In accordance with the established research methodology, the subsequent matrix correlates the outcomes of technology assessment in the Silesia Voivodeship, incorporating two distinct criteria: efficiency and the impact of technology on the technological landscape. The results of the study are presented in the matrix in Figure 3.

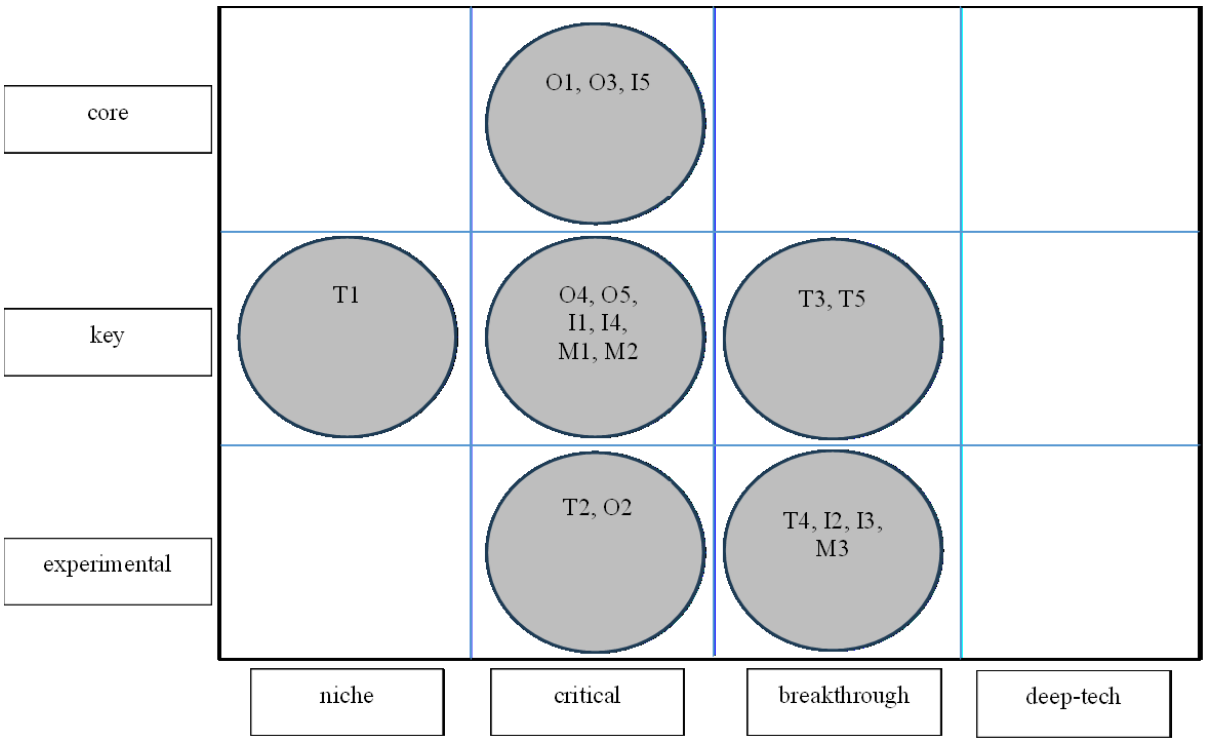

Figure 3. Assessment of technologies in the area of transport and logistics in terms of efficiency and impact on the technological landscape.

Source: own work.

Surveys carried out in the Silesian Voivodship revealed a total of 11 niche technologies, 11 critical technologies and six breakthrough technologies. This finding indicates that the majority of technologies (61%) possess considerable potential for the advancement of the region. Simultaneously, six pioneering technologies have been developed as innovative solutions with the potential to effect substantial changes in the transport and logistics systems of the province, and occasionally even to bring about a complete revolution in these systems. The only identified niche key technology is technologies for intermodal transport (T1). This attests to their pivotal role in enhancing the region's competitiveness in the domain of freight transport. Nevertheless, their utilisation is restricted to a select demographic due to their focus on a particular market segment. Within the critical technologies, three are designated as core technologies, six as key technologies, and two as experimental technologies. It is important to note that all technologies in the domain of passenger transport are classified as critical technologies. Among these, two stand out as being fundamental: technologies for public transport (O1) and technologies for micromobility (O3). The remaining technologies are either key (technologies for parking systems (O4), technologies for integrated transport (O5)) or experimental (technologies for autonomous vehicles in passenger transport (O2)). Furthermore, other technologies for identification and tracking in transport and logistics (I5) were classified as critical core technologies. The critical core technologies encompassed intelligent transport systems (I1), web and mobile technologies for transport and logistics (I4), warehouse process automation technologies (M1), and warehouse process robotisation technologies (M2). Meanwhile, in the domain of critical experimental technologies, in addition to autonomous vehicle technologies for passenger transport (O2), there were autonomous vehicle and unmanned aerial vehicle technologies for freight transport (T2). Among the breakthrough technologies, two key technologies (technologies for low-carbon modes of transport (T3), other technologies for last mile transport (T5)) and four experimental technologies (cutting-edge technologies for last mile transport (T4), IoT technologies for logistics and transport (I2), artificial intelligence, virtual and augmented reality in logistics (I3) and technologies for green warehouses (M3) were identified.

As a result of classifying each of the 18 technologies into the appropriate area in matrix I (summary of effectiveness and age of technologies) and matrix II (summary of effectiveness and impact on the technological landscape), six subsets of technologies in the Silesian Voivodeship were identified. Taking into account their characteristics, recommendations were proposed for them, presented in Figure 4.

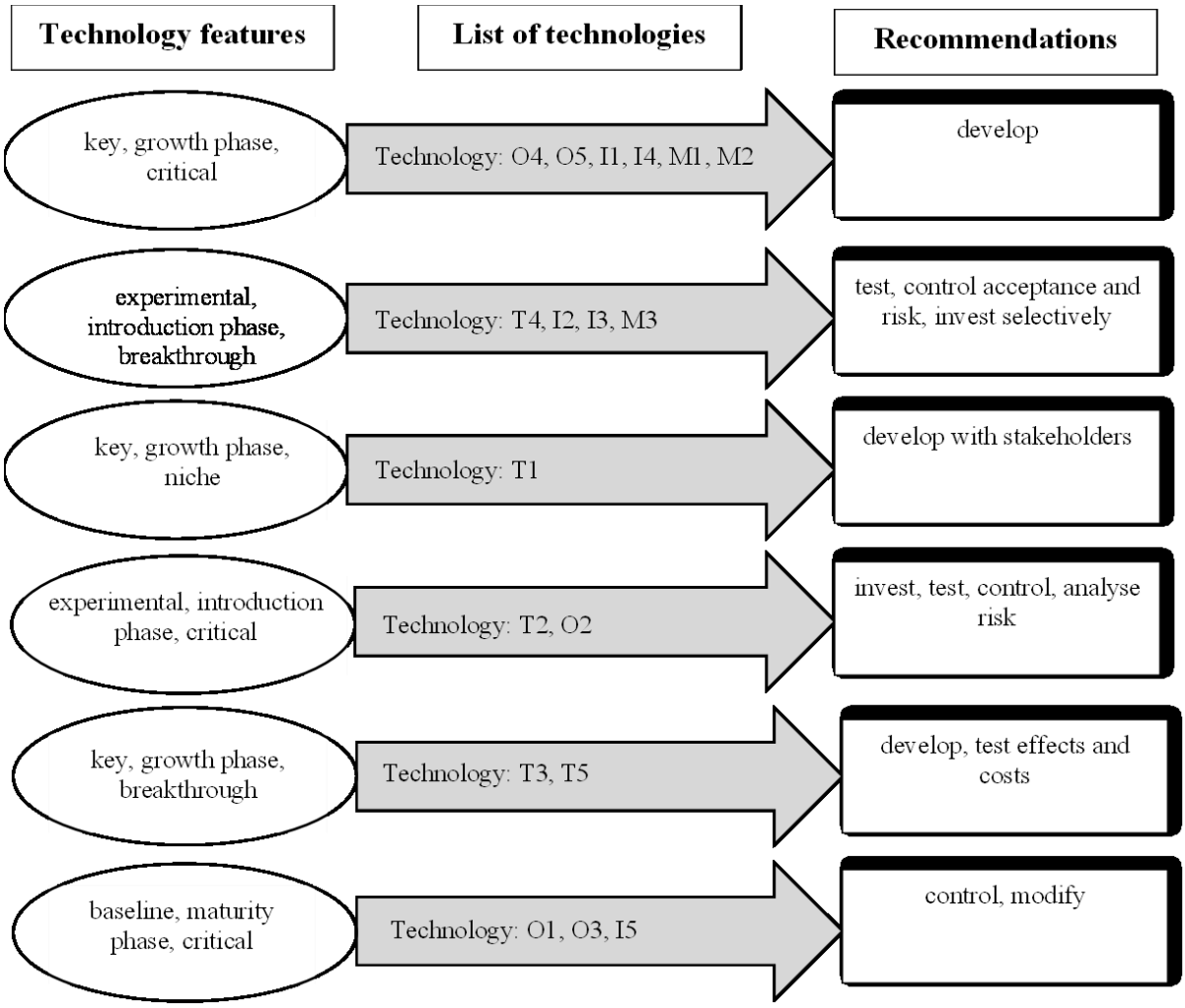

Figure 4. Summary of technologies in the field of transport and logistics for the Silesian Voivodeship – recommendations.

Source: own work.

As outlined in Figure 4, with regard to technologies O1 (technologies for public transport), O3 (technologies for micromobility), and I5 (other identification and tracking technologies), continuous observation and control is necessary. These technologies are fundamental to the operation of passenger transportation within the province. The efficacy of the control measures implemented will dictate the necessity for modifications and upgrades to be made, with the objective of enhancing the technologies in question through the implementation of contemporary organisational and technical solutions.

It is imperative to allocate resources to the development, testing, control, and evaluation of technologies for autonomous vehicles and unmanned aerial vehicles in freight transport (T2) and autonomous vehicles in passenger transport (O2). This approach is essential to assess the potential risks associated with the widespread implementation of these technologies in practical applications. In the case of technologies T4 (modern technologies for last mile transport), I2 (technologies in the area of IoT), I3 (artificial intelligence, virtual and augmented reality), M3 (technologies for green warehouses), some activities are analogous to the previously

mentioned technologies T2, O2. The necessity for research is predicated on the assumption that there is a need to control the level of acceptance by different stakeholders. Furthermore, the potential risks of their application must be analysed, and, depending on the results obtained, selection and selective investment will be made.

With regard to T1 technologies (technologies for intermodal transport), due to their pivotal role in the region, their development is recommended. However, due to the niche nature of the project, it is important to strongly involve stakeholders such as, for example, intermodal terminal managers or selected logistics operators in this development. Consequently, cooperation in organisational and financial terms (e.g. public-private partnerships) assumes significant importance. It is evident that development is required in the following technologies: O4 (parking system technologies), O5 (technologies for integrated transport), I1 (intelligent transport systems), I4 (mobile and web technologies), M1 (automation technologies in warehousing) and M2 (robotics technologies in warehousing). It is evident that these technologies are pivotal to the province's functioning. Their extensive implementation has the potential to yield substantial benefits for the region. In relation to the final group of technologies, namely T3 (technologies for low-carbon means of transport) and M5 (technologies for green warehouses), it is recommended that development be pursued. However, it is imperative that the potential effects and financial implications of the proposed solutions be thoroughly examined.

5. Conclusions

Transport and logistics processes within urban and regional systems are supported by a variety of technologies. However, it should be noted that the status and level of development of these technologies may vary across different regions. The paper conducts research into the assessment of technologies in the area of transport and logistics in the Silesian Voivodeship. The study resulted in the identification of 18 groups of technologies, which were subsequently assigned to four categories: technologies for freight transport, technologies for passenger transport, information technologies and warehouse technologies. It is important to note that each of the 18 groups of technologies is quite broad, including a number of detailed solutions that are in practice, at different stages of development. This approach constitutes a limitation of the analyses carried out. Concurrently, it delineates the trajectory of prospective research endeavours, which will centre on the meticulous examination of technologies, encompassing both their intricacies and fragmentation. Another limitation is the lack of separate consideration in the analyses of waste flows in the city, which constitute a significant subsystem of the city's logistics system. This aspect will also be developed by the Authors in further research.

The assessment of technologies was conducted using three distinct criteria, namely technology effectiveness, technology age, and its impact on the technological landscape. The assessment of the Silesian Voivodeship was conducted by experts using research methods. The research enabled the identification of six distinct technological clusters within the domain of transport and logistics in the Silesian Voivodeship. Each of these groups technologies at a similar level of development and use in practice. It is imperative to emphasise that the method of analysis employed is universally applicable, independent of the geographical location in which the research was conducted. However, it is important to note that the assessment itself and its results are applicable to the Silesian Voivodeship. Focusing on a single region does not allow for a comparative analysis. Therefore, this aspect constitutes a limitation of the research. In the subsequent phase of research, it is envisaged that analyses will be conducted for additional regions within Poland and Europe. This will facilitate a comparative analysis of the results obtained.

The presented technology assessment results are targeted at various stakeholder groups. The most important are three groups that participate in the implementation or development of technologies. The primary target group for the results are provincial and city authorities, as the main decision-makers for actions undertaken in the region and cities. Knowledge regarding the status of existing technologies and the identified recommendations is crucial and should be used to: determine directions and plans for regional and city development, develop financial plans, prepare measures to counteract the potential exclusion of various social groups, conduct activities aimed at establishing cooperation with other stakeholders, and conduct information and awareness-raising activities to minimize potential concerns and lack of acceptance among residents. Other stakeholder groups targeted by the results include R&D institutions and TSL companies. These groups should collaborate with cities regarding the transport and logistics processes implemented in their areas. Therefore, knowledge regarding technology assessment and recommendations for their development should form the basis for research and implementation activities. This article does not focus on the stakeholders who will receive the research results or the directions for their use. However, the Authors' research interests and publications address the issue of stakeholders in the city's logistics ecosystem. Therefore, the issue of benefits for various stakeholder groups from the obtained results will also form the basis for the Authors' further research.

Acknowledgements

The paper presents selected results of the regional project "Creation of Regional Innovation Observatory". The project is financed by the European Funds for Silesia programme and state budget (project number: FESL.01.03-IP.02-06CF/23).

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

SOCIOECONOMIC IMPLICATIONS OF SUCCESSION IN FAMILY FARMS IN POLAND

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Purpose: The article aims to determine the causes of conflicts in farming families in Poland and find out what people who left family farms received and how the estate was distributed. The first specific objective is to identify the social implications of sibling buyouts and the distribution of the family farm among the heirs. We sought to improve the available knowledge on the frequency of legitim claims addressed to the heirs to the family farm. The other specific objective is to determine the influence of the awareness of legitim on the satisfaction with family financial arrangements linked to farm inheritance.
Design/methodology/approach: The article employs a CAWI survey. It was completed by 596 respondents. The results are analysed with tables and descriptions, with variable relationships shown in figures.
Findings: The article contributes empirical observations on the sources of conflicts in farming families. Those who do not inherit the farm are bestowed with some land to build a house or funds to buy a flat. Every tenth respondent received no support linked to succession in the family farm.
Research limitations/implications: No in-depth case studies were possible because of the delicate financial matters investigated under the study. Inheritance and succession are not discussed outside the close family circle.
Practical implications: Certain tools found in other European Union member states are proposed that would protect heirs to family farms against excessive financial obligations towards siblings.
Originality/value: The article successfully investigates whether family farm inheritance processes in Poland threaten farm stability.
Keywords: Inheritance, Family farm, Conflicts, Legitim.
Article Type: Research paper.

Introduction

The research problem investigated in the article is sibling buyout and its impact on inheritance satisfaction. Some off-farm respondents reported dissatisfaction with estate distribution. Sometimes, it can threaten the stability and continuity of family farms. Sibling buyouts and legitim claims may exacerbate family conflicts. Hence, one question in the survey concerned the causes of conflicts in farming families. The questionnaire included a question about the buyout method in farming families: in-kind or monetary: single payment or instalments. Another question concerned whether the respondent's family properly resolved financial issues related to farm inheritance. The respondents were also asked about sibling buyout by heirs to the farm. A group of questions concerned the frequency of legitim claims.

The literature review focused on farm inheritance principles in the context of estate buyout. The literature shows that the problem of farm fragmentation was widespread as far back as among noble houses. The references noted that Poland has introduced regulations to prevent the fragmentation of inherited farms.

Objectives, materials, and methods

The farm inheritance dynamics are particularly relevant in Europe, where the political agenda is to support generational renewal towards improved modernisation and innovation in farming (Bertolozzi-Caredio, 2024). The article deals with succession-related conflicts in Polish families. Succession is linked to buyouts of off-farm heirs. Following Matser (2019), we also consider the perspective of those siblings who did not participate in farm succession, as they are central to a successful process. However, their role and position in the process are far from clear. We compare the inheritance satisfaction of on-farm and off-farm heirs. Similarly to Taylor and Norris (2000), we look into conflicts between succeeding and non-succeeding siblings in the context of family farm inheritance.

The article aims to determine the causes of conflicts in Polish farming families linked to succession to family farms and to investigate the frequency of legitim claims made to heirs to the farm. The first specific objective is to identify the social implications of sibling buyouts and the distribution of the family farm among the heirs. The other specific objective is to determine the influence of the awareness of legitim on the financial arrangements linked to farm inheritance. Legitim is an amount ordered by the court to be paid by the beneficiary of the estate to their siblings who did not receive at least 50% of the family farm buyout amount due to them under inheritance law.

The article reports the results of a CAWI (computer-assisted web interview) survey carried out from February to April 2024. The survey involved anonymous electronic questionnaires that respondents completed online. They were invited by e-mail. The invitations were sent to all local governments and farm wives associations. The survey covered 596 respondents. The returned questionnaires were collected and answers analysed in Statistica after coding into an MS Excel file. The software generated summary tables, some of which were converted into graphs. The results are presented as tables and descriptive text.

The term 'buyout' and its various forms, as used in the article, do not necessarily refer to a transaction. Under Polish inheritance law, an heir can be 'bought out' in the sense that they are compensated for what they would have received in inheritance proceedings, but did not because they agreed to disclaim inheritance in exchange for money or other consideration, for example. This does not entail the automatic transfer of title or interest unless a notarial deed is executed for that purpose.

Literature review on sibling buyouts

Mogaji (2024) is right to caution that defining the specific niche consistent with the research objective is critical in the dynamic environment of family business research. This approach requires an in-depth literature review to identify worthy gaps. The sources show that no authors have investigated conflicts in family farms caused by farm inheritance. Our niche is family farms and the problem of farm estate distribution. Succession is the central theme in family business research (Ratten et al., 2006). Just as most companies globally are family businesses, Polish agriculture is dominated by family farms. These farms are inherently linked to the homes where people were raised and can be considered home-based food production businesses (Mail et al., 2024). Farm inheritance processes affect family relationships, the number of farms, and the average farm size in Poland. Successors are typically satisfied with how things are (Li, Marshall, 2019). Off-farm siblings have yet to be asked about their satisfaction with the farm inheritance process.

Land fragmentation and its impact on the economic viability of farms are serious issues linked to farm inheritance. Distribution of farm estate among multiple heirs can result in smaller, often economically unviable, plots. The literature shows that the problem of farm fragmentation was widespread as far back as among noble houses. S. Przybyszewski estimated that ‘over three centuries, the Slaski family held about 60 villages’ in total. The large size of the family necessitated farmland division and distribution, leading to land fragmentation. Buyouts absorbed significant assets of the successor. This, in turn, reduced the social advancement potential among the gentry. As a result, while the Slaskis were still married

representatives of wealthy families in the late eighteenth century, their strategy shifted to the same stratum, mid-landed gentry, in the nineteenth and twentieth centuries (Nowak, 2017).

The problem of farm fragmentation due to farmland division and distribution is by no means new. One author investigated the process of farm fragmentation in Piotrowice Wielkie (Proszowicki District). Over thirteen years, the village gained thirteen new farms: 68% from farmland division and distribution, 25% from farmland division and distribution and marriage, and 7% from purchase. This summary demonstrates the substantial dominance of farmland division and distribution. Lack of non-agricultural work for farmers' children contributed to the division of the parental estate. Farmland division and distribution would surely intensify after the Second World War, were it not for the political, social, and economic transition in Poland. Many people migrated from Piotrowice Wielkie and other overpopulated central Poland areas to the Recovered Territories (Prochownik, 1962). This movement reduced the pressure on farmland division and distribution and farm fragmentation.

Many European states adopted inheritance strategies to avert farm fragmentation and maintain their cohesion. Most inheritance systems in the United Kingdom provide for a single heir and no compensation for the other children. A similar inheritance scheme to ‘keep title to land’ is found in Finland. Inheritance law of some Aegean Sea islands (like Karpathos and Nisyros) still provides for the firstborn to receive substantial real estate gifts. The French inheritance principles take the middle ground. The successor pays compensation to the other heirs, but the land is on average undervalued by half compared to market prices (Blanc, Perrier-Cornet, 1993). Danish and Belgian regions follow the French lead of equal shares and a single successor (Bika, 2007).

European legal systems employ diverse tools to protect family farms against excessive debts caused by estate buyouts. One solution is to estimate the farm estate value, which is then used to determine the buyout amounts below the market values. It is usually the fiscal value (Germany), income value (Switzerland) or official prices of farms (France, Finland, and Italy – the Bolzano region). Another method for protecting family farms against excessive debt is to divide the buyout amount into instalments paid over a relatively long period (typically 10 years, as seen in Switzerland, Germany, Spain, Belgium, Finland, Luxembourg, and the Austrian federal states) (Lichorowicz, 2015).

The privileged position of successors vis-à-vis other heirs who are bought out entails specific obligations under most European jurisdictions. The successors are usually obliged to perform work on the inherited farm in person (for example, for five years in France) (Lichorowicz, 2015). Sibling buyouts can place family farms in debt. This could pry the farm from the family's hands. As Belmonte, Seaman and Bent (2016) put it, if you have no debts, you are the master of your fate, but if you have debts, the bank is the master of your fate.

Heirs are constrained by relatively long restrictions on selling the farm (10-15 years in Germany). In the case of an early sale, any buyout amounts due to the siblings are immediately due and payable. What is more, the settlements include the buyout amounts and the free-market

price at which the farm was sold (Germany, the Austrian federal states, Spain, Norway, Switzerland, and Norway). In Germany, the amount due to other heirs is reduced on a *pro rata* basis to the length of the period when the successor worked on it before selling the estate, for example, by 25% after 10 years of work (Lichorowicz, 2015).

French legislation allows heirs to establish an agricultural land association during estate distribution proceedings. The heirs eligible to receive buyout payments may contribute their credit to the successor as their share in the company. Then, they are entitled to a proportionate share in farm income, which suspends the buyout payments (Lichorowicz, 2015).

Poland is among the few states whose constitutions have the family farm as the basis of the agricultural system of the state. This principle does not contravene Article 21, which states that 'The Republic of Poland shall protect ownership and the right of succession' (Constitution, 1997). Preservation of the farm in its current shape from before estate distribution is not guaranteed. The Polish law does not protect the farm's integrity by forcing a single successor. Although the estate can be gifted to a single descendant, the others may request legitim payments. These payments are the owner's liability.

Statutory inheritance principles provide for joint ownership of the farm. The Polish Civil Code may apply in this case. Its Article 216(1) states that 'The farm buyout amounts due to joint owners are agreed by them.' According to Article 216(2), 'Should no agreement be reached, the buyout amounts due to the joint owners may be reduced.' The degree of the reduction is determined considering 1) the type, size, and condition of the farm subject to the buyout; and 2) the personal and financial situation of the joint owners obliged to pay and entitled to receive the amounts (Code, 1964).

On 5 July 1963, the Polish Sejm enacted the Act of 29 June 1963 on preventing farm fragmentation (Polish Journal of Laws No. 28, item 168). The reason for these restrictions was to arrive at specific economic and sociological effects in line with the objectives of the agricultural policy at the time. The legislator decided to prevent the creeping fragmentation of farms, caused by inheritance among other things, to ensure economic viability and increase the intensity of the peasant agricultural economy. One solution effective in legal terms was to make the farm a separate part of the estate. The inhibition of farm fragmentation through inheritance is a generalised consequence of the agricultural policy with norms for large farms, introduced with the Act of 29 June 1963 on preventing farm fragmentation and later incorporated into the Civil Code (Łysakowski, Stelmach, 1971).

The individual farmer is defined as a natural person who owns or rents agricultural property with a total area of agricultural usable land of up to 300 hectares, manages the farm in person, has agricultural qualifications, and lives in the municipality where one of the pieces of agricultural property forming their farm is located (Act of 11 April 2003 on shaping the agricultural system). Legitim dates back to Roman law. It was introduced to curb the pathology of a dying *pater familias* denying his children the inheritance and gifting it to other people. Note that in pre-modern societies, like Ancient Rome or Poland until recently, adult children

and wives worked on the farm for no remuneration. Their efforts contributed to the senior's wealth. Therefore, the public did not appreciate leaving the children and the wife bereft of their heritage. People who dedicated their lives to farm work, hoping to receive the estate after the father or husband dies, were left destitute (Sobczak, 2014).

As rightly noted by Gaffney-Rhys and Jones (2013), if the owner of a family farm fails to take appropriate action and appoint a successor in their last will, conflicts may arise between the heirs after the owner dies. In Poland, those excluded in the last will may demand a legitim from the appointed beneficiaries. The person not provided for in the last will may demand 50% of their potential statutory share of the estate. It is practised in the case of farm inheritance in Poland. Children who were not gifted an adequate area of land or its monetary equivalent from the decedent file a legitim claim with a court. Conflicts arising from farm inheritance will become more prevalent. This is because farmers above the age of 65 constitute more than 30% of the farming population in the European Union, with an average age of 51.4 (Czyżewski et al., 2024).

The literature on succession in family farms tends to focus on the succession strategy and the effects of leadership and ownership changes (Wang, 2023). It makes references to such notions as socio-emotional wealth, entrepreneurship, and management. They demonstrate how multidimensional the problem is. Furthermore, the literature provides diverse theoretical frameworks that can potentially facilitate an in-depth understanding of various phases of succession (Zashan et al., 2025). Management structure significantly contributes to successful succession. Researchers suggest that family farm management is a complex process as opposed to non-family farms. It is mostly because of the dual nature of the relationships (family and business) (Marath, 2023). The choice of the successor for a family farm is considered to potentially affect its growth, an occurrence conventionally referred to as the succession effect. Family issues can impact business, and conversely, business can affect the family (Kubicek, Machek, 2022). For example, Glover (2014) investigated farming family conflicts on the male-female plane among joint owners of the farm. The conflicts revolved around different opinions on how to run the farm.

Succession in individual farms has a significant impact on the structure of the Polish agricultural industry (Dudek, Pawłowska, 2022). Seymour (1993) suggests that the lack of a succession plan threatens the existence and continuity of the family farm. Researchers and decision-makers consider generational renewal in farms as the critical driver of agricultural innovation and modernisation. Many European states suffer from declining succession rates in agriculture (Schuh et al., 2022). It is linked to land abandonment, farm productivity decline, capital loss, business stagnation, and reduced investments (Wheeler et al., 2012; Mishra, El-Osta, 2007). Eventually, it may compromise the industry's ability to meet public expectations and achieve policy goals (Lobley et al., 2010). However, there are some legal issues associated with unreasonable farm estate distribution and the effective exercise of the agricultural qualification prerequisite for farmland buyers. The farm inheritance system lacks effective

structural solutions to ensure farm continuity. The Act on shaping the agricultural system provides for farm inheritance under testate and intestate succession by persons who are not individual farmers in line with universal inheritance principles introduced in Poland in 2001. Succession duration is long, and the perception of justice by non-succeeding siblings may vary over time, which can potentially disturb harmonious coexistence within the family and threaten the continuity of the farm (Matser et al., 2019).

Proactive succession planning, utilising multiple legal tools, may be an effective method for managing the challenges of farm estate distribution among heirs (Dudek, 2016). The legal methods include gifts, contracts to transfer the farm to the successor (Lukas, 2019), last wills, and contracts to provide care and lodgings in exchange for property title transfer. A family foundation can be established under Polish law for long-term management of farm assets. A gift of agricultural real property to immediate family members is not subject to donation tax, which makes it an attractive option. Moreover, the farmer may secure their right to live on the farm with a contract under which they transfer the ownership title to another person in exchange for care, lodgings, and food or personal servitude. A written succession plan is crucial for adapting to changing conditions and addressing potential issues with land transfer (Dudek, 2016). Contracts supporting generational renewal in agriculture are pillars of the agricultural law.

The literature emphasises numerous benefits of succession planning in agriculture (Sroka et al., 2019). It helps ensure the continuity and stability of family farms and avoid future conflicts among potential heirs (Borychowski et al., 2023). The Common Agricultural Policy of the European Union aims to reinforce the socioeconomic structure in rural areas, notably through generational renewal (European Commission, 2019). Succession planning helps protect investments, preserve the cultural and emotional load of the farm, stabilise the financial situation of the family, and maintain control over land and natural resources. A written succession plan is a must if the farm is to follow the changing constraints and to address potential problems with the transfer of land. Regrettably, methods of succession planning for family farms are still little known and even less practised in Poland.

Legal and family conflicts are often part of farm estate distribution among heirs (Matyka, 2025). Estate distribution court proceedings determine the composition and value of the estate. They also decide on disputes over whether a specific asset belongs to the estate. If the heirs cannot agree on the distribution, the decision is the court's after considering the parties' proposals. In general, the court is bound by an agreed petition of the heirs regarding the distribution arrangements unless it is illegal or contravenes principles of social coexistence or interests of eligible parties.

Profile of the sample

The respondents are from various places in Poland. Half of them come from five voivodeships: Wielkopolskie, Mazowieckie, Lubelskie, Podkarpackie, and Małopolskie. The smallest groups are from Lubuskie and Zachodniopomorskie Voivodeships. The sample is predominantly composed of women (70.6%). Most of the respondents were local government staff (71.8%). Farmers amounted to 9.4% of the sample. Local government representatives who were also farmers made up 6.4%. Businesspeople accounted for a mere 2% of the sample. The largest age group was 40-50 (35.7%, Figure 1). An overwhelming majority of respondents (70.5%) lived in the countryside, while the others were urban residents.

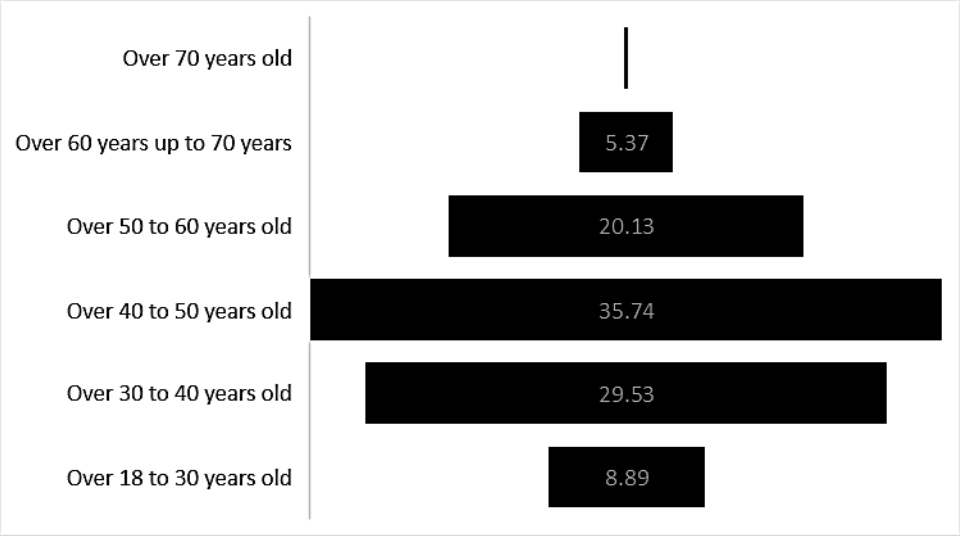


Figure 1. Age structure of the respondents (%).

Source: Authors own work, original work based on the survey (N = 596).

Primary causes of conflicts in farming families

The survey of 596 respondents shows that the primary cause of conflicts in farming families is unresolved mutual financial claims resulting from sibling buyouts (47.3% of answers, Figure 2).

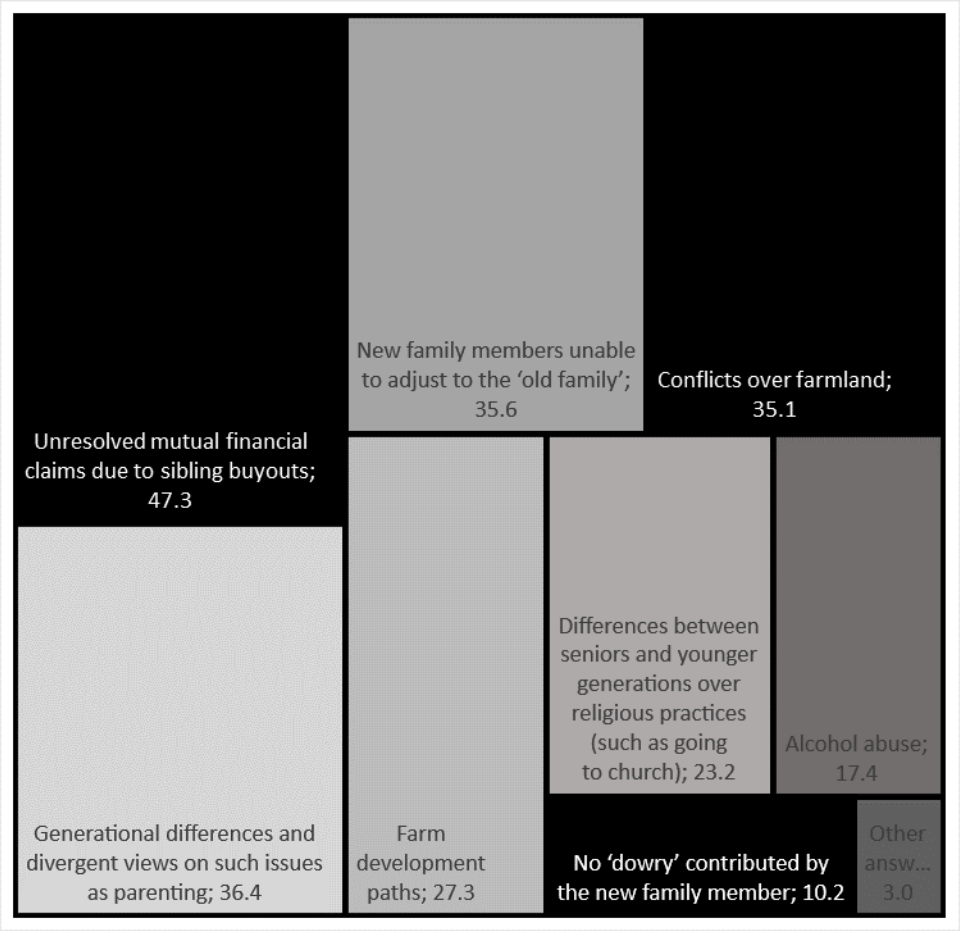


Figure 2. Structure of answers to the question 'What are the primary causes of conflicts in farming families?' Percentages do not total 100% because respondents could select more than one answer (%).

Source: Authors own work, original work based on the survey (N = 596).

The results show that those who indicated 'Unresolved mutual financial claims due to sibling buyouts' also selected 'Conflicts over farmland'. The second most popular cause of conflicts was 'Generational differences and divergent views on such issues as parenting' (36.4%). 'New family members unable to adjust to the "old family"' was selected almost just as often (35.6%). The economic factors that disrupt family relationships include conflicts over farmland (35.1%), mutual financial claims due to sibling buyouts, and the absence of a dowry.

Sibling buyout methods

The respondents were asked 'Have you heard of someone receiving a buyout payment from a sibling who inherited a farm?' About 52% chose the affirmative answer (Figure 3). Every fifth respondent was unable to tell whether they had heard of such a situation.

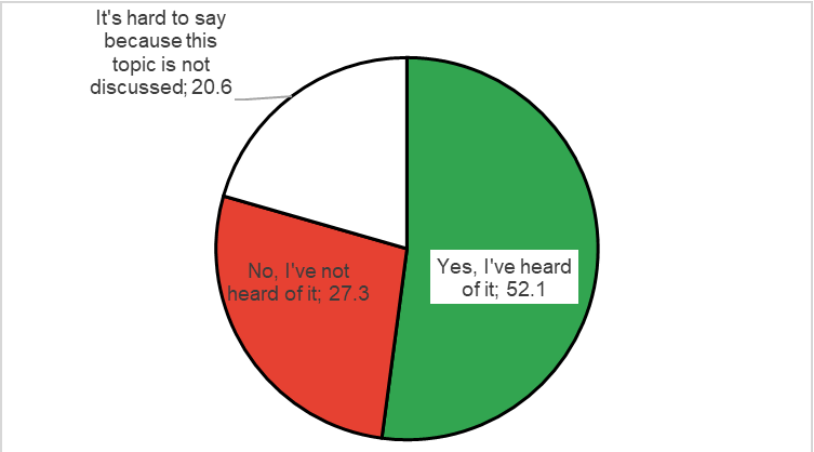


Figure 3. Structure of answers to the question 'Have you heard of someone in your municipality receiving a buyout payment from a sibling who inherited a farm?' (%).

Source: Authors own work, original work based on the survey (N = 545).

About a third of the sample had never heard about a sibling receiving a buyout payment from the successor (27.3%). One in five found it difficult to answer the question, mainly because the problem is not discussed in casual conversations (20.6%, Figure 3). People still do not talk about such weighty issues with friends and family in the twenty-first century. Possibly, the financial aspect of a sibling buyout from the farm can be difficult to discuss with strangers.

The buyout usually involved a single payment equivalent to the non-succeeding sibling's share of the farm estate (48.9%). The second most common answer was buyout in instalments (45.6%, Figure 4).

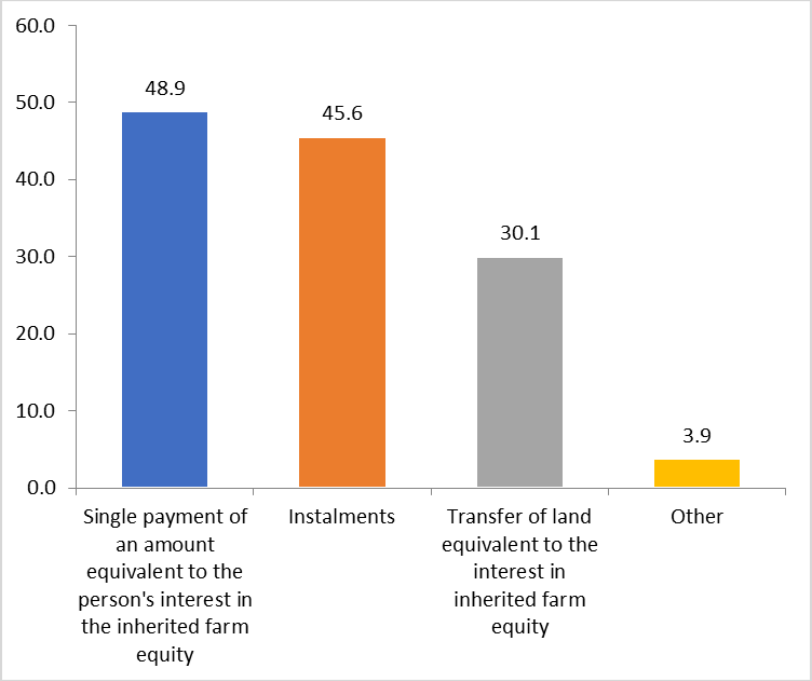


Figure 4. Structure of answers to the question 'What form of sibling buyout was used?' (%). Percentages do not total 100% because respondents could select more than one answer.

Source: Authors own work, original work based on the survey (N = 309. Only those respondents who reported having heard of sibling buyouts in their municipality).

Transfer of land equivalent to the interest in farm equity was the least popular option (30.1%). The data in Figure 4 shows that the transfer of land is chosen the least often to buy out siblings. Other answers included help with building a house, buying a flat, and expanding a business. Some buyouts were hybrid, combining a transfer of some land and instalments, for example. The respondents reported other methods as well. Individual answers mentioned a transfer of a building plot. In one case, the buyout was financed with money from the sale of some farm plots.

The respondents were asked whether financial matters linked to farm inheritance had been resolved properly in their families. In the overall sample, financial issues related to farm inheritance were resolved for half the cases (50.7%, 302 people). One-fifth believed they were yet to be handled (19.3%). Every fourth respondent was unable to answer the question (25.5%). Rural residents more often considered farm inheritance finances handled properly than respondents from cities (54.5% and 40.7%, respectively, Figure 5).

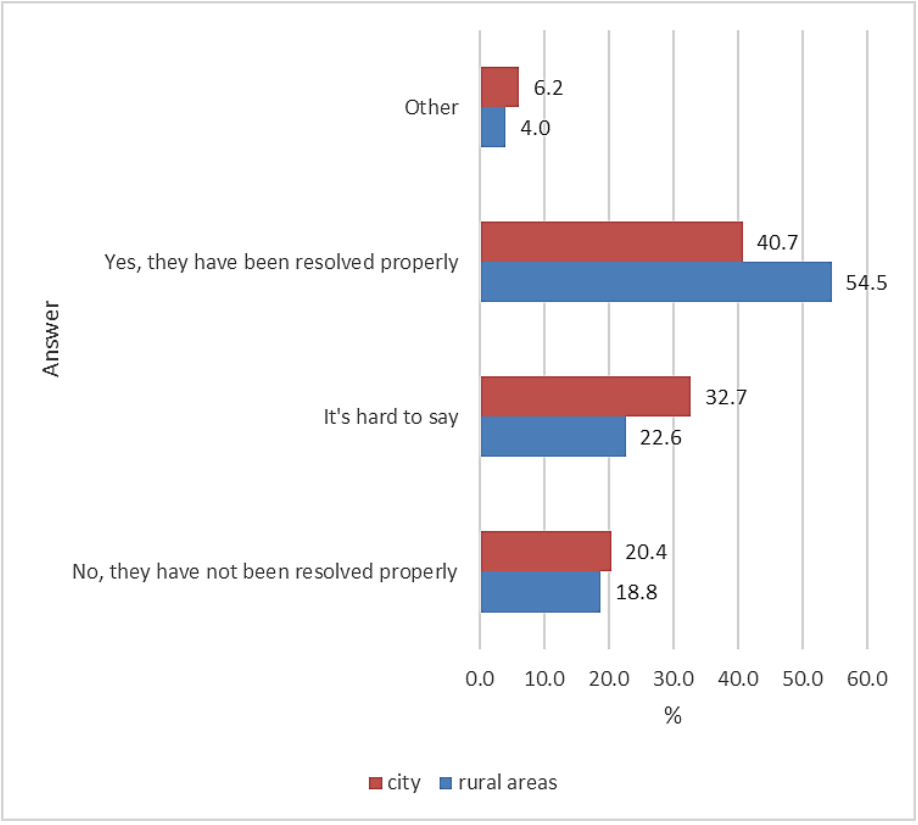


Figure 5. Structure of answers to the question 'Have farm inheritance finances been resolved properly in your family?' Answers by place of living (%).

Source: Authors own work, original work based on the survey (N = 596).

Urban residents were more often unable to say whether farm inheritance finances had been resolved properly in their families (32.7%, Figure 5).

The survey suggests that women were more unsure whether family financial issues linked to farm inheritance had been resolved properly (Figure 6). The 'It's hard to say' answer was selected by 27.3% of the women and 21.1% of the men.

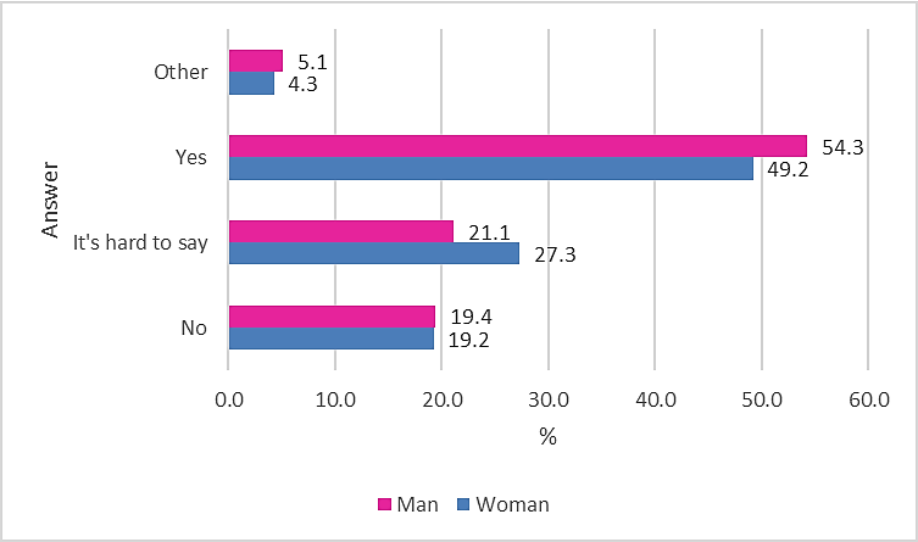


Figure 6. Structure of answers to the question 'Have farm inheritance finances been resolved properly in your family?' Answers by sex (%).

Source: Authors own work, original work based on the survey (N = 596).

More than half of the men reported that farm inheritance finances had been resolved properly in their families (54.3%). Five percentage points fewer women believed so (49.2%, Figure 6).

The financial matters were more often settled in the families of those who were aware of the legitim (56.9%), compared to those who were unfamiliar with the term (44.1%, Figure 7).

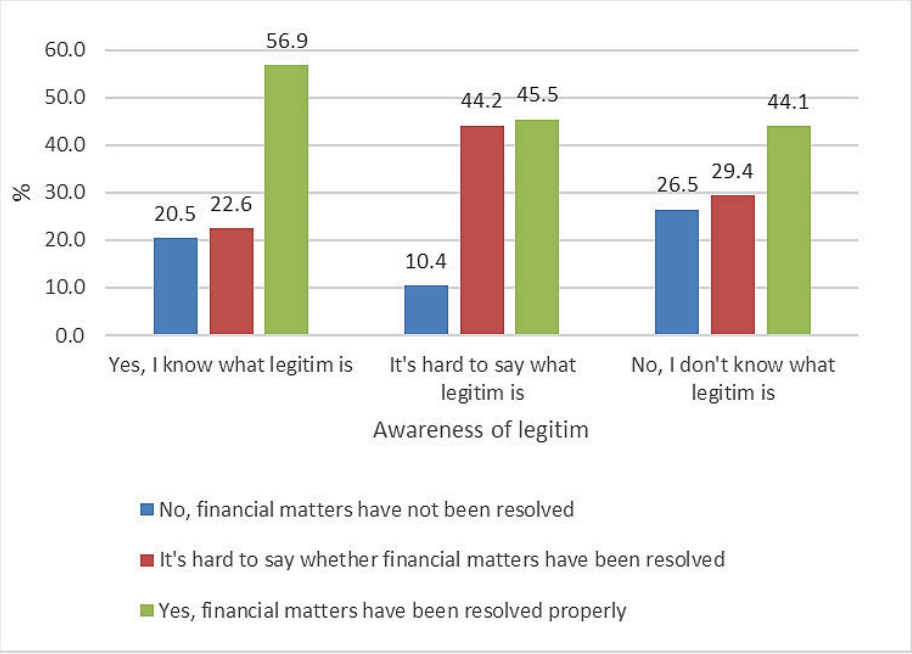


Figure 7. Satisfaction with how farm inheritance finances were settled in groups of respondents with different levels of awareness of legitim (%).

Source: Authors own work, original work based on the survey (N = 569).

Persons who received part of the divided farmland were more satisfied (about 66%) than those who received money (54%, Figure 8). Possibly it is because the value of land constantly increases while the value of money decreases with price inflation.

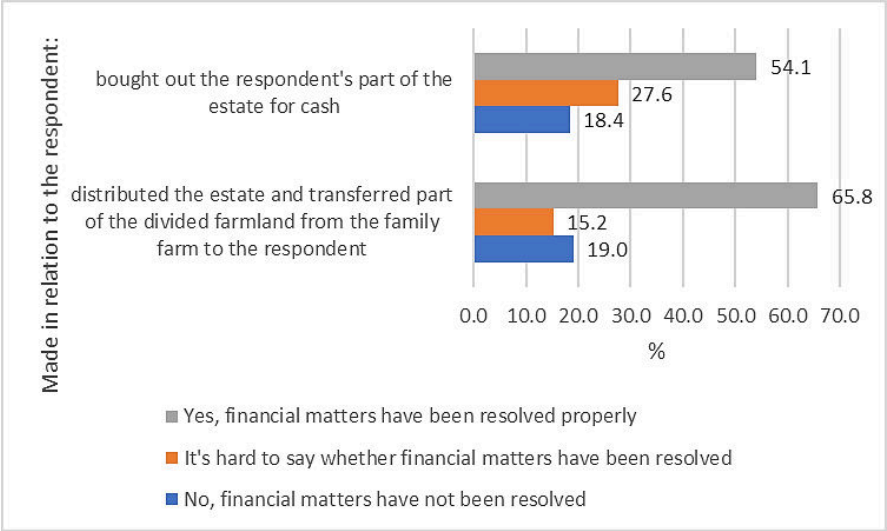


Figure 8. Satisfaction with the settlement of financial matters linked to farm inheritance in groups with experience of different buyout methods (land and cash): people who received land or who were bought out (%).

Source: Authors own work, original work based on the survey (N = 458).

People who bought siblings out with cash and transfer of land were similarly satisfied with the settlement. The survey shows that about 70% of the respondents who bought out siblings considered the issues of farm inheritance resolved properly (Figure 9). When compared, Figures 8 and 9 clearly demonstrate that people who made transfers to siblings (Figure 9) were more satisfied than siblings who were bought out (Figure 8). This suggests that off-farm siblings are usually dissatisfied with the compensation they receive.

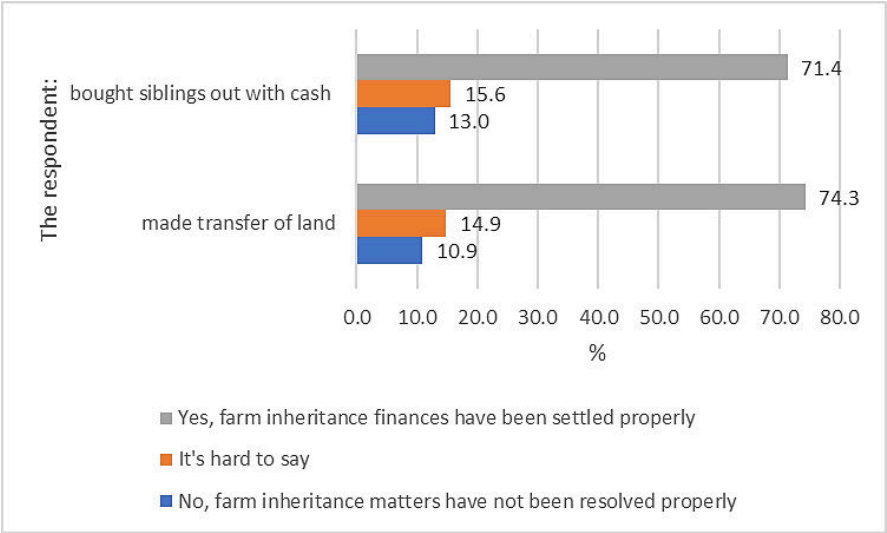


Figure 9. Satisfaction with the settlement of financial matters linked to farm inheritance in groups with experience of different buyout methods (land and cash): people who bought out siblings/child or transferred land to siblings/child (%).

Source: Authors own work, original work based on the survey (N = 178).

Respondents who stayed on their parents' farm (on-farm) were more satisfied with how the financial aspects of farm inheritance were handled than off-farm heirs (Figure 10). The answer 'Yes, financial farm inheritance matters have been resolved properly' was selected by 54% of the respondents who stayed on the farm and 42% of the respondents who left the parents' farm. Note that every fourth non-succeeding respondent believed that matters related to farm inheritance had not been resolved properly. It is double that of those who stayed on the farm (12.9%, Figure 10).

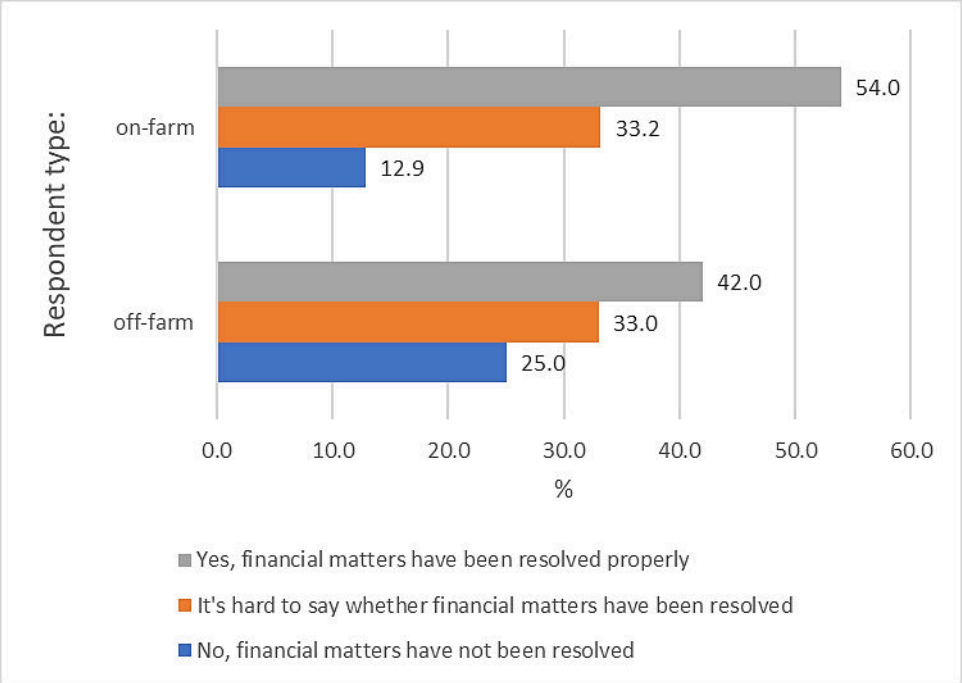
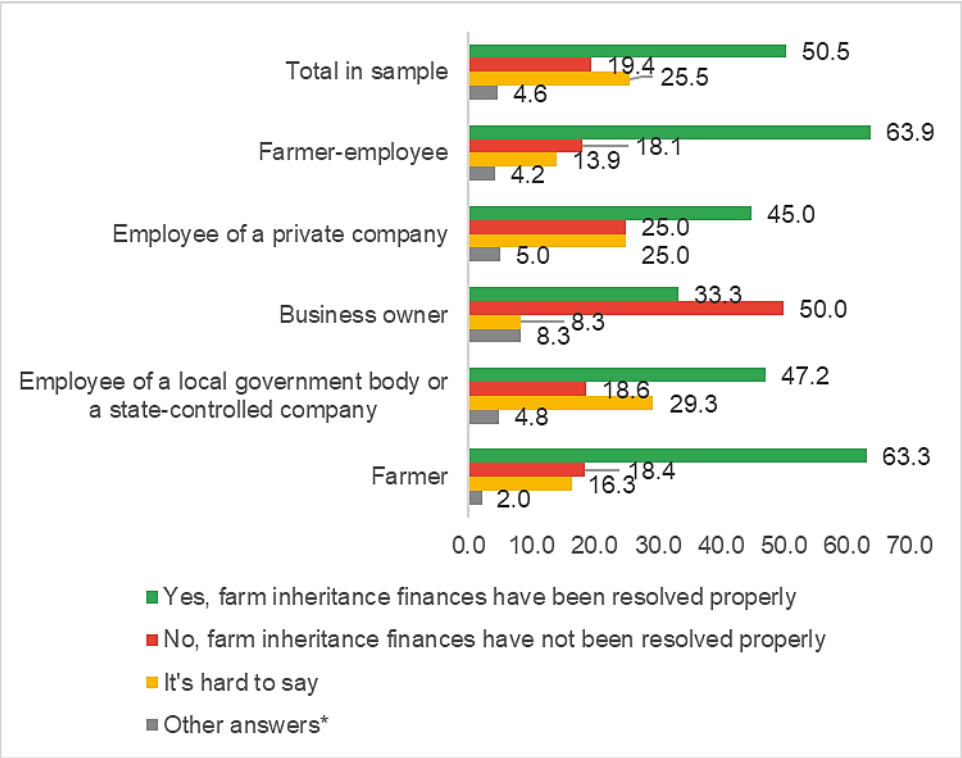


Figure 10. Satisfaction with how farm inheritance finances were settled in on- and off-farm groups of respondents (%).

Source: Authors own work, original work based on the survey (N = 178).

Financial matters linked to farm inheritance were resolved properly mostly in the opinions of farmers (63%, Figure 11). Businesspeople were the least satisfied with how financial matters related to farm inheritance were resolved in their families (33%).



Other answers*: not yet, pending completion, the matter has not been discussed yet, no farm inheritance occurred, the matters remain unresolved, the problems are being resolved, the farm has not been distributed yet because the parents still farm the land.

Figure 11. Structure of answers to the question 'Have farm inheritance finances been resolved properly in your family?' by employment (%).

Source: Authors own work, original work based on the survey (N = 545).

Sibling buyout by successors to the farm

About 56% of the 596 respondents (332 people) left the parents' farm. Those who stayed were asked whether they bought off their siblings. On-farm respondents settled the buyout mainly through the division and transfer of farmland (44%, Figure 12) and less often by paying them the amount equivalent to the value of their share of the estate (33.6%, Figure 12).

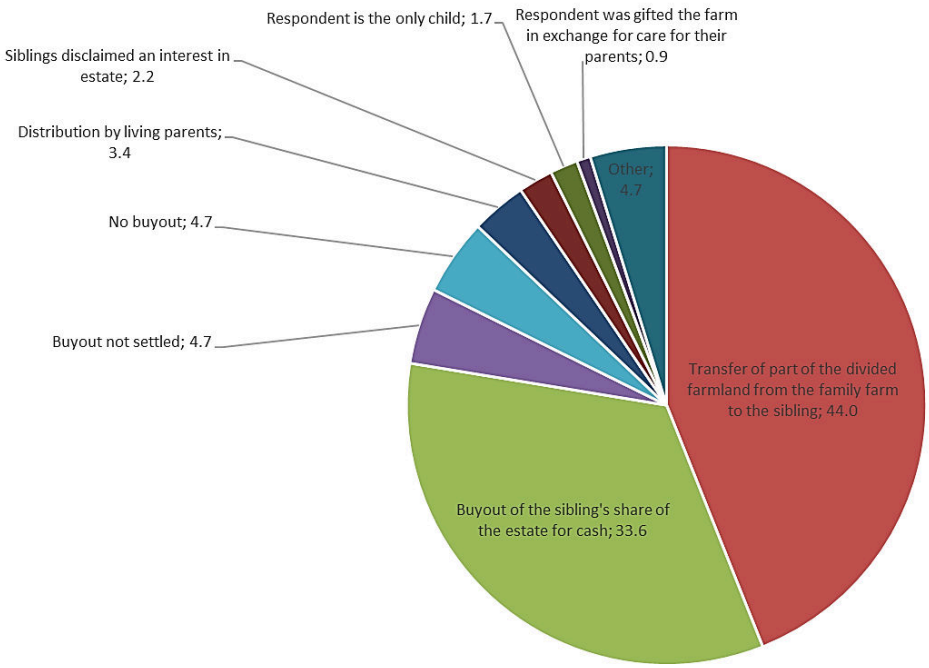


Figure 12. Structure of answers concerning buyout by succeeding siblings (%).

Source: Authors own work, original work based on the survey (N = 232, on-farm heirs).

The survey shows that in several cases, the parents applied an *inter vivos* distribution of the farm estate (3.4%). They gifted off-farm children, for example. Parents often gift building plots to children who leave the family farm. By making specific donations to children who left the family home, the parents relieve the succeeding sibling from obligations towards their brothers and sisters.

Only children (1.7%) had no issues with estate distribution, farm included. The sample included some respondents (0.9%) who did not engage in buyout procedures because they were gifted the farm in exchange for caring for their parents. The results show that siblings rarely disclaimed an interest in a farm estate (2.2%).

Some respondents reported not buying out their siblings (4.7%). A few gave reasons. One of them inherited poor-quality land, 'class 6, and the farm had to be modernised.' Therefore, they had no funds to buy out the siblings. Another participant clarified that their 'siblings got building plots, and I got eight hectares of arable land'.

The study shows that in some cases, the buyout has not been settled and is not discussed by the family (4.7%). Sometimes it was because the farm had not yet been handed down. The results revealed that some inherited farms are in debt. To keep it, the respondent had to pay the debt they inherited along with the agricultural land. Often, the matter was not settled because the farm had not been transferred.

The respondents also selected other answers (4.7%). Some reported that the topic had not been discussed in the family or settled. Another respondent shared that the parcels had been sold, and the proceeds divided among the heirs. Testate succession was reported in just one case.

Buyouts of non-succeeding respondents

Some respondents represented siblings who had left the farm. This group was less satisfied with the buyouts.

Off-farm respondents were asked to provide the method of sibling buyout they experienced. Most of the 325 answers reported transfer of some divided farmland distributed from the family farm estate (48.6%). The second most common answer was payment of amounts equivalent to the value of the respondent's interest in the estate (30.8%).

The survey shows that the respondents who received no buyout payments (10.5%) referred to respecting the deceased parents' last will regarding the succession. One respondent shared that ‘the youngest sister took over the farm in exchange for taking care of the parents. None of the remaining children expected any repayment.’ Another respondent wrote that she ‘was given several thousand złotys of buyout from the parents while a brother inherited the entire farm worth several hundred thousand złotys and movables worth several dozen thousand’. The latter case exemplifies unequal treatment of children by their parents. Some respondents who received no buyout compensation indicated that they had not wanted to stay on the farm. They left it intentionally and did not expect any compensation from the succeeding siblings.

Those respondents who reported that their buyout was not settled properly (3.4%) clarified that the topic of buyout ‘is not discussed’ or they ‘have not talked about the farm distribution yet’. In one case, the sale of the farm was discussed, and so the matter has not been resolved yet.

Non-succeeding siblings received gifts in-kind (3.4%), notably a flat bought by the parents or a building plot. One person wrote that they ‘can count on the brother's help with anything as long as they live.’ Another respondent received a ‘small dowry’ but did not specify the nature of the gift.

Those who left the parents' farm reported receiving part of the divided farmland (48.6%, Figure 13). Buyout payment in cash was less common (30.8%).

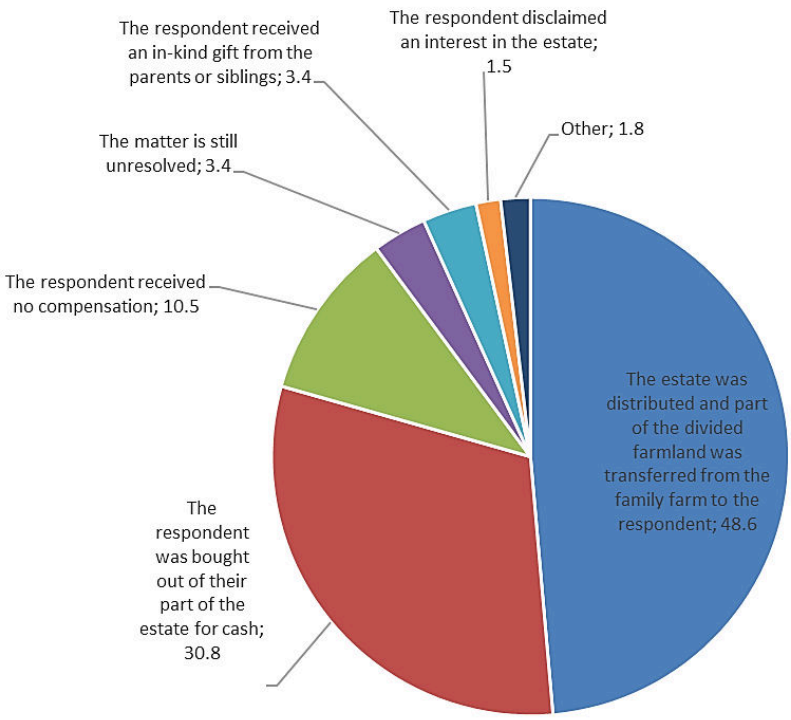


Figure 13. Farmland division and distribution and buyouts of off-farm respondents (%).

Source: Authors own work, original work based on the survey (N = 325).

Farmland division is common in southeastern Poland and Zachodniopomorskie Voivodeship. Buyouts are typical of central Poland (Figure 14).

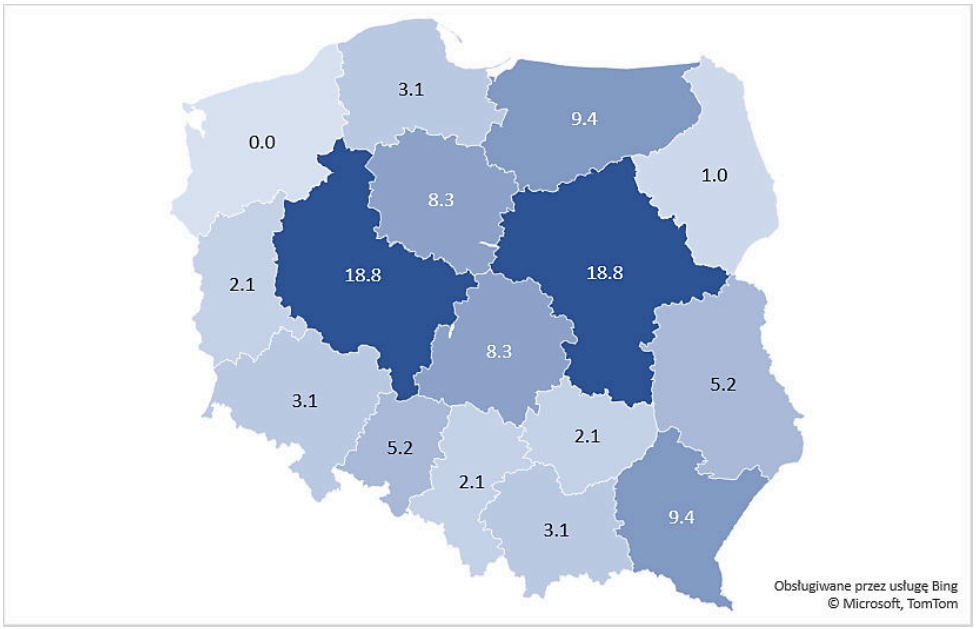


Figure 14. Regional structure of answers concerning buyout of respondents' shares of estate for cash (%).

Source: Authors own work, original work based on the survey.

Buyout for cash was reported mainly in Wielkopolskie Voivodeship (30%). It was the least popular in Zachodniopomorskie and Małopolskie (7.1%), followed by Śląskie and Świętokrzyskie (8% each).

Some respondents described extreme unfair treatment during the farmland division and distribution. One answer shows that the decisions are not always impartial. One respondent wrote that she 'was given several thousand złotys of buyout from the parents while a brother got the entire farm worth several hundred thousand złotys and all movables worth several dozen thousand'. I agreed to the notarial deed so that my mother could get sickness allowance. The brother does not feel inclined to buy me out.' Some respondents noted that the succeeding sibling had more responsibilities in terms of caring for their parents. The farm went to the youngest sister, who undertook to provide care for the parents. None of the remaining sisters expected any compensation'. 'The youngest brother got the farm "for care"'.

The respondents were asked, 'Have you heard of someone disclaiming inheritance of a part of a farm in a notarial deed provided they are compensated in the future, but they have never been compensated?'. There were 17.6% of affirmative answers. More than half of the respondents (51.5%) have never encountered such a situation. Every third respondent found it hard to answer the question (30.9%).

Seven out of ten participants were familiar with how legitim works (69.4%). Eligibility for legitim from the successor was news to 17.6% of the respondents. About 13% of the sample found it hard to answer the question.

More than one-fourth of the respondents have heard of legitim court proceeding in their neighbourhood (26.3%). A majority of the respondents did not notice legitim cases in their surroundings (57.4%). Approximately one in six people could not answer this question (16.3%).

Some respondents shared details of legitim procedures with which they were familiar (15%). One of the most telling examples involves a succeeding person's siblings who remembered their eligibility for legitim after living abroad for many years and following the death of their parents. One of the respondents noted that 'the farm was large, and the land gained significant value. The conflict is over money'. This meaningful perspective shows that the increase in land prices makes voicing legitim claims worthwhile. The later it is made, the better for the petitioner. According to the respondent, 'despite making the buyout payments, the greedy siblings petitioned the court requesting a legitim, but lost'. Another case involved a farm that was handed down to one son, while the other received cash and a plot to build a house. After both parents died, the non-succeeding son petitioned the court for a legitim despite having received financial support from his parents.

The respondents reported situations in which a non-succeeding son petitioned for legitim despite having received a new house from the parents. The brother demanded a legitim after 20 years of the farming sibling's substantial investments in the farm. In a different case, a legitim petition was made after the successor started selling off the farm. Their siblings demanded a legitim because 'there was an unwritten agreement that he was supposed to run the farm and

hand it down to his children'. Sometimes the farm had to be liquidated to pay out legitim. There was 'an auction of property under debt enforcement proceedings to pay legitim debts to siblings'.

In one case, 'legitim was demanded by siblings of a deceased owner whose wife gifted her nephew the farm'. Emigrants often demand a legitim after a long time abroad or in a city, and after their parents die. Sometimes, a conflict 'over everything' erupts after parents die despite previous oral agreements between them and the children.

It also happens that children who moved to a city received regular yet undocumented payments from their parents as a 'buyout'. When the parents die, they demand legitim from the succeeding sibling.

Life holds the most interesting stories. One respondent recalled a story of the youngest son who inherited a farm. He died childless after several decades and bequeathed the entire farm to his sister's son. His other siblings demanded a legitim.

In a different family, 'a brother was gifted the entire farm so that the father could be granted a farmer's pension'. After both parents died, his sister demanded a legitim. Yet another successor failed to provide care for his parents. The siblings demanded a legitim, which they spent on care services for the parents.

Discussion and conclusions

The survey reveals that the primary cause of family conflicts is unresolved mutual financial claims stemming from sibling buyouts. Nearly half of the respondents have heard of siblings receiving buyout payments from the successor. In the overall sample, financial issues linked to farm inheritance were resolved properly for half of the cases. Men were more often satisfied with buyouts than women. The financial matters were more often settled in the families of those who were aware of the legitim compared to those who did not know the term. On-farm respondents settled the buyout mainly by transferring land, and less often by paying their siblings the amount equivalent to the value of their share of the estate in cash. More than one-fourth of the respondents have heard of legitim court proceeding in their neighbourhood.

The article contributes empirical observations on the sources of conflicts in farming families. Those respondents more familiar with the law and the notion of legitim (a court-ordered compensation for being disinherited) are the most satisfied with how estate matters are resolved in their families. Typically, the succeeding sibling is more satisfied with how financial issues linked to the farm inheritance have been resolved. Those who do not inherit the farm are bestowed with some land to build a house or funds to buy a flat in a city. The same happened in New Zealand, where parents tried to compensate non-succeeding children with other assets or opportunities (Keating, Little, 1997). Every tenth respondent received no support linked to

succession in the family farm. Typically, the succeeding sibling is the most satisfied with the financial settlement under farm succession.

It would be beneficial to employ some Western European farm inheritance solutions in Poland. The results show that more than a quarter of the respondents knew about legitim court proceedings nearby. Non-farming heirs often demand legitim from the successors after the parents pass away. It would be desirable to implement the German principle that the sum due to other beneficiaries is reduced by 25% after 10 years of work on the inherited farm.

Western European countries establish laws to ensure the stability and development of family farms. The Polish mechanisms are limited to several specific provisions (Lichorowicz, 2015). One can only hope that the gaps in the Polish agricultural legislation will be addressed quickly and reasonably.

Another interesting solution worth considering is enabling the heirs to appoint a family agricultural land association under estate distribution proceedings. This French tool facilitates the integration of heirs into a family business. In this case, the family that lives in a city help the successor during vacations, for example. A member of the land association is entitled to a portion of the farm's income but not to a legitim. A share in a land association could also hedge a mortgage loan. The latter option might be valuable to persons seeking funding for the purchase of a building plot in the suburbs.

The reason why many successors are sued for legitim is poor knowledge of the law. It is particularly harmful in the case of the deceased person's parents. The heir could be protected against legitim claims if they are gifted the farm in exchange for care. Another mistake decedents make is undocumented financial gifts in cash instead of bank transfers. This way, children who received financial support from their parents file claims for legitim because there is no proof of the gifts.

Limitations and future research

The respondents were anonymous. We were unable to ask for more details on the conflicts caused by the unfair distribution of the estate they described. Although we know the municipality in each case, it would be costly and time-consuming to reach the individuals scattered all over Poland. Furthermore, it is a challenge to obtain answers to questions concerning financial settlements related to farm inheritance. We attempted to investigate individual cases more closely by trying to reach people engaged in such conflicts through the heads of villages. However, they refused to identify families with farm inheritance conflicts. Next, we attempted to build case studies by reaching out to young farmers who benefited from EU support programmes that help with generational renewal in agriculture. Once again, the Agency for Restructurisation and Modernisation of Agriculture refused to share their

addresses protected under the GDPR. Then, we managed to contact several young farmers through the village heads, but there were no conflicts linked to farm inheritance in their families.

Future research will require gaining the trust of rural residents, also by ensuring anonymity, and assuring them their input will be used for research only.

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ORGANIZATION AND MANAGEMENT SERIES NO. 231

HUMAN CAPITAL MANAGEMENT IN A SECONDARY SCHOOL IN VUCA TIMES

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Purpose: Human capital management in a volatile and unpredictable reality poses a challenge for all organisations. This is particularly important in the case of secondary schools, educational institutions preparing young people for final secondary education exam and entry to the job market. The article aims to present the opportunities and limitations related to managing human capital in a school in the context of VUCA, i.e. Volatility (V), Uncertainty (U), Complexity (C) and Ambiguity (A).
Design/methodology/approach: The present discussion is based on the literature of the subject, as well as the expertise and practical experience of the authors, who are academic and secondary school teachers. The article analyses studies on VUCA in Polish and foreign publications, employs quantitative analysis of existing statistical information and monitors trends present in secondary schools.
Findings: The VUCA reality demands a fresh outlook on human capital management in a school with a poor employee succession rate, staff shortages and, sometimes, reluctance to change. In a knowledge-based organisation, VUCA primarily means lifelong learning, investing in new competences, flexibility, openness and creating a well-defined growth vision. For head teachers/school managers, this entails developing a suitable management style, which will be beneficial both for different generations of teachers and a new generation of students, working and learning in a complex reality.
Practical implications: Each educational institution is committed to achieving and maintaining strong results, prestige, and a distinguished reputation in the educational market. Today, the volatile and unpredictable reality requires a novel approach to human capital management and the implementation of a growth strategy which will determine the school's path of development. This also necessitates the introduction of a specific management model.
Originality/value: The present article discusses the problem of human capital management in a complex reality. Headteachers are faced with the challenge of developing a defined vision and management style for their schools. For teachers, this means a new outlook on education, didactics and teaching methods.
Keywords: human capital, secondary school, VUCA.
Category of the paper: viewpoint, literature review.

1. Introduction

Running a school is one of the more important aspects pertaining to the functioning of an educational institution on the educational market. The headteacher's management style determines the future of the school's teaching staff and students, and is affected by such factors as first grade enrolment, educational innovations implemented by teachers or the quality of instruction. In addition, it also includes the method of managing human capital, i.e. school staff.

In Poland, headteachers' responsibilities are stipulated e.g. in the Education Law Act of 14 December 2016 (Journal of Laws 2017, item 59), the Teachers' Charter Act of 26 January 1982 (Journal of Laws 1982, no. 3, item 19), the System of Education Act of 7 September 1991 (Journal of Laws 1991, no. 95, item 425), the Regulation of the Minister of Education of 27 October 2009 on the criteria to be met by a person working as a headteacher or a different managerial position in various types of public schools an educational institutions (Journal of Laws 2009, no. 184, item 1436).

The role of a headteacher gains special importance in the context of human capital resource management in the VUCA reality, characterised by volatility, unpredictability and complexity.

Secondary schools were selected as the subject of this study for a number of reasons. First, it is students who decide if they wish to enrol in a particular secondary school, e.g. a general secondary school, a technical college or a vocational school. In Poland, secondary schools prepare students for the final secondary education examination (*matura*) or for work in an occupation. At this stage, young people become adults and are able to make their own decisions.

The article aims to present the opportunities and limitations related to managing human capital in a school in the context of VUCA, i.e. Volatility (V), Uncertainty (U), Complexity (C) and Ambiguity (A).

The authors formulated the following hypotheses:

1. Human capital management in a school is riddled with uncertainty, unpredictability and ambiguity.
2. As a learning organisation, school must face multiple contemporary challenges.
3. There is no single universal human capital management model for schools.

2. Methods

The article refers to publications on managing human capital in school, discussing problems such as school feminisation, staff shortages, generational diversity, knowledge management or teacher upskilling. The issues are global in scope and need to be handled by the authorities which run schools.

The VUCA reality in schools is far from a novel phenomenon. There are many studies on the aspects of the functioning of educational institutions. The publications attempt to provide solutions in crisis situations.

The present article discusses selected issues faced by secondary school headteachers in VUCA times. The authors highlight matters pertaining to the development of teachers' competences, investing in digital knowledge and skills essential for innovative teaching. Opportunities and limitations related to teaching staff knowledge management are also outlined.

The study also identifies human capital management areas both directly controlled by the headteacher (e.g. encouraging teachers to study further, implementation of educational innovations or experiments, teamwork, knowledge sharing) and those beyond the headteacher's control, such as the aging faculty or staff deficiency. It is also a reflection on constructing a human capital management model which would be compatible with the unique characteristics of secondary school.

The authors present VUCA-related problems from the perspective of practicing teachers. There is a scarcity of publications examining the volatile realities of secondary schools and the issues requiring attention from teachers and headteachers.

The following methods were applied in this article:

1. Analysis of texts and studies on VUCA published in Poland and abroad.
2. Quantitative analysis of existing statistical information.
3. Monitoring trends in secondary schools.

3. Human capital at school − characteristics and possibilities

"Human capital" eludes a single definition. As an interdisciplinary term, it is present in many sciences. Nevertheless, when analysing this concept, one may notice certain tendencies. Firstly, human capital is the most fundamental asset of every organisation regardless of its line of business. Secondly, human capital is an investment in employees, aimed at building a team of experts in a given discipline. This is of particular importance in the context of working in a secondary school. Thirdly, human capital is unique in each organization, since it is generated by persons characterised by individualism.

J. Fitz-Enz described human capital in the context of economic activity as a combination of the three following factors:

1. traits contributed by a human being: intelligence, energy, positive attitude, credibility, involvement,
2. the employee's learning capabilities: mental receptiveness, imagination and creative abilities, as well as common sense,
3. employee's motivation to share information and knowledge: team spirit and focus on the target (Fitz-Enz, 2001, p. 9).

A school is a learning rather than economic organisation (Fazlagić, 2005; Fura, 2007; Rabiej, 2013), which means that its employees should invest in their knowledge and skills. Article 12 of the Teacher's Charter stipulates that the teacher should broaden their general and vocational knowledge using the right to participate in all forms of professional training at the highest level (Teacher's Charter Act). Therefore, the headteacher should enable the teacher to develop and improve themselves, since it also affects the quality of instruction. Studies by Hyseni Duraku, Blakaj, Shllaku Likaj, Boci, Shtylla showed that early-education teachers' knowledge and skills had increased after the completion of training and that such projects support personal and professional development of the faculty (Hyseni Duraku, Blakaj, Shllaku Likaj, Boci, Shtylla, 2022). Graduating from a university is prerequisite for employment, although it is no longer sufficient. Today, it is a stepping stone to further skill improvement, updating knowledge on teaching methodology or a broadly-defined classroom work. However, the three factors referred to by Fitz-Enz strongly correspond to the human capital management process in a secondary school. Each employee carries a specific set of characteristics, competence and skills. In the case of vocational schools, this list should also include practical knowledge. Commitment and attitude to work in an organisation providing services to young people often determine the quality of a given educational institution. Employee's abilities translate into the effectiveness of teaching, adaptability, flexibility and openness to the need to enhance their competences. Working in a school entails participation in subject-based and interdisciplinary teams, which also means sharing knowledge and experience. Otherwise, it would be impossible to achieve the expected outcomes. Therefore, encouraging employees to work in teams should be one of the responsibilities of a headteacher (Polega, Neto, Brilowski, Baker, 2019).

As a learning organisation, a secondary school has specific features (Fig. 1).

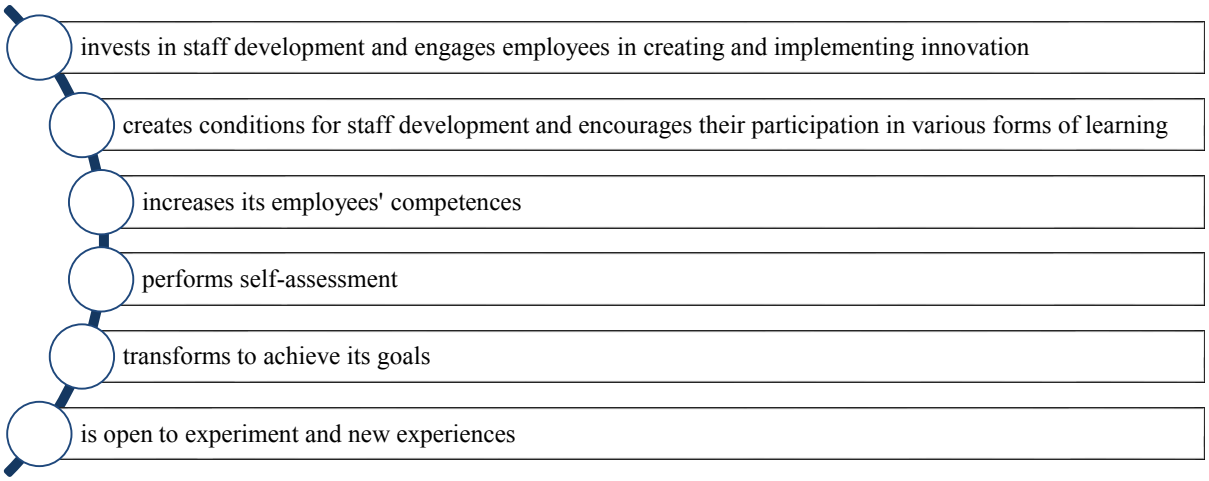

Figure 1. Selected features of a learning organization.

Source: Illustration by the authors, based on Pasieczny, Rosiak, 2021.

In a school, pedagogical innovations are innovative solutions implemented by teachers to improve work quality, support students in learning (Budirahayu, Saud, 2023) and facilitate their educational and job-related decisions. This also includes searching for new teaching methods (Çelik, Baturay, 2024). Introducing innovations entails effort and commitment on part of the teacher. Yet, every educational institution needs an innovative approach to teaching and working with students. This is particularly important in a secondary school, which is by definition intended to prepare a young person for tertiary education or entry on the job market.

Teacher's self-assessment is an intentional and systematic collection of information on the teacher's own work.

"Self-evaluation is intentional and systematic collection of information on one's own work. It is necessary to compare the results with the expectations of other participants in the education process, i.e. school as a workplace (management and other teachers), parents and, last but not least, students" (Kapuścińska-Kozakiewicz, 2021).

Self-evaluation is relevant for the teacher's further professional development (Ross, Bruce, 2007), constitutes a key component of managing a school, affects the efficiency and performance of teaching staff, as well as its professional development (Hašková, Lukáčová, Noga, 2019).

At school, openness to experiments and new experiences lies at the core of VUCA. This involves the introduction of new methods of working with teenagers, methodological experiments, teaching young people to think critically, openness to change, creativity. Another aspect is of this openness is encouraging teachers to create interactive lessons to enhance their digital skills. Thus, secondary schools face a further challenge of learning to manage change (Gayef, 2014; Niculescu, Voicu, 2018).

Managing teachers and investing in their expertise contributes to an improvement in teaching quality, enables extensive support for students in their educational and job-related choices, grows their key competences and the ability to cope in a changeable and demanding environment.

4. Human capital at school – challenges

According to data from the Ministry of National Education, as of 10 October 2024, Polish schools employed 690,821 teachers − 580,387 women and 110,434 men − highlighting strong gender imbalance in the profession, with women making up 84% and men just 16% of the teaching workforce (Ministry of National Education…, 2024).

In Poland, and elsewhere, teaching as a job has the face, personality and individuality of a woman. In other countries, teaching is considered a female profession (Gromkowska-Melosik, 2013; Guy-Evans, 2024). The feminisation of the profession is global in scope (Piróg, Wiejaczka, 2020). Primary schools, in particular, face a shortage of male teachers.

Additionally, many schools are managed by women. Based on studies by Can Coco He, female leaders enhance team cohesion (He, 2025). Research by Al-Mughyirah, Abunaser, Al-Taher, Al-Otaibi, in Saudi Arabia demonstrates that every female leader has a unique method of working with people, which reflects her vision that she attempts to promote in school culture (Al-Mughyirah, Abunaser, Al-Taher, Al-Otaibi, 2023).

Teachers' age is one of the challenges for education in Poland. The mean age of a female teacher is 45; the corresponding figure for male teachers is 47 (according to data from the Ministry of National Education…, 2024). They are people several or over a dozen years before retirement, with experience and practical competences that could be transferred to younger generations of teachers, were it not for the issues with generational succession in Polish schools. The older generation has well-developed teaching methods, yet they may find challenging working with modern technologies such as artificial intelligence or the use of interactive platforms (Ratiu, 2023; Fahmiyah, Utami, Ningrum, Fakhruzzaman, Pratama, Triangga, 2023). Currently, Polish schools are witnessing a clash between multiple generations of teachers with a young generation of students raised as digital natives. On the one hand, the mature faculty have stable personal lives and good rapport with teenagers. However, it should be noted that new technologies used by young persons may present a difficulty for older staff. As a result, leading a multi-generational team means balancing the expectations of both faculty and students. Undoubtedly, it is a taxing situation for headteachers, who need to show understanding and adopt an appropriate management style. Nonetheless, generational diversity also creates enormous added value for every organisation (Bailey, Owens, 2020), fostering the capacity to recognize and utilize the varied capabilities across generations (Pitout, Hoque, 2022).

Staff shortages are another problem in Polish secondary schools. Figure 2 shows the number of teachers in secondary schools in the years 2021-2025.

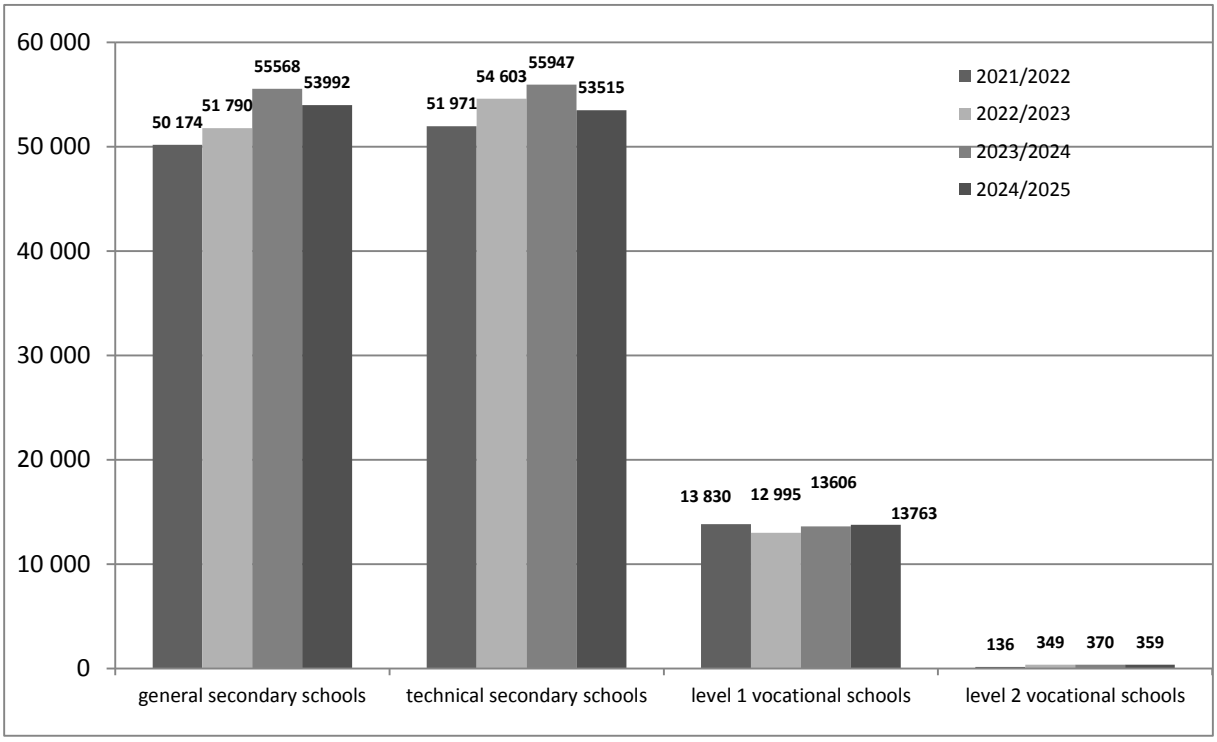

Figure 2. Number of teachers in secondary schools in 2021-2025 (school positions).

Source: Illustration by the authors, based on: *Edukacja w roku szkolnym 2022/2023 (wyniki wstępne), GUS*, https://stat.gov.pl/obszary-tematyczne/edukacja/edukacja/edukacja-w-roku-szkolnym-20222023-wyniki-wstepne,21,1.html, 12.07.2025; *Edukacja w roku szkolnym 2024/2025 (wyniki wstępne)*, GUS, https://stat.gov.pl/files/gfx/portalinformacyjny/pl/defaultaktualnosci/5488/21/3/1/edukacja_w_roku_szkolnym_20242025_wyniki_wstepne.pdf, 12.07.2025.

The number of teachers in all types of schools is decreasing. Teacher scarcity most severely affects level 1 and 2 vocational schools. The situation is caused by several factors, e.g. low pay, very low prestige of the profession, burnout, stress, high accountability for student's results, and working conditions. The lack of well-educated and qualified teaching staff can be observed globally (Global report on teachers…, 2024; Symeonidis, Guberman, Cooper, 2025). This issue creates challenges for headteachers, particularly in secondary schools, forcing them to adopt an extremely flexible approach to managing human resources, which involves hiring retired teachers (especially teachers of vocational subjects), encouraging working teachers to commence post-graduate studies, hiring teachers working for other schools to work part-time, introduction of flexible timetables or hiring university students to teach classes.

5. VUCA and the reality of Polish schools

The acronym VUCA stands for volatility, uncertainty, complexity and ambiguity. In order to function on the educational market, perform well and be recognisable, every organisation, including school, must respond quickly to changes and implement them, deploy a specific human capital management style, allowing the organisation to work faster, more easily and more effectively. This also involves building a growth strategy for the school on the basis of several pillars, which include:

- competences,
- access to new technology,
- life-long learning.

Among key competences of the management staff and teachers in a secondary school are:

- the ability to make decision flexibly and adapt quickly to new conditions,
- communication skills,
- the ability to create teams,
- motivation to work (Tokarski, 2024).

In the VUCA world, it is imperative to manage competences in a way which will make the educational institution a recognisable brand to all stakeholders, both internal and external. This means selecting the right staff, managing through results, conducting appraisals, developing human resources and managing payroll (Kacała, Kacała, 2013).

VUCA also necessitates investing in new technologies and the students' and teachers' ability to apply them. In a secondary school, which prepares young people for the job market, access to the digital world and its responsible use is a basic core skill. However, if its mission is to succeed and yield benefits, teachers must be trained and classrooms properly equipped. Technology is a powerful tool which may support education, help teachers create didactic materials and offer a new way to learn and cooperate (How Has Technology…, 2024). Education must reflect and adapt to the new reality so as to successfully prepare students for life, and the teaching staff should be able to use modern technology effectively (Kiryakova, Kozhuharova, 2024).

Life-long learning is a competence which has gained significance in the VUCA reality, affecting all human activities. Even the best school will fail to meet students' and teachers' expectations if it does not respond to changes in the world, remain flexible in teaching methods or provide young people with suitable competences. VUCA is a concept describing a specific reality but for schools it primarily means a new outlook on managing the institution and human capital.

6. Knowledge management and its use in the context of Polish secondary schools

Knowledge management is another term which does not have a single definition. Assuming that a secondary school is an organisation wherein knowledge is a fundamental component, we may argue, in line with P. Murray and A. Myers, that knowledge management is a sum of processes enabling the creation, dissemination and use of knowledge to advance the organisation's goals (Jagielski, 2018, p. 101).

For a secondary school, the goals include: well-qualified teaching staff, final secondary education exam results and first-grade enrolment. As knowledge-based organisations, school make an effort to maximize intangible resources on their path to systematic growth. In this type of organisation, intellectual capital is a source of competitive advantage (Skrzypek, 2014).

On an employee level, benefits related to knowledge management mainly include:

- constant growth and increase of competences,
- forming a bond with the organisation to keep staff turnover to a minimum,
- easy access to sources of knowledge, translating into streamlined and more efficient work,
- saving time required to access the desired data,
- creativity, leading to generating new value for the organisation,
- boosting employees' self-esteem, fostering mutual trust,
- self-realisation,
- a sense of belonging to the organisation, forming, maintaining and reinforcing long-term bonds with staff,
- being satisfied with work,
- increasing employee competitiveness on the job market (Stachowska, 2020).

All of the above elements are reflected in practice at schools. Table 1 present possible benefits of knowledge management in reference to the faculty, together with its capabilities and limitations.

Table 1.
Capabilities and limitations related to knowledge management in reference to a school's teaching staff

S. Stachowska*	**Capabilities**	**Limitations**
Constant growth and increase of competences.	Participation in training and courses. Completing a post-graduate programme. Attaining a doctoral or higher degree.	Insufficient funds, raising competences sometimes unrelated to school requirements, increasing competences through a post-graduate programme, training, etc. does not translate into compensation.

Cont. table 1.

Forming a bond with the organisation keeps staff turnover to a minimum.	A healthy atmosphere in the school, incentive pay, cooperation with parents and the school's external environment.	Awarding an incentive pay is the exclusive right of the headteacher. The incentive pay is not an obligatory part of a teacher's compensation. This bonus is discretionary in nature.
Easy access to sources of knowledge, translating into streamline work and its higher efficiency,	Access to the Internet, educational and e-learning platforms, the use of school library resources.	No access to broadband Internet for teachers and students, lack of the ability to use applications designed for teachers.
Saving time required to access the desired data.	The ability to use artificial intelligence, access to information available on school platforms. The use of Teams.	Lack of the AI skills and knowledge, limited use of Teams.
Creativity, leading to generating new value for the organisation.	Implementation of new methods and forms of teaching, as well as experimenting on them. Collaboration with other teachers, flexible approach to change.	Change indicates hardship and reluctance; new solutions are time-consuming labour-intensive.
Boosting employees' self-esteem, fostering mutual trust.	Good communication between staff and headteacher, and among teachers, clear recruitment criteria, onboarding.	Barriers to communication, e.g. physical barriers (crowded classrooms), language barriers (working with teachers and students from other countries), absence of defined onboarding principles.
Self-realisation.	Personal and professional growth boosting motivation.	No training, webinars or other forms of teacher education matching the staff's needs, inability to cope with stress, lack of motivation, burnout.
A sense of belonging to the organisation, forming, maintaining and reinforcing long-term bonds with staff.	Maintaining good contacts with all staff, team-building events, fostering sense of security.	Potential problems include lack of acceptance and appreciation for teachers' work, no opportunity to speak one's mind openly, mobbing, discrimination, lack of appreciation for team-building initiatives.
Being satisfied with work.	Contentment with one's work, managing and coping with stress, maintaining a work-life balance, creating a positive atmosphere at work.	Unfavourable atmosphere at work, lack of transparency when making decisions, obstacles to growth and self-improvement, inability to keep work-life balance.
Increasing employee competitiveness on the job market	For a teacher, higher qualifications means better employability, e.g. in teacher-training organisations or other institutions, as well as greater opportunities to start one's own business.	Teachers leaving the school in favour of other schools, institutions or jobs, causing staff shortages.

Source: Stachowska, 2020, p. 41.

Given that the school needs to function in a volatile and unpredictable reality, we should pay close attention to all of the above elements. Still, the headteacher (who has a double role as a manager and faculty member) will be unable to cope with some of its aspects without proper support from both state and local government. School needs a broadly-defined change and the capability to adapt to a difficult reality. Otherwise, it will be unable to achieve its basic goal of preparing a young person for existence in the world of VUCA.

7. Results

Managing diverse human capital in a secondary school is a problematic task to be faced by the management of the educational institution. The VUCA reality, with is unpredictability and ambiguity, has exposed several inadequacies.

First of all, the aging faculty: teachers with long track record will retire in a matter of several or a dozen years. Generational succession is insufficient, with young people choosing different careers.

Secondly, school as a knowledge-based institution must make a commitment to staff development, which testifies to its brand reputation and quality. Coping in VUCA times primarily means investing in digital skills, working with artificial intelligence or educational platforms. This could prove a formidable task for the older generation of teachers.

A third finding is of special significance for primary schools. There are no incentives encouraging men to work at school. Staff diversity translates into its strength.

Fourthly, human capital at school includes every teacher's knowledge, skills, competences which had to be grown. The current generation of secondary school students are digital natives immersed in modern technologies. To be able to work with them is a key competence which should be given special attention when selecting the subject matter of courses for teachers.

Another important point is creating a healthy atmosphere at work, developing communication skills, introduction of onboarding and mentoring for the new intake, as well as implementing new methods and forms of teaching, which would be attractive for young people.

School development strategy is a certain model of school management in a temporal perspective. VUCA demonstrates that the model needs to be flexible and often adapted to crises. The better educated the teachers are, the greater the chances of navigating difficult realities.

8. Discussion

Managing the employees of an educational institution is one of the most important responsibilities of the headteacher, whose skill, experience and competences will determine the success of the school and its students. However, gaining a foothold in the educational market will prove impossible without support form teachers, parents, local and national government. On the one hand, VUCA has exposed the weaknesses of schools, uncovering specific threats, necessitating a critical on human capital management; on the other hand, it ushered an opportunity to make changes in the methods of managing institutions of crucial importance to every person.

What can be inferred from this process is that we cannot create a single, universal school management model which could be effective in every possible situation (as proved by the closure of school during the Covid pandemic). Another pressing issue is the need for headteachers to update their knowledge of management. This is especially relevant in VUCA times.

Secondary schools are grappling with many problems of particular significance for their functioning, such as aging faculty or inadequate generational succession. There are not enough young teachers, vocational instructors, psychologists (counsellors). This shortage recurs every single school year, forcing headteachers to hire teachers who are retired or who already work for other institutions.

Being a learning institution, a school must develop and respond to the challenges of reality:

- targeted training for teachers, with particular emphasis on modern technologies,
- encouraging teachers to raise the competences in the school's deficient areas,
- introduction of mentoring for teachers new to the profession,
- introduction of onboarding programmes for newly employed staff,
- modernizing and upgrading the equipment used by schools.

All of the above activities intended to address VUCA require considerable financial outlays, making it necessary for headteachers to overcome administrative or bureaucratic obstacles. The projects involved cannot be implemented all at once; some of them may not receive the required funding, and headteachers will be put in an unenviable position to make difficult decisions concerning investments or education. Still, schools must meet their goals, so a school management model need to be adjusted to its unique characteristics, financial and organisational capacity.

9. Conclusion

Leading a secondary school in an unpredictable reality calls for a fresh perspective on staff motivation, commitment, and capacity to address challenges. A new philosophy is being put in place, based on the premise that all employees are treated as valuable capital which can grow; staff involvement in the work performed for the organisation also gains importance (Dziwulski, Harasim, 2018).

A school is managed by its headteacher in cooperation with teachers, parents and students. It is the headteacher who bears the greatest burden of responsibility related to the function of the educational institution, provides pedagogical supervision, manages the school's finances and performs tasks arising from applicable regulations. The manager of a school should be acquainted with modern methods of running an organisation, put them in practice, be flexible and open to change. Today's secondary school educates future employees, young adults who

will have to take important job- and education-related decisions. However, without proper support from teaching staff they will be unable to meet these challenges. In young people's view, Polish schools are old-fashioned, boring, discriminatory and unfriendly (Gagatek, Karaś, Kelsz, 2025). This opinion may be a derivative of several issues.

First, times change but school does not. It remains an institution incompatible with the needs of the next generation of students. This means that it is not open to change, has no strategy or a vision of growth. Second, schools do not have enough young staff willing to raise their competences and learn from older generations of teachers. Third, effective and efficient communication between all stakeholders is paramount. Fourth, modern schools must quickly respond to change, which necessitates developing a suitable management model with values such as human capital, quality-committed employees, school brand and, last but not least, the effectiveness of teaching and preparing a young person to live in unpredictable times. "Human capital is becoming a prism through which one should evaluate the achievements of an organisation" (Nowicka-Mieszała, 2012, p. 89).

The VUCA concept demonstrates that school must adapt to change, which means designing a specific style of management and preparation for new tasks and challenges. Sill, VUCA also opens a host of possibilities related to upgrading an institution's skillset, mastering a new approach to teaching and communicating with students. Being aware of changes and capable of implementing them allows headteachers and teachers to develop a new paradigm based on flexibility and openness.

The subject matter discussed here is of relevant problem which should be analysed for various school types, e.g. general secondary schools, technical colleges, vocational schools, with school management issues in the context of VUCA. Some of them will share certain characteristics but there will be some aspects different across schools. Importantly, this should lead to developing a human capital management model which will enable schools to thrive and succeed on the educational market.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

THE SCOPE OF EBITDA UTILISATION IN SELECTED DOMAINS OF CORPORATE FINANCIAL MANAGEMENT

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Purpose: The paper aims to present selected areas of EBITDA (Earnings Before Interest, Taxes, Depreciation and Amortization) use in corporate financial management, particularly its use in assessing companies' profitability and debt-servicing capacity.
Design/methodology/approach: The paper is theoretical and analytical in nature. A critical analysis of pertinent literature focuses the structure of EBITDA, its advantages and disadvantages, and how it is used to evaluate profitability and debt-servicing capacity. A comparative analysis of profitability based on EBITDA and operating profitability was conducted in energy companies to determine the impact of depreciation and amortisation on the level of EBITDA and its use to assess these companies' ability to service debt. Based on 2014-2024 data, ratios showing the differences between EBITDA Margin and Operating Margin were calculated, as was the level of energy companies' debt, and their ability to repay the debt were determined based on the Net Debt to EBITDA ratio.
Findings: The research has established that the difference between EBITDA Margin and Operating Margin in Polish energy companies is caused by the amount of depreciation charged. Depreciation also affects companies' capacity to service debt and it is high in energy companies. Their average debt repayment period is just over two years, and the average time to complete an investment in the energy sector is 3-5 years. This also indicates the possibility of timely completion of investments and elimination of delays in their implementation given a lack of other financing sources.
Research limitations/implications: The energy transition of the Polish economy requires extensive investments. Further research should determine whether energy companies will be able to take more debt and whether a higher than current ratio of Net Debt to EBITDA in these companies will be accepted by external capital providers. The research presented in the paper is based on historical data from published sources. Further research may attempt to compare the forecast values. Polish companies must implement a number of investments around renewable energy sources, modernisation of power transmission networks and construction of nuclear power plants.
Practical implications: The results of the study can be of use to the management of Polish energy companies by assisting them in the selection of financing sources, considering the criterion of repayment time and the relationship between this time and the ratio of net debt to EBITDA. The results of the study can also be used to support doctoral and other researchers in their studies and theses.

http://dx.doi.org/10.29119/1641-3466.2025.231.27 http://managementpapers.polsl.pl/

Social implications: The results of the study may raise awareness of what is the rational level of debt for energy companies in relation to their ability to repay liabilities, so as not to prolong ongoing investments due to a shortage of financing sources.
Originality/value: The results of the study show those interested in the energy sector how depreciation impacts profitability. EBITDA reflects a company's capacity to service debt and its ability to raise external capital for investments. The question of whether Polish energy companies will be able to restructure according to EU requirements is the focus of widespread public interest.
Keywords: energy companies, Operating Margin, EBITDA Margin, debt level, Net Debt/EBITDA.
Category of the paper: Research paper on corporate finance.

1. Introduction

During financial decision-making processes, a number of economic ratios are used. Recently, EBITDA has gained wide application. It is widely used in companies, banks and partnering entities. Companies use it to assess their operational efficiency, determine executive bonuses, valuate companies using the multiplier method, evaluate the possibilities and potential outcomes of restructuring, and assess the attractiveness of companies for acquisition. EBITDA can be used periodically to ensure liquidity as profit and depreciation can cover current liabilities. The broadly defined category of "potential' EBITDA" profit is used for cross-country or cross-industry efficiency comparisons in a given country, as well as between classes of individual industrial groups.

Research into the use of EBITDA in selected areas of business operations was conducted in Polish energy companies. Their EBITDA level depends on the amount of depreciation charged. The energy sector, like the chemical, metallurgical and mining industries, is capital-intensive, having more long-term than current assets.

The paper aims to assess the use of EBITDA to evaluate the economic efficiency and debt repayment capacity of economic entities. The research conducted in energy capital groups in Poland aims to verify the following research hypotheses.

H1. Significant differences between EBITDA Margin and Operating Margin result from depreciation of tangible assets and amortisation of intangible assets.

H2. The direction of changes in the share of debt in the liabilities plus equity of energy companies is the same as the direction of changes in the debt service coverage ratio calculated from generated EBITDA.

Energy sector companies may pursue different financial strategies affecting their financial results. They also have different asset bases. Some energy companies have a larger share of long-term assets tied to coal-based energy. This leads them to favour higher depreciation write-offs due to planned CO_2 emission restrictions on coal-based energy production.

These are topical issues which are particularly relevant in the context of urgent energy sector restructuring and required huge capital expenditure. Moreover, one of the conditions justifying public aid for the restructuring of the sector involves the efficiency of the entities in this sector, typically measured by Operating and EBITDA Margins.

2. The concept, advantages and disadvantages, and areas of application of EBITDA in companies

2.1. EBITDA structure

EBITDA (Earnings Before Interest, Taxes, Depreciation and Amortisation) is calculated as the operating result (profit/loss) plus depreciation and amortisation of tangible and intangible assets, respectively. Operating profit concisely reflects the level of results of operating activities, excluding the strategy used for selecting financing sources. The level of operating profit is strongly affected by the characteristics of the sector/industry, funding policy for core activities, the risk level of the company's operations, and related factors. However, attention should be given to what constitutes operating profit. According to the profit and loss account, operating profit comprises core activity results (profit/loss on sales) and other operating results. Other operating activities include risk mitigation operations: receivable write-offs and their settlement, employment restructuring provisions, warranty provisions, income tax provisions, received and paid penalties/fines/damages, non-culpable long-term and current asset shortages, overdue, lost, or uncollectible liabilities and receivables. Subsidies, grants and direct payments related to operating activities under preferential policies of the relevant authorities may also be significant. Operations related to social activities, disposal of non-financial long-term assets, transfer or receipt of assets free of charge (including donations) and the revaluation of tangible fixed assets are also included. Other operating items may also include recording of depreciation-related operations: depreciation write-offs of tangible fixed assets, amortisation of intangible assets received free of charge, negative goodwill amortisation, above-standard depreciation/amortisation, and adjustment for lease payments exceeding the leased asset depreciation.

EBITDA adds depreciation and amortisation to operating profit. Depreciation/amortisation allocates the asset’s value over its useful life, writing it off as a cost to recover acquisition expenditure and create a replacement fund. "American standards stress the need for rational depreciation write-offs, using a well-considered (logical) formula for allocating depreciable value, acceptable to another accountant following objective criteria. Literature also views depreciation as a cost arising from a subjective reduction in fixed assets value" (Sigidov et al., 2016; Maruszewska, 2018, p. 138).

Depreciation starts when a fixed asset is placed for use and ends when its accumulated depreciation equals the initial value or when the asset is marked for sale, liquidation, or declared missing, considering the expected net sale price of the remainder of the fixed asset upon liquidation. When determining the depreciation period and the annual depreciation rate, the useful life of the fixed asset is taken into account, which is influenced by:

- asset usage frequency (number of shifts),
- rate of technical and economic progress,
- asset productivity, measured in operating hours, or number of units manufactured or by other appropriate metrics,
- legal or other regulatory usage restrictions,
- expected net sale price of the fixed asset upon liquidation.

The accuracy of the depreciation periods and rates applied to fixed assets should be periodically reviewed by the entity, resulting in a suitable adjustment of depreciation write-offs in subsequent financial years (Accounting Act..., Article 32). In the event of a change in production technology, intended liquidation, withdrawal from use or other reasons causing a permanent loss of a fixed asset's value, an appropriate write-down of its value is made – charged to other operating costs. Low-value fixed assets may be depreciated using simplified methods: collective write-offs for similar asset groups or one-off write-offs expensed.

Micro and small entities can apply depreciation write-offs on fixed assets following tax regulation rules. This option is not available to public finance sector entities, capital companies, or limited joint-stock partnerships, general partnerships and limited partnerships (Accounting Act... Article 28, paragraph 7).

Depreciation write-offs are calculated based on the fixed asset's original value. The basis may be the purchase price or, for in-house assets, the production/construction cost of the fixed asset. For inherited, donated, or gratuitously transferred assets, depreciation is based on fair market value, and for assets received as a contribution in kind, the valuation-determined value is used, for leased assets, depreciation is based on the lease-determined value (Aleszczuk, 2012, p. 148). Over time, a fixed asset's initial value may change due to improvements, modernisation, or official revaluation. The amount of depreciation depends on asset valuation, chosen method, useful life, and residual value estimates.

However, depreciation can be distorted by one-off write-offs and above-standard depreciation aimed at quickly recovering acquisition costs. Corporate and personal taxpayers may deduct one-off depreciation of up to PLN 100,000 as taxable costs, irrespective of income, pursuant to Article 22k(14)-(21) of the PIT Act and Article 16k(14)-(21) of the CIT Act. In accordance with these provisions, all business taxpayers can use preferential depreciation, writing off newly purchased fixed assets in groups 3-6 and 8 in the fiscal year they are registered (Kuchta, 2025). The PLN 100,000 limit covers both depreciation write-offs and purchase payments considered tax-deductible.

2.2. Advantages and disadvantages of the EBITDA metric

Because EBITDA has shortcomings—especially regarding intangible asset amortisation — some literature recommends using EBITD, which excludes such amortisation. Reporting profits excluding intangible amortisation but including tangible depreciation has become increasingly popular, though it is not a new practice (Heflin, Hsu, 2008; Kolev et al., 2008; Zhang, Zheng, 2011). Excluding intangible amortisation is justified mainly by the differing treatment of acquired versus internally developed intangible assets. Acquired intangibles are capitalised and amortised; internally developed intangibles are usually expensed immediately or recognised over time through accruals. Such differences can distort results and reduce comparability across companies and periods (Nissan, 2024a).

The increased share of intangible assets in long-term assets and of their amortisation is a result of the transition from an industrial economy to a knowledge-based economy. While some of these changes have occurred across all industries, the growth in intangible assets is mainly due to companies in knowledge-intensive sectors, including business services, communications, pharmaceuticals, healthcare and computers (e.g. Fama, French, 2004; Srivastava, 2014). Over the past two decades, intangible assets, excluding goodwill, have grown and are amortised, unlike goodwill. Consequently, amortisation has become a major expense (Nissan, 2024b). Finally, companies can avoid recognising write-offs and depreciation/amortisation by classifying assets as ‘under construction’ or ‘held for sale’. Flexibility in depreciation/amortisation measurement enables profit management, which may reduce the informational value of reported earnings. Morevover, the degree of such earnings management differs across firms and periods, limiting comparability of profits.

A third issue related to depreciation is that depreciation may also include costs of financing asset acquisition. For assets with long construction periods, such as buildings and structures, the asset’s acquisition cost, depreciated once in use, may include interest on construction debt. Interest is capitalised when three criteria are met: construction has started, construction costs are incurred, and interest costs are incurred. The amount of capitalised interest depends on the timing and scale of construction expenditure and financing costs or issuing bonds. Interest expense will be capitalised in future years, as the benefits of borrowing are realised in future periods when the asset is in use. Consequently, in accordance with the matching principle, the cost of external financing is incorporated into the asset’s cost and depreciated when the asset is in use. This accounting approach makes EBIT a distorted measure of operating profitability, as it blends operating and financing activities. Companies building similar assets may report significantly different asset values and depreciation depending on whether financing is via debt or equity. Companies often have considerable flexibility regarding the timing of cash outflows for asset replacement or may not need significant capital expenditures for extended periods, making EBITDA a better short-term indicator of cash available to service debt. However, for assessing long-term profitability and free cash flow – key determinants of equity value – depreciation and amortisation should not be ignored.

Another limitation of EBITDA arises in manufacturing companies, where it may be subject to a substantial margin of error. EBITDA is computed by adding depreciation and amortisation from the cash flow statement to EBIT. The cash flow statement shows total depreciation/amortisation for fixed and intangible assets in a given period. In manufacturing companies, most depreciation is embedded in the cost of goods sold (COGS), while the remainder is included on the final balance sheet as work in progress and finished goods inventories. This means that the cash flow statement includes depreciation amounts that have been capitalised in the final balance of inventories reported on the balance sheet, rather than recognised in costs. Consequently, including the full depreciation and amortisation from the cash flow statement overstates EBITDA, as it counts depreciation already capitalised in inventory.

Finally, EBITDA is more sensitive than EBIT to earnings management through excessive capitalisation of expenses. Companies can increase current period income by designating period costs as directly related to the acquisition of an asset or its preparation for use, thereby capitalising these costs on the balance sheet rather than recognising them in the profit and loss account. This is common for both tangible and intangible assets subject to depreciation/amortisation.

Companies enjoy considerable discretion in classifying expenditures as improvements, additions, or replacements, which enhance an asset or extend its useful life and capitalise them, unlike repairs, maintenance or other operating expenditures which enable the asset to function as originally expected and are therefore considered period costs. Most internally generated investments in intangible assets are expensed when incurred, which means that the reported assets and equity understate their fair values. However, profits may not be understated, since excluding amortisation offsets investment expenditure in intangible assets.

2.3. The use of EBIDTA in assessing a company's profitability and its ability to repay debts

A high EBITDA level indicates a company’s stable operational foundations, which is why it is referred to as an indicator of the company's financial health. Operating profit in the profit and loss account can be assessed in the measurement of efficiency in two ways: unadjusted and adjusted. Companies adjust this category to determine its value and changes over time. It is of interest not only to shareholders, but also to other stakeholders and managers, for whom value growth is the basis for calculating long-term bonuses. The adjustment system must be adapted to the company's internal records and the availability of information for its preparation. The consistency of this system will ensure the comparability of EBITDA changes over time and accurate calculation of the variable component of managers' remuneration.

Considering the structure of EBITDA, it should be noted that depreciation and amortisation in EBIDTA are generally treated as a non-cash expense for asset replacement but can occasionally be used to repay debt. Banks use EBITDA-based ratios in covenants to assess the risk associated with an entity's ability to repay debt (Sierpińska-Sawicz, 2018). However,

they adjust operating profit to reflect all incidental, non-recurring operations that affected the level of operating profit and are unlikely to recur. After the adjustments, the remaining elements of the result that reflect deliberate management actions and that can serve as a basis for forecasting future financial results are used to assess the entity's ability to repay its debts (Sierpińska, 2021).

The Net Debt to EBITDA ratio shows the number of years required to repay debt using operating profit plus depreciation/amortisation, assuming EBITDA remains constant (Mosiejko, Bernardelli, 2021). Operating profit plus depreciation/amortisation approximate operating cash flow. In capital-intensive industries, high depreciation can dominate EBITDA calculations, so that a company may report positive EBITDA even during a loss. This situation occurred in some companies during the energy sector crisis (Sierpińska-Sawicz et al., 2020, pp. 5-20).

It is assumed that a ratio of one means that the company can generate sufficient cash flow during the year to cover its interest-bearing debt. Calculating the ratio in reverse (EBITDA to Net Debt) indicates the percentage of debt the company could repay annually from its EBITDA. These ratios are indicative, as an investment financed with debt should generate additional profit and increase the level of depreciation. Higher EBITDA at a given debt level shortens the repayment period. Banks sometimes determine this ratio based on projected EBITDA. It is also commonly included as a covenant in loan and bond agreements (Sierpińska-Sawicz, 2018, p. 168).

3. Research methods

To analyse operating profitability and EBITDA-based profitability, as well as debt levels and the Net Debt to EBITDA ratio, the author selected four Polish capital groups from the energy sector. The groups – Energa, Enea, PGE and Tauron – are listed on the Warsaw Stock Exchange. They produce and supply energy to customers throughout Poland. Only a small share of customers, mostly in Warsaw, receive energy from Stoen. The basic parameters of the energy sector in Poland are presented in Table 1.

Table 1.
Share of analysed energy companies in the Polish energy sector in 2024

Breakdown	Enea	Tauron	Energa	PGE	Poland total	Share of companies in national totals, %
Customers, M	2.82	5.98	3.4	5.79	19.1	94.2
Distribution, Thw	19.9	50.8	22.7	36.3	137	94.7
Area, thousand km²	58.0	57.0	75.0	122.0	312.0	99.9
Line ength, thousand km	112.0	203.0	172.0	304.0	808	97.9
Investments, billion PLN	1.9	3.2	3.0	3.8	12.5	95.2

Source: The Largest Electricity Distributors in Poland in 2024, Polish Society for Transmission and Distribution of Electric Power (PTP REE), 20 August 2025, https://wysokienapiecie.pl

As shown by the data presented in Table 1, the entities included in the study supply energy to nearly 95% of consumers in Poland. Their territorial coverage spans the entire country, and the length of their power lines accounts for almost 98% of the total power line length in Poland.

The calculations were based on the companies' financial statements and calculations published on their websites. These companies publish basic economic ratios on their investor relations websites. The data contained therein is comparable, as the financial statements are prepared in accordance with IFRS and the requirements of the Warsaw Stock Exchange. Using a uniform method to calculate economic ratios allows for meaningful comparisons between companies and supports robust conclusions.

On the Warsaw stock market, there are a dozen or so small energy sector companies. These companies publish individual financial statements, the data from which are not comparable with those from consolidated statements. They are primarily specialized in generating energy from renewable sources. The companies included in the study have diversified operations, producing energy from various carriers — coal, gas, and renewables. This results in a similar structure of tangible assets, and depreciation is calculated using comparable rates. Depreciation is an important component of EBITDA, which is used to calculate the economic ratios under study.

To verify the hypotheses presented in the introduction use was made of several indicators. EBITDA Margin and Operating Margin ratios were employed to evaluate the profitability of companies in the energy sector. EBITDA Margin indicates what percentage of the revenue generated by the sale of products, goods and services plus depreciation of tangible fixed assets and amortisation of intangible assets constitutes operating profit. To determine the extent to which depreciation/amortisation affects the margin calculated on the basis of EBITDA, operating profitability was calculated as the ratio of operating profit to revenue from the sale of products, goods and services.

In the study of the consistency of changes in the level of debt and the debt service ratio based on EBITDA, the following ratios were employed: company debt as the ratio of debt to liabilities and equity and the ratio of Net Debt to EBITDA. The power sector is highly capital-intensive. The production and distribution of electricity requires significant capital investment in tangible fixed assets, financed through liabilities to financial institutions—mainly banks and bondholders—and, to some extent, trade credit from subsidiaries. For this reason, the debt level of companies was calculated on the basis of the companies' total debt. In their annual reports, companies indicated that EBITDA could be used periodically to maintain liquidity. These issues were not addressed in the paper.

4. Research results

Table 2 presents the EBITDA Margin and Operating Margin ratios in 2014-2024 in the energy companies examined in the study. The companies listed on the stock market at different times, so the study period was limited to eleven years, during which all companies prepared financial statements under the same accounting principles. Since 2009, listed companies have been required to prepare their financial statements in accordance with IFRS, while unlisted companies may prepare theirs in accordance with the Accounting Act.

Table 2.
EBITDA Margin and Operating Margin in Polish energy companies in 2014-2024, (%)

Company	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Avg	Medn
EBITDA Margin													
Enea	19.5	21.5	20.8	23.5	18.4	17.5	17.8	16.5	7.4	13.1	20.6	19.5	18.4
Energa	23.2	21.6	20.5	21.0	18.8	16.8	16.5	18.1	13.2	10.4	18.9	18.1	18.9
PGE	30.0	29.3	26.2	33.5	24.9	19.2	12.6	12.6	11.7	11.1	14.5	20.5	19.2
Tauron	9.8	(10.4)	4.5	20.3	18.6	18.4	20.3	16.2	10.8	13.0	19.9	12.8	16.2
Average	20.6	15.5	18.0	24.6	20.2	18.0	16.8	15.9	10.8	11.9	18.5	-	-
Median	30.0	29.3	26.2	33.5	24.9	19.2	20.3	18.1	13.2	13.1	20.6	-	-
Standard deviation	7.31	15.3	8.1	5.3	2.7	0.9	2.8	2.0	2.1	1.2	2.6	-	
Operating Margin													
Enea	12.0	(4.2)	9.9	13.0	8.2	10.5	(10.9)	9.2	2.0	2.2	9.3	5.6	9.2
Energa	13.7	11.8	4.8	11.5	11.4	3.8	5.3	9.3	6.7	6.4	6.1	8.3	6.7
PGE	16.8	(12.5)	12.9	15.1	9.5	(11.1)	3.1	9.6	5.8	(3.6)	(0.1)	4.5	5.8
Tauron	8.1	(12.0)	2.9	10.8	4.4	4.0	(7.3)	5.4	2.9	6.5	8.1	3.2	4.4
Average	12.7	(4.2)	7.6	12.6	8.4	1.8	(2.5)	8.4	4.4	2.9	5.9	-	-
Median	12.9	(8.1)	7.4	12.3	8.9	3.9	(2.1)	9.3	4.4	4.3	7.1	-	-
Standard deviation	3.1	9.8	4.0	1.6	2.6	7.9	6.8	1.7	2.0	4.1	3.6		

Source: own work based on data taken from websites Informacje finansowe | TAURON https://www.tauron.pl/tauron/relacje-inwestorskie, Dane finansowe i operacyjne | Serwis Relacji Inwestorskich Grupy Enea, Relacje inwestorskie | PGE Polska Grupa Energetyczna, Dane finansowe | Serwis relacji inwestorskich ENERGA SA, 20.06.2025; Financial Information | TAURON: https://www.tauron.pl/tauron/relacje-inwestorskie, Financial and Operational Data | Investor Relations Service, Enea Group, Investor Relations | PGE Polska Grupa Energetyczna, Financial Data | Investor Relations Service, ENERGA SA, 20.06.2025.

Profitability calculated on the basis of EBITDA during the study period reveals that the EBITDA Margin grew steadily until 2017, after which it became highly volatile across all companies in the subsequent years. It was most volatile in Tauron. In 2015, the EBITDA-based deficit reached 10.4%. This means that the losses on operating activities were higher than the calculated depreciation, which resulted in a negative result. In 2020, the EBITDA Margin stood at 20.3%, only to drop to 10.8% in 2022. PGE's EBITDA Margin reached 33.5% in 2017, dropping to 11.1% in 2023, a threefold decrease". At Enea, the ratio fell from 17.8% in 2020 to 7.4% in 2022. The average EBITDA margin in the Polish industry that year was 28.3%, while the Operating Margin was 20.5%. For energy companies, these ratios were significantly lower than the industry averages.

For example, in the U.S. company NextEra, which invests in modern energy infrastructure, the EBITDA margin was 43.6% in 2023, up from 41.4% the previous year. The Operating Margin was 19.5%, compared to 17.1% in the prior year. In the U.S. company SSE PLC, the EBITDA margin was 0.7% in 2023, down from 45.7% the previous year, while the Operating Margin was negative at -1.2%, compared to 43.7% a year earlier. The average margins for the U.S. industry in 2023 were 18.4% and 10.2%, respectively.

In the U.K. company Xcel Energy Inc., which uses renewable energy sources for electricity generation, the EBITDA Margin was 32.5% in 2023, compared to 33.2% the previous year, against an industry average of 31.3%. The Operating Margin was 15.8%, down slightly from 16.4% the previous year, while the industry average was 17.5% (Reuters). The margins in the U.K. company were very close to the industry averages.

In summary, EBITDA and Operating Margins in Polish energy companies are broadly similar to those of foreign entities, and changes over time are largely influenced by fuel market conditions and the energy mix used by the company.

A comparison of operating profitability with EBITDA Margin shows that Operating Margin ratios are consistently lower than EBITDA-based ratios. This means that the EBITDA Margin level is significantly influenced by the level of depreciation and amortisation. Three companies reported an operating deficit in 2015 and two in 2020. In 2015, Enea's EBITDA Margin reached 21.5% and its operating margin was negative at 4.2%. Likewise, at PGE, the EBITDA Margin totalled 28.5% that year, and at the operating level, the company made a loss of 12.5%. However, it should be noted that depreciation and amortisation, which are included in the EBITDA Margin, were included to the cost. Therefore, the higher the depreciation/amortisation charged, the higher the difference between the presented profitability ratios. At PGE, in the years 2016-2019, large impairment write-downs of utilised assets affected the ratios calculated using this measure (PGE investor relations).

Over the last three years of the period under review, operating profitability of Polish energy companies declined considerably. This was the result of rising costs due to higher prices of energy carriers and high CO_2 emission charges. At the same time, high inflation prompted successive governments to apply measures aiming to protect consumers and to maintain fixed energy prices despite increasing production costs. This worsened the financial results of energy companies. In addition, high interest rates somewhat slowed down investment in renewable energy sources, which would reduce CO_2 emission charges. Companies made high depreciation write-offs, especially on assets used to produce electricity from coal. In the coming years, coal-based generation capacities are expected to be shut down. Higher depreciation charges can be used periodically to finance new investments and investments in natural gas-based capacity. Its burning is less harmful to the environment than coal burning.

In 2023, the industry's median EBITDA Margin was 28.3%, while the operating margin was 20.5%. In energy companies, the median EBITDA Margin that year reached 13.1% versus a 4.3% Operating Margin. The EBITDA Margin was more than three times higher than the

Operating Margin, indicating that depreciation and amortisation had a substantial effect on financial results. This is further corroborated by data from previous years. In 2024, the median EBITDA Margin increased significantly compared to the previous year and amounted to 20.6%, while the Operating Margin stood at 7.1%, with the ratio difference being nearly threefold. This means that the first hypothesis has been confirmed. The differences in profitability levels are the result of depreciation of tangible assets and amortisation of intangible assets. It should be added that profitability in traditional, capital-intensive industries, is generally lower than in modern industries.

It is also worth noting the standard deviation of the profitability ratios. It provides information about the dispersion of data around the mean. In the case of EBITDA Margin, only in the first three years analysed was the standard deviation relatively high, which means that profitability ratios differed significantly from the mean. In 2014, the EBITDA Margin ratio reached 30% at PGE and 9.8% at Tauron. In 2015, at PGE the ratio reached 29.3%, while Tauron reported a negative margin of 10.4%. The low ratios in subsequent years indicate that the data is concentrated around the average. For the Operating Margin ratio, the standard deviation exhibited high volatility during the analysed period. In several years, it was high, which was the result of changes in the operating results of energy companies. In 2015, all companies incurred operating losses. In 2020, Enea and Tauron reported operating deficits, and in 2023-2024, only PGE generated losses.

The debt level of Polish energy companies calculated on the basis of balance sheet data is shown in Table 3. The average share of debt in liabilities and equity was calculated both vertically, across the four companies in each year, and horizontally, as the average share in individual companies in the analysed period (2014-2024).

Table 3.
Debt ratios of the analysed energy companies in 2014-2024, (%)

Company	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Avg	Medn
Enea	33.7	50.7	50.4	53.8	56.0	56.7	59.5	59.5	60.3	60.5	58.6	54.2	56.7
Energa	53.0	52.5	53.1	55.3	52.3	55.9	55.4	52.9	59.7	60.7	62.6	55.8	55.9
PGE	32.4	34.2	36.7	37.3	38.4	45.5	47.9	46.6	49.4	57.8	56.2	43.9	45.5
Tauron	48.0	50.1	50.2	49.6	50.7	56.6	60.6	58.8	63.4	64.7	51.2	54.9	56.6
Average	41.8	46.9	47.4	49.0	49.4	53.7	55.9	54.5	58.2	60.9	57.2	-	-
Median	40.8	50.4	50.3	51.7	51.5	56.2	57.5	55.8	60.0	60.6	57.4		

Source: own work based on data taken from websites Informacje finansowe | TAURON https://www.tauron.pl/tauron/relacje-inwestorskie, Dane finansowe i operacyjne | Serwis Relacji Inwestorskich Grupy Enea, Relacje inwestorskie | PGE Polska Grupa Energetyczna, Dane finansowe | Serwis relacji inwestorskich ENERGA SA, 20.06.2025; Financial Information | TAURON: https://www.tauron.pl/tauron/relacje-inwestorskie, Financial and Operational Data | Investor Relations Service, Enea Group, Investor Relations | PGE Polska Grupa Energetyczna, Financial Data | Investor Relations Service, ENERGA SA, 20.06.2025.

Prior to 2023, the debt levels of all analysed companies increased steadily. While in 2014 almost 42% of liabilities and equity represented debt, by 2023 this figure had risen to as much as 60.9%. PGE debt grew at a similarly rapid pace. At Energa and Tauron, the increase was

slower. In 2024, Tauron's debt fell by as much as 13.5 percentage points compared to the previous year. At Energa, debt increased from 53% to 62.6% during the period in question.

In three companies, the average share of liabilities in total liabilities and equity was very similar, with PGE alone having an average debt level of almost 44% in the period under review. In 2014, PGE's debt was the lowest relative to the other companies and increased by as much as 23.8 percentage points. At Enea, debt increased by 26.8 percentage points from 2014 to 2023, at Tauron by 16.4 percentage points, and at Energa by a mere 7.7 percentage points. Interestingly, in 2021, the debt of several international corporations was higher than that of Polish energy companies, ranging between 63% and 93%. For example, in 2022, the debt ratio was 75.3% in NextEra, 64.5% in SSE PLC, and 72.7% in Xcel Energy Inc. Foreign companies can make greater use of debt financing than their Polish counterparts, as interest rates on loans are lower there than in Poland, and they also have more opportunities to tap into the debt market (Sierpińska, 2023).

In the entities in this study, the median – the value above and below which an equal number of observations occur – does not differ significantly from the average. The horizontally calculated median for all four companies was higher than the average. In the first five years (2014-2018), debt grew faster than in 2020-2024. The vertically calculated median for the four companies varied: it was below the average in 2014 but exceeded it in subsequent years, reflecting differences in the indebtedness of individual energy companies.

Table 4 presents the Net Debt/EBITDA ratios, indicating the companies' ability to service their debt from EBITDA generated in the individual years under review.

Table 4.
Net Debt/EBITDA ratio in selected energy companies in 2014-2024 (multiple)

Company	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Avg	Medn
Enea	1.56	1.16	1.75	1.85	2.38	2.22	2.00	1.29	1.38	0.85	0.46	1.53	1.56
Energa	1.21	1.47	2.03	2.30	1.40	1.80	2.30	1.60	1.80	1.90	3.30	1.92	1.80
PGE	-	0.07	0.66	0.90	1.31	1.41	1.37	0.85	0.07	1.14	0.81	0.86	0.88
Tauron	1.61	2.00	2.45	2.45	2.54	2.81	2.51	2.44	2.93	2.10	1.70	2.32	2.45
Average	1.46	1.18	1.72	1.88	1.91	2.06	2.05	1.55	1.55	1.50	1.57	-	
Median	1.21	1.32	1.89	2.08	1.89	2.01	2.15	1.45	1.49	1.52	1.26	-	

Source: own work based on data taken from websites Informacje finansowe | TAURON https://www.tauron.pl/tauron/relacje-inwestorskie, Dane finansowe i operacyjne | Serwis Relacji Inwestorskich Grupy Enea, Relacje inwestorskie | PGE Polska Grupa Energetyczna, Dane finansowe | Serwis relacji inwestorskich ENERGA SA, 20.06.2025; Financial Information | TAURON: https://www.tauron.pl/tauron/relacje-inwestorskie, Financial and Operational Data | Investor Relations Service, Enea Group, Investor Relations | PGE Polska Grupa Energetyczna, Financial Data | Investor Relations Service, ENERGA SA, 20.06.2025.

The average ratios of the companies' ability to repay debt calculated on the basis of EBITDA were relatively low, as was the median. The highest average ratios of slightly over 2 years occurred in 2019-2020, driven by fluctuations in global energy commodity prices. Tauron needed an average of 2.3 years to repay its debt, while the other companies needed less than two years. Energa had the highest ratio in 2024 at 3.3 years, while PGE had the lowest repayment period at 0.81 years. These ratios indicate significant potential for financing

restructuring, expected to accelerate due to EU climate policy requirements. At Enea, the ratio was higher than two years only in 2018-2020. At Energa, with an increase in debt in 2020-2023, the Net Debt to EBITDA ratio decreased. PGE had the lowest ratio and the lowest debt compared to the other energy companies, but changes in the ratio did not correspond to changes in its level of debt. n the foreign companies included in the comparison, the net debt-to-EBITDA ratios vary. For example, in NextEra the ratio was 6.44 in 2023, compared with 7.15 the previous year. In SSE PLC, it was 2.01, down from 7.84 the year before, while in Xcel Energy Inc. the ratio stood at 4.82 in 2023, compared with 4.92 a year earlier.

In none of the companies reviewed, did changes in debt levels affect the Net Debt to EBITDA ratio, which exhibited high volatility in the subsequent years. Therefore, the second hypothesis was not confirmed. The direction of changes in the share of debt within the capital structure of energy companies does not correspond to the changes in the debt service coverage ratio derived from generated EBITDA. The excess depreciation – both from impairment of coal-based assets and depreciation of assets put into operation as a result of investments made in previous years – increased EBITDA, contributing to lower debt servicing ratios.

5. Summary

EBITDA is a measure of a company's financial health. A review of pertinent literature has shown that EBITDA can be used to make decisions in many areas of a company's operations. EBITDA-based metrics are widely used to evaluate companies' current and future financial positions and their capacity to service debt. EBITDA can be used for intra-industry and international comparisons of profitability. However, international comparisons require that companies report results under the same accounting standards (IFRS or GAAP). Differences in accounting standards used may render international results non-comparable. This is important for subsidiaries of large international capital groups located in different countries, where the achievement of the target EBITDA level is often used to reward managers.

This empirical research involving data from Polish energy companies has allowed verification of the research hypotheses presented in the introduction. The first hypothesis assumed that depreciation/amortisation has a significant impact on the differences between EBITDA Margin and Operating Margin. In recent years, the amount of depreciation, particularly above-standard depreciation reflecting revaluation of tangible fixed assets, has been on the rise. This trend reflects energy sector restructuring, the shift from coal to gas and renewable sources, and the need to modernize energy networks. Higher CO_2 emission charges for coal-based energy increase production costs and are further compounded by rising energy prices and wages.

The second hypothesis concerning the relationship between debt level and the Net Debt to EBITDA ratio has not been confirmed. Changes in debt servicing capacity ratios of the energy companies differed from changes in debt's share of total liabilities and equity over time. Meanwhile, the companies' debt rose steadily, and Net debt/EBITDA ratios were highly volatile, influenced by both operating results and depreciation, including write-downs of tangible assets.

The energy companies under review pursued a similar financial strategy regarding debt, using bank loans and bond issues, including green bonds. The increase in their debt is the result of accelerated restructuring of the energy sector. The pace of debt increases in energy companies in 2014-2023 varied. Enea's debt increased by 26.8 percentage points over the analysed period, PGE's by 23.8, Tauron's by 16.4, and Energa's by 7.7 percentage points. In 2024, debt increased only at Energa. The highest (13.5 percentage points) decrease in debt in 2024 was reported by Tauron. In the other three companies included in this study, the average share of debt in liabilities and equity, like the median, was similar only at PGE, where it amounted to 44%, but in 2014 the company reported the lowest debt level.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

STATISTICAL ASSESSMENT OF THE IMPLEMENTATION OF SUSTAINABLE DEVELOPMENT GOAL 9 IN THE EUROPEAN UNION COUNTRIES

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Purpose: The development of modern infrastructure, support for sustainable industry, and the promotion of innovation and new technologies are the main objectives of SDG 9. The aim of the article is to provide a synthetic assessment of the level of SDG 9 implementation in these three areas by the 27 EU countries in 2023.
Design/methodology/approach: The value of the synthetic measure reflecting the level of SDG 9 implementation was calculated using two selected linear ordering methods: the zeroed unitarization method and the TOPSIS method. The study used a set of indicators from Eurostat assigned to SDG 9. These indicators are a key tool for monitoring progress in achieving the goals, enabling analyses at international, national, and regional levels. The findings are presented in tabular form.
Findings: Based on the conducted research, EU country rankings were constructed, and countries were grouped according to similar levels of SDG 9 implementation. The results showed that the leaders in implementing SDG 9 were Sweden, Denmark, Belgium, and Germany, while Bulgaria, Romania, Latvia, and Portugal ranked lowest. Both applied linear ordering methods produced similar rankings of EU countries with regard to SDG 9 implementation, as confirmed by the Spearman's rank correlation coefficient at the level of 0.8993.
Research limitations/implications: In this study, only fully complete indicators related to Sustainable Development Goal 9, as provided by Eurostat, were utilized. The selection of variables for cross-country analyses presents a considerable challenge, as differences in data collection methods and reporting standards may limit comparability. For this reason, the choice of variables in the article was primarily determined by the availability, consistency, and completeness of statistical data in the Eurostat database. Ensuring an appropriate and comprehensive set of variables is crucial, as any gaps or inadequacies in the dataset may influence the reliability, validity, and overall interpretability of the research findings.
Practical implications: The research results provide a general overview of the studied phenomenon and offer policymakers valuable diagnostic information that enables the monitoring of progress and the identification of areas requiring intervention. Countries lagging in the implementation of Goal 9—particularly in Central, Eastern, and Southern Europe—may benefit from support programs tailored to their specific contexts, the development of digital

infrastructure, and investments in education and human capital development. The study's conclusions can also support the effective allocation of EU funds and resources in order to maximize their impact and ensure that all Member States are able to fully achieve the objectives set out in the 2030 Agenda, including SDG 9. These actions may therefore contribute to ensuring sustainable development across the entire European Union.
Originality/value: The originality of the article lies in the authors' individual approach to the chosen research issues. An original selection of research methods was made, including the ordering of individual countries and their grouping, thereby enriching the research methodology. The obtained results may serve as a basis for broadening knowledge in this area, preparing and subsequently applying more advanced research assumptions and methods, as well as expanding research conclusions. The added value of the study is the proposed original research procedure, which may be applied to analyses of other Sustainable Development Goals within the EU or in individual Member States.
Keywords: sustainable development, Sustainable Development Goals (SDGs), SDG9, European Union countries, zero unitarization method, TOPSIS methods.
Category of the paper: Research paper.

1. Introduction

One of the key challenges of the global economy in the 21st century is the implementation of development policies based on the concept of sustainable development. The Member States of the European Union have actively participated in international debates concerning the assumptions of this model, an important outcome of which was the adoption, on 15 September 2015, by the United Nations General Assembly of the resolution entitled *Transforming our world: the 2030 Agenda for Sustainable Development* (The 2030 Agenda, 2015).

Within the framework of the 2030 Agenda, UN Member States agreed on the Sustainable Development Goals (SDGs), which serve as the basis for verifying progress towards the overarching objective of sustainable development. Seventeen goals were defined and described as "integrated and indivisible, global in nature and universal". These goals encompass 169 specific targets, to which measurable quantitative and qualitative indicators were assigned. The responsibility for monitoring and reporting the degree of their implementation rests with national governments. Initially, the concept of sustainable development focused on reducing the negative impact of economies on the natural environment. Later, it emphasized the balance between the three main dimensions: environmental protection, social progress, and economic growth. The implementation of the individual Sustainable Development Goals is expected to contribute to improving the overall level of development, taking into account economic, social, and environmental aspects (Raczkowska, 2024).

The European Union approaches sustainable development holistically, which means that the principles and programs derived from it must be integrated into all EU policies and projects. The European Commission monitors the implementation of individual sustainable development strategy goals, while Eurostat publishes the results of this monitoring. The practical realization

of the provisions of the EU sustainable development strategy would not be possible without the financial guarantees embedded in the community's budget (Jantoń-Drozdowska, Juskowiak, 2023).

The concept of sustainable development has been the subject of reflection by researchers representing various fields of science. Among them, scholars in economics and management sciences play a particularly significant role. However, attention should be drawn to the continuously increasing number of scientific publications addressing this issue. In the 1980s, the number of new publications indexed in the Scopus database with the expression "sustainable development" included in the abstract did not exceed 60 per year; in the 1990s, the figure rose to around 600 annually; whereas in 2022-2023, more than 20,000 publications were added (Raczkowska, 2024).

One of the areas covered by the 2030 Agenda is SDG 9, which concerns building resilient infrastructure, promoting sustainable industrialization, and fostering innovation. As noted by Jantoń-Drozdowska and Juskowiak (2023), achieving this goal requires the development of sustainable and durable infrastructure that supports economic growth and human well-being, the promotion of sustainable industrialization, the modernization of infrastructure, and the upgrading of industry towards sustainability and innovation—both internationally and nationally.

The research presented in this article was aimed at a comprehensive examination of the level of SDG 9 implementation in the EU Member States. The objective of the study was therefore to assess the degree of SDG 9 implementation by the 27 EU countries in 2023. To analyze disparities in the level of implementation, indicators from the Eurostat database describing this goal were applied.

The article attempts to answer the following research questions:

- Which EU countries are the leaders, and which occupy the lowest positions in the EU rankings with respect to the synthetic measure of SDG 9 in 2023?
- Which EU countries formed groups characterized by high, medium-high, medium-low, and low levels of SDG 9 implementation?
- What is the degree of consistency between the EU country rankings regarding SDG 9 implementation obtained using two selected linear ordering methods, namely the zeroed unitarization method and the TOPSIS method?

The implementation of the article's research objectives required its division into several parts. In the first part, a literature review was conducted with respect to the areas covered by SDG 9. This was followed by the presentation of methodological assumptions and the indicators considered as characterizing this goal. An important part of the article consists of the results and the discussion of the conducted research. The final part presents a short analysis of the findings.

2. Pillars of SDG 9: Resilient Infrastructure, Sustainable Industrialization, and Innovation

The main pillars of SDG 9 are the construction of stable infrastructure, the promotion of sustainable industrialization, and the fostering of innovation. As noted by Fura et al. (2025), developed and modern infrastructure can improve residents' living standards and contribute to a country's economic development. Infrastructure provides the basic physical systems, assets, and structures that are essential for maintaining vital societal functions, health, security, and the economic and social well-being of people. Adequate infrastructure is closely linked to the achievement of social development, economic growth, and environmental goals. Poor access to basic infrastructure reduces opportunities for employment, education, and healthcare, thereby compromising quality of life and creating barriers to business activity. Progress in railways, roads, water systems, irrigation systems, electrical power, sanitation, and information technologies is visibly connected to economic growth and enables the attainment of many other goals that depend on it.

In times of intense uncertainty, a resilient infrastructure system reduces vulnerability, minimizes the consequences of threats, accelerates responses and recovery, and facilitates adaptation to disruptive events (Cabrita et al., 2023; NIAC, 2020). The development of stable, accessible, high-quality infrastructure helps prevent social exclusion due to lack of connectivity and can also have a positive impact on the natural environment. Building resilient infrastructure therefore requires thinking and acting for future generations (Cabrita et al., 2023).

The UNDRR (2022) identifies six interconnected principles for resilient infrastructure:

- Continuously learning – highlighting the challenges in understanding infrastructure resilience due to the internal complexity and external hyperconnectivity of related systems and sectors.
- Proactively protected – ensuring preparedness for hazards, acknowledging that infrastructure is exposed to various known and unknown risks, and that the nature of these hazards is constantly evolving.
- Environmentally integrated – working proactively and positively with the natural environment, both biological (flora and fauna) and physical (land, air, water).
- Socially engaged – actively involving people and communities so they understand how they can help prevent and respond to disruptions.
- Shared responsibility – encouraging collaborative approaches to sharing data, knowledge, and expertise.
- Adaptively transforming – changing the ways in which infrastructure systems operate or the outputs they are intended to deliver.

"Industrialization" is a broad term for a set of economic and social processes related to finding more efficient ways of creating value. Industrialization is often an indirect result of adequate and resilient infrastructure, generating jobs with positive impacts on social and economic life (Cammarano et al., 2022). While industrialization has brought economic prosperity, it is also responsible for adverse ecological effects such as pollution (air, water, and land), forest degradation, and biodiversity loss (Cabrita et al., 2023). This is particularly evident in former post-communist countries, which share a common history, similar economic structures, levels of development, and energy profiles. The centrally planned economies of these countries heavily invested in energy-intensive, high-emission heavy industries, creating a unique energy culture based on the availability of cheap resources such as coal, crude oil, and natural gas (Pach-Gurgul, Ulbrych, 2019).

According to Ulbrych (2020), sustainable industrial development should be understood as fostering growth in manufacturing capacity and competitiveness, creating employment, and improving environmental performance. Other scholars (Nkoa, Fonguen-Kong-Nogh, 2024) add that industrial development should be based on ambitious, multilateral, and international frameworks for financing new technologies, energy transition, and so-called green industrialization to support low-income economies.

Innovation and technological progress are essential for achieving economic and employment growth, as well as for finding lasting solutions to environmental challenges such as improved resource and energy efficiency. The use of new technologies supports the development of a knowledge economy and leads to further inventions that enhance living conditions in areas such as medicine, transportation, production, and energy use. Innovation and creativity are vital for making more efficient and effective use of resources and are key mechanisms for achieving the SDGs (Cabrita et al., 2023). Investment in research and development, along with the growth of human capital, contributes to fostering innovation (Beck-Krala, Duda, 2014). Thanks to innovation and technological progress, inclusive and sustainable industrial development supports environmental goals, including increased resource and energy efficiency (Worrell et al., 2008).

3. Methodological Assumptions

The calculation of the synthetic measure value using linear ordering methods involves several stages (Nowak, 1990):

I. Selection of diagnostic variables.

At this stage, variables are verified according to substantive, formal, and statistical criteria. For the statistical assessment, measures of variability and correlation are applied.

Most often, the classical coefficient of variation, defined by the following formula, is adopted as the measure of variability:

$$v_j = \frac{s_j}{\bar{x}_j} \quad (j=1,2, ...,m) \tag{1}$$

where:

s_j – standard deviation of variable X_j,

$\bar{x}_j$ – arithmetic mean of variable X_j.

From the set of potential diagnostic variables, those that meet the following condition are eliminated:

$$\left|v_j\right| \leq v^* \tag{2}$$

where: v^* – the critical value of the coefficient of variation.

The critical value is most often assumed at the level of 0.1. In the literature, it is accepted that the variable then does not possess discriminative ability, and thus has little informational value (Panek, 2009; Nowak, 1990).

For the assessment of variable correlation, the inverted correlation matrix method proposed by Malina and Zeliaś (1998) may be applied. This method consists of:

1. Calculating the matrix $\boldsymbol{R}$ of Pearson's linear correlation coefficients between the variables:

$$\boldsymbol{R} = \begin{bmatrix} 1 & r_{12} & \cdots & r_{1m} \\ r_{21} & 1 & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & 1 \end{bmatrix} \tag{3}$$

where: r_{jk} – Pearson's linear correlation coefficient between variables X_j and Xk.

2. Determining the inverse matrix of $\boldsymbol{R}$:

$$\mathbf{R}^{-1} = \left[r^{(ij)}\right] \tag{4}$$

where: $r^{(ij)}$ $(i, j = 1, 2, ..., m)$ – the elements of the inverse matrix $\boldsymbol{R^{-1}}$.

The diagonal elements of the inverse matrix are significantly greater than one in cases of excessive correlation of a given variable with the remaining variables. In such cases, variables for which the following condition is satisfied are subject to elimination:

$$\left|r^{(jj)}\right| > r^* \tag{5}$$

where:

$r^{(jj)}$ – the diagonal element of the inverse matrix $\boldsymbol{R^{-1}}$,

r^* – the critical value of the diagonal elements of the inverse matrix $\boldsymbol{R^{-1}}$, most often set at the level of 10.

After conducting the statistical verification of variables, the set of so-called diagnostic variables remains.

II. Application of Selected Linear Ordering Methods.

In the study assessing EU countries with respect to the implementation of SDG 9, two linear ordering methods are applied: the min–max method, also known as the zero unitarization method, and the TOPSIS method. The first belongs to the so-called non-pattern methods, while the second is classified as a pattern method of linear ordering. Both methods make it possible to obtain the value of a synthetic measure, which is a function of many variables. This, in turn, enables the comparison of countries in terms of a so-called complex phenomenon, i.e., one described by several variables.

The methodological assumptions of both methods are presented below.

The min-max method (zero unitarization) requires several stages (Kukuła, 2000):

– Construction of the so-called observation matrix:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \tag{6}$$

– Determining the nature of the variables. Variables can be classified as stimulants or destimulants. Stimulants are features whose high values are desirable from the adopted point of view, while low values are undesirable. Destimulants, on the other hand, are features for which low values are desirable from the perspective of the studied phenomenon, whereas high values are considered undesirable (Hellwig, 1968).

– Normalization of variable values, i.e., making them comparable by means of formulas:

For stimulants:

$$z_{ij} = \frac{x_{ij} - \min\limits_{i}\{x_{ij}\}}{R_j} \tag{7}$$

For destimulants:

$$z_{ij} = \frac{\max\limits_{i}\{x_{ij}\} - x_{ij}}{R_j} \tag{8}$$

– Determining the value of the synthetic measure using the following formula:

$$MS_i = \frac{1}{m}\sum_{j=1}^{m} z_{ij} \tag{9}$$

where:

MS_i – synthetic measure for the i-th object,

z_i – normalized values of the variables,

m – number of variables.

The TOPSIS method was developed by Hwang and Yoon (1981) and is widely used due to its flexibility in both theoretical and practical analyses. It enables decision-making in complex multi-criteria problems while taking into account various aspects of the studied phenomena (Roszkowska, 2011). This method includes steps defined by formulas (6-8) and additionally by formulas (10-14):

– Determining the coordinates of the model units – the development pattern (A^+) and the anti-pattern (A^-):

$$A^+ = (\max_i(z_{i1}), \max_i(z_{i2}), \ldots, \max_i(z_{im})) = (z_1^+, z_2^+, \ldots, z_m^+) \quad (10)$$

$$A^- = (\min_i(z_{i1}), \min_i(z_{i2}), \ldots, \min_i(z_{im})) = (z_1^-, z_2^-, \ldots, z_m^-) \quad (11)$$

– Calculation of the Euclidean distances of each object from the pattern z^+ and the anti-pattern z^-using the following formulas:

$$d_i^+ = \sqrt{\sum_{j=1}^m \left(z_{ij} - z_m^+\right)^2} \quad (12)$$

$$d_i^- = \sqrt{\sum_{j=1}^m \left(z_{ij} - z_m^-\right)^2} \quad (13)$$

– Determination of the synthetic measure value:

$$MST_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (14)$$

The synthetic measure MST_i takes values in the range [0;1]. An object is considered more advanced in terms of the analyzed complex phenomenon the closer the value of the synthetic measure is to one; that is, the smaller the distance of a given object from the pattern and, consequently, the greater its distance from the anti-pattern.

After calculating the values of the synthetic measures MS_i and MST_i for the objects, it is possible to classify the countries into similar groups according to the following scheme (Nowak, 1990):

Group 1: $MS_i \geq \overline{MS}_i + S_i$ high level

Group 2: $\overline{MS}_i + S_i > MS_i \geq \overline{MS}_i$ medium-high level

Group 3: $\overline{MS}_i > MS_i \geq \overline{MS}_i - S_i$ medium-low level (15)

Group 4: $MS_i < \overline{MS}_i - S_i$ low level

where:

$\overline{MS}_i$ – the mean value of the synthetic measure,

S_i – standard deviation of the synthetic measure.

The use of this scheme made it possible to identify groups of countries with a similar level of SDG 9 development in 2023.

4. SDG 9 Indicators

Sustainable development indicators for the European Union are developed by a reliable institution, Eurostat, in cooperation with national statistical offices of the member states and other EU institutions.

In this study, a ready-made set of Eurostat indicators assigned to SDG 9 was used. These indicators serve as a key tool for monitoring progress in achieving the goals, enabling analyses at the international, national, and regional levels (Raczkowska et al., 2024).

The following variables were proposed to assess the implementation of Sustainable Development Goal 9:

X1 – Gross domestic expenditure on R&D by sector [sdg_09_10],
X2 – R&D personnel by sector [sdg_09_30],
X3 – Patent applications to the European Patent Office by applicants' / inventors' country of residence [sdg_09_40],
X4 – Share of buses and trains in inland passenger transport [sdg_09_50],
X5 – Share of rail and inland waterways in inland freight transport [sdg_09_60],
X6 – Air emission intensity from industry [sdg_09_70],
X7 – Tertiary educational attainment by sex [sdg_04_20],
X8 – Gross value added in environmental goods and services sector [sdg_12_61],
X9 – High-speed internet coverage, by type of area [sdg_17_60].

The values of the variables were obtained from Eurostat via the website: https://ec.europa.eu/eurostat/data/database.

Within the research and development & innovation area, the following four indicators were analyzed: Gross domestic expenditure on R&D (X1), Research and development personnel (X2), Patent applications to the European Patent Office by applicants' country of residence (X3), and Tertiary education attainment of the population (X7).

In the sustainable industry area, two indicators were analyzed: Air emission intensity from industry (X6) and Gross value added in the environmental goods and services sector (EGSS) (X8).

In the sustainable infrastructure area, the following indicators were considered: Share of buses and trains in passenger transport (X4), Share of railways and inland waterways in inland freight transport (X5), and Broadband Internet coverage (X9).

Variables X1-X5 and X7-X9 are stimulants, while only variable X6 is a destimulant.

The variables were also checked for completeness. Missing data for Cyprus and Malta regarding variable X5 led to its removal from the set of indicators.

The calculated values of the coefficient of variation for the proposed variables across the 27 EU countries ranged from 18.5% for variable X9 to 234.4% for variable X6. Therefore, the variables met the criterion of an appropriate level of variability.

The application of the inverse correlation matrix method made it possible to assess the correlations between the variables (Table 1).

Table 1.
Inverse matrix

	X1	X2	X3	X4	X6	X7	X8	X9
X1	**6.882**	-6.203	-1.236	-0.527	0.051	0.094	0.852	-0.102
X2	-6.203	**7.582**	0.582	0.109	-0.248	-0.222	-1.905	0.204
X3	-1.236	0.582	**1.452**	0.338	0.244	0.172	-0.106	-0.044
X4	-0.527	0.109	0.338	**1.381**	0.544	0.391	-0.037	-0.094
X6	0.051	-0.248	0.244	0.544	**1.304**	0.292	0.162	-0.252
X7	0.094	-0.222	0.172	0.391	0.292	**1.340**	-0.311	-0.353
X8	0.852	-1.905	-0.106	-0.037	0.162	-0.311	**1.975**	-0.168
X9	-0.102	0.204	-0.044	-0.094	-0.252	-0.353	-0.168	**1.152**

Source: Author's own elaboration.

The data presented in Table 1 indicate that the examined variables are not strongly correlated with each other and therefore do not replicate similar information.

5. Results

Using the proposed linear ordering methods, i.e., the zero unitarization method and TOPSIS, rankings of EU countries in terms of SDG 9 implementation were constructed. Applying Scheme 15, the EU countries were also classified into groups with a similar level of achievement of the examined goal. The results are presented in Table 2.

Table 2.
Ranking of EU Countries by Synthetic Measure Values in 2023

	Country	MS_i	Group	Country	MST_i	Group
1	Sweden	0.734	I. high level	Sweden	0.641	I. high level
2	Denmark	0.698		Germany	0.634	
3	Belgium	0.691		Denmark	0.612	
4	Germany	0.670		Austria	0.602	
5	Austria	0.669		Finland	0.598	
6	Netherlands	0.658		Belgium	0.594	
7	Luxembourg	0.657		Netherlands	0.566	
8	Finland	0.643		Luxembourg	0.537	II. medium-high level
9	France	0.591	II. medium-high level	France	0.503	
10	Ireland	0.580		Ireland	0.454	
11	Spain	0.511		Hungary	0.438	

Cont. table 2.

12	Slovenia	0.465	III. medium-low level	Spain	0.423	III. medium-low level
13	Estonia	0.459		Slovenia	0.410	
14	Poland	0.453		Portugal	0.408	
15	Hungary	0.448		Estonia	0.388	
16	Malta	0.429		Czechia	0.380	
17	Czechia	0.419		Malta	0.380	
18	Italy	0.414		Poland	0.379	
19	Cyprus	0.401		Italy	0.364	
20	Slovakia	0.399		Romania	0.361	
21	Lithuania	0.386		Slovakia	0.352	
22	Greece	0.369		Bulgaria	0.302	IV. low level
23	Croatia	0.368		Croatia	0.299	
24	Latvia	0.345	IV. low level	Greece	0.294	
25	Portugal	0.341		Cyprus	0.292	
26	Romania	0.322		Latvia	0.279	
27	Bulgaria	0.320		Lithuania	0.267	

Source: Author's own elaboration.

The results obtained using the two linear ordering methods – the zeroed unitaryzation method and the TOPSIS method – allow for a comparison of the positions of European countries in terms of SDG9 implementation in 2023.

A high level of the analyzed composite phenomenon, according to the zeroed unitaryzation method, was achieved by eight countries: Sweden, Denmark, Belgium, Germany, Austria, Netherlands, Luxembourg, and Finland. Three countries – France, Ireland, and Spain – were classified in the group with a medium-high level of SDG9 implementation. The largest group, consisting of 12 countries, showed a medium-low level of SDG9 implementation. Latvia, Portugal, Romania, and Bulgaria occupied the lowest positions in the EU country ranking.

The TOPSIS method similarly orders EU countries in terms of SDG9 implementation. Some shifts between groups were observed for certain countries. The largest changes concerned the following countries: Portugal (25th place according to the zeroed unitaryzation method, but 14th place in TOPSIS – an increase of 11 positions), Romania (26th place vs. 20th place), Bulgaria (27th place vs. 22nd place), Cyprus (19th place vs. 25th place), and Lithuania (21st place vs. 27th place – a drop of 6 positions).

The consistency of the rankings obtained using the zeroed unitaryzation and TOPSIS methods was also assessed using Spearman's rank correlation coefficient. The obtained value of 0.8993 indicates a high similarity between the rankings generated by both methods.

6. Discussion

The implementation of the Sustainable Development Goals (SDGs) outlined in the 2030 Agenda requires coordinated actions in three key areas: social, economic, and environmental. Effective achievement of these goals necessitates continuous monitoring, which allows for an objective assessment of progress. In recent years, particular attention in the scientific community has focused on Goal 9 (SDG 9), concerning the development of infrastructure, industry, and innovation, as well as the possibilities for its practical implementation.

The analysis of the research results presented in this article indicates that the level of SDG 9 implementation in European Union countries is not uniform. The highest performance was observed in northern, particularly Scandinavian, countries, while the lowest levels were recorded in southern European countries, especially those that joined the EU in 2004 or later, such as Romania and Bulgaria. Poland falls into the group of countries with a medium-low level of SDG 9 implementation. The results obtained are consistent with findings from other authors, despite the use of different research methods.

An example of such analyses is the study by Fura et al. (2025), who assessed the level of digital transformation in the areas of industry, innovation, and infrastructure in 27 EU countries in 2015 and 2020. The authors developed an aggregated indicator, the Digital Transformation Assessment Indicator (DTAI), measuring countries' progress in achieving SDG 9. The results showed that the highest values were observed in Scandinavian countries and highly developed nations such as Austria, Germany, and the Netherlands, both in 2015 and 2020. The lowest indicators were recorded in Romania, Greece, Malta, Cyprus, and Portugal. The study confirmed that the greatest challenges in implementing SDG 9 occur in Central, Eastern, and Southern European countries, while the leaders remain the Scandinavian and Western European states. Among the new EU members, Slovenia achieved a high ranking, while among former Eastern Bloc countries, Lithuania ranked highest (in the present study — Hungary). Romania and Bulgaria consistently occupied the lowest positions.

A similar topic was addressed by Burhan (2024), who analyzed the implementation of SDG 9 in EU countries and Turkey (2020) using an integrated MCDM approach, combining objective criterion weighting with VIKOR and MAIRCA techniques. Excluding Turkey, Sweden achieved the highest score, while Greece and Croatia scored the lowest.

Another significant study was conducted by Brodny and Tutak (2023), who evaluated the level of sustainable development in the EU-27 countries (SDG 9) based on 14 specific indicators between 2015 and 2020. They employed MCDM methods (TOPSIS, WASPAS, EDAS) to construct the indicator and used Entropy, CRITIC, and standard deviation (SD) methods to determine weights. Analysis using non-parametric Spearman's tau and Kendall tests examined the relationships between SDG 9 and economic, environmental, energy, and digitalization indicators. The results confirmed substantial differences between EU

countries. The highest levels of SDG 9 achievement were observed in Denmark, Germany, Luxembourg, the Netherlands, Finland, and Sweden, while the lowest were in Bulgaria, Greece, Portugal, and Lithuania. The study also allowed for a temporal comparison between the "old" and "new" EU member states.

The consistency of the above findings with previous studies (Szopik-Depczyńska et al., 2018; Stanujkic et al., 2020; Hametner, Kostetckaia, 2020; Ozkaya et al., 2021; Kuc-Czarnecka et al., 2023) confirms the reproducibility of the results. These authors, using various research methods, indicated that the leaders in implementing SDG 9 are countries in Northern Europe (Sweden, Denmark, Finland) and Western Europe (Germany, the Netherlands, Belgium), while the lowest positions are occupied by Southern European countries, such as Greece, Croatia, Bulgaria, and Romania.

7. Conclusions

Innovation, industrialization and infrastructure development (issues included in Goal 9 of Agenda 2030) are closely intertwined and play an important role in building sustainable economic prosperity for societies around the world. They are therefore a fundament for ensuring sustainable and peaceful development of the world (Brodny, Tutak, 2023).

A comparative analysis of EU countries in terms of SDG 9 implementation in 2023 indicates that the highest performance is achieved by the Nordic countries, including the Scandinavian Peninsula states such as Sweden, Denmark, and Finland, as well as Western European countries, including Germany, Belgium, and the Netherlands. In contrast, Eastern European countries, such as Romania, Bulgaria, and Greece, exhibit the lowest values of the analyzed indicators. The development model of these economies requires a comprehensive transformation toward sustainable growth, which will necessitate ongoing dialogue and close cooperation among all stakeholders directly or indirectly involved in this process. In this context, managers can identify best practices in individual countries, make informed strategic decisions, and implement corrective actions.

The applied research methods, namely the zero unitaryzation method and the TOPSIS method, produced similar rankings of EU countries in terms of SDG 9 implementation, as indicated by the high Spearman rank correlation coefficient.

The conducted analysis and obtained research results provide a significant contribution to deepening the understanding of SDG 9 implementation under the 2030 Agenda in European Union member states, encompassing issues of innovation, industrial development, and infrastructure. These findings can serve as a solid foundation for formulating long-term development strategies for the European Union, as well as for shaping public policies that support digital transformation, the adoption of modern technologies in the industrial sector,

and the expansion of digital and transport infrastructure. Consequently, these actions can contribute to enhancing the global competitiveness of the European economy.

The research results also provide policymakers with valuable diagnostic information, enabling them to monitor progress and identify areas requiring intervention. Countries lagging in SDG 9 implementation—particularly in Central, Eastern, and Southern Europe—can benefit from support programs tailored to their specific needs, including digital infrastructure development and investments in education and human capital. Such actions can contribute to ensuring the sustainable development of the entire European Union.

Furthermore, the study's conclusions can support the effective allocation of EU funds and resources to maximize their impact and ensure that all member states have the opportunity to fully achieve the goals outlined in the 2030 Agenda, including Sustainable Development Goal 9. Thus, the obtained results constitute a valuable source of knowledge that can support decision-making processes and the design of targeted actions in key areas of SDG 9.

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SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

PERSONAL FINANCE AND MACROECONOMIC INDICATORS IN POLAND: AN ANALYSIS OF HOUSEHOLD SAVING BEHAVIOR

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Purpose: The aim of this study is to examine the savings dimension of household personal finance in Poland and the factors influencing it. To achieve this, the analysis focuses on the relationship between the household saving rate and selected socio-economic indicators in Poland over the period from 2000 to 2022.
Design/methodology/approach: This study includes both correlation analysis and interpretation of observed relationships. Its approach is to determine whether fluctuations in household savings levels are related to noticeable macroeconomic changes and to identify the variables that most effectively explain changes in savers' behaviour.
Findings: Empirical findings showed that neither GDP growth nor GDP per capita growth showed a statistically significant correlation with household savings. Key empirical findings include the fact that unemployment and the average NBP interest rate showed positive and statistically significant correlation with household savings. The study highlights the complexity of household behaviour with regard to savings and the importance of taking several macroeconomic factors into account simultaneously.
Research limitations/implications: Limitations of the methodology include the use of aggregate-level data, which may obscure differences in the savings behaviour of different household groups, as well as a focus on linear relationships, which may not reflect more complex non-linear interactions between variables.
Practical implications: These results may be of particular practical significance in the context of monetary policy, as they indicate that interest rate policy influences household behaviour with regard to savings, although the effectiveness of such policy may depend on labour market conditions and economic uncertainty. The significant relationship between unemployment and saving rates confirms the relevance of of Poles' precautionary saving motives, highlighting the importance of employment security in household financial planning.
Originality/value: The research contributes to the literature on Polish household saving behavior by providing empirical evidence on the relationships between saving rates and macroeconomic conditions. The findings suggest that Polish households exhibit rational responses to economic uncertainty, particularly regarding employment security, while being less sensitive to aggregate economic growth or inflation than might be theoretically expected.
Keywords: personal finance, wealth planning, savings, financial behavior, financial security.
Category of the paper: research paper.

1. Introduction

Savings represent a crucial component of household personal finance, influencing not only the economic prosperity of individual households but also reflecting broader trends in the macroeconomic environment. On one hand, the level of household savings, being the counterpart of consumption, affects aggregate demand in a market economy. On the other hand, savings represent a vital source of capital for investment by entrepreneurs. The issue of household savings represents a pressing concern for individual households and a matter of considerable importance for other economic actors, thereby underscoring its relevance and broader economic significance.

On the micro level, the capacity to save is closely associated with long-term financial well-being, resilience to economic shocks, and overall psychological security. At the macroeconomic level, household savings represent a critical determinant of national investment capacity, influencing capital accumulation, interest rates, and long-term economic growth. As such, the dynamics of household saving behavior are of central concern not only to policymakers and economists, but also to sociologists, psychologists, and anthropologists seeking to understand economic decision-making within a broader social context.

The importance of savings extends beyond financial planning; it reflects consumption patterns, economic confidence, and responses to both structural and cyclical economic forces. From the Keynesian perspective, savings and consumption are inherently interrelated, with savings often viewed as deferred consumption (Keynes, 1936). Consequently, changes in saving rates can provide valuable insights into household expectations, financial constraints, and perceived risks.

Some studies suggest that savings have a positive impact on households' mental well-being and their perceived sense of financial security (Ambaw et al., 2025). However, the structure and level of savings exhibit variations across different countries (Zawadzka, Grzywińska-Rąpca, 2021).

The level of savings among households may arise from various causes, including insufficient income or a heightened desire for material possessions, often described as consumerism. The saving behavior of households is shaped by a complex set of underlying factors and motivations, which provides the objective for this study. The aim of this study is to examine the savings dimension of household personal finance in Poland and the factors influencing it. To achieve this, the analysis focuses on the relationship between the household saving rate and selected socio-economic indicators in Poland over the period from 2000 to 2022.

This study encompasses both a correlation-based analysis and a contextual interpretation of the observed relationships within the framework of existing literature and economic policy. It seeks to determine whether fluctuations in the household saving rate are associated with notable macroeconomic developments and to identify which variables most effectively account

for variations in saving behavior. The analysis covers the period from 2000 to 2022, as it allows for an examination of household behavior in response to significant economic events, including Poland's accession to the European Union in 2004, the impact of the 2008 global financial crisis, and the COVID-19 recession.

Understanding the determinants of household saving behavior is crucial for designing effective fiscal, monetary, and social policies. Given the growing complexity of financial environments and the emergence of new economic uncertainties, the study of savings remains a timely and essential area of research in the field of personal finance and macroeconomic analysis.

2. Literature Review

The motivation to save has been a subject of interest for researchers across various disciplines, including economics, sociology, psychology, anthropology, and others. Classical and neoclassical economic theories typically conceptualize savings as a function of income, interest rates, and intertemporal preferences. The life-cycle hypothesis (Ando, Modigliani, 1963) and the permanent income hypothesis (Friedman, 1957) argue that individuals smooth consumption over time based on lifetime expected income, implying that short-term income fluctuations have limited impact on savings. The interplay between individual savings behavior and life expectancy is fundamentally mediated by the structure of the pension system and households' perceived financial security in retirement (Aizenman et al., 2015; Barembruch, Bielawska, 2023; Bielawska, Kozłowski, 2024; Jing et al., 2025). Economic theory and empirical evidence suggest that these institutional and psychological determinants significantly shape savings responses to increasing longevity (Barr, Diamond, 2006; OECD, 2021).

A foundational contribution to the study of saving behavior comes from John Maynard Keynes who introduced the concept of the consumption function, positing that consumption and savings are primarily determined by current income levels. According to Keynes, as income rises, households increase their consumption but by a smaller proportion, leading to a rise in the marginal propensity to save. Keynesian theory also emphasizes the psychological motives for saving, including precaution, foresight, and the desire to leave bequests, framing saving behavior not only as a rational economic decision but also a function of individual expectations and social context (Keynes, 1936).

However, empirical evidence suggests that households do not always behave in accordance with these models, particularly under conditions of financial uncertainty, liquidity constraints, or behavioral biases (Korzeniowska, Ulman, 2023). In contemporary economic contexts, individual decision-making is significantly influenced by considerations of environmental sustainability, as well as the pursuit of harmony and balance in consumption and lifestyle

choices (Bitkowska et al., 2022; Kędzierska-Szczepaniak, 2024; Majerowska, Jasik, 2024; Płoska et al., 2024; Stepanok, 2024; Balla, 2024). This reflects a growing integration of ecological awareness into rational economic behavior, where utility maximization increasingly incorporates non-monetary factors such as personal well-being and long-term environmental impacts.

Cronqvist & Siegel (2015) employing a large sample of monozygotic and dizygotic twins has demonstrated that genetic variation accounts for approximately one-third of the individual differences in savings behavior. The findings suggest that individuals possess a stable, genetically influenced predisposition toward certain saving patterns. While parental influence appears to play a significant role in shaping savings behavior during early life stages, its impact diminishes with age. Moreover, early-life environmental factors, such as parental wealth, interact with genetic predispositions to influence financial behavior.

Psychological and sociological perspectives emphasize the influence of social norms, cultural context, and individual traits such as time preference and risk aversion on saving behavior (Beverly, Sherraden, 1999). The relationship between savings behavior and longevity is further complicated by national cultural traits, collective economic mentality, and historical institutional development, necessitating country-specific analysis (Brounen et al., 2016; Lee et al., 2025; Emara, 2025). Variations in savings rates across nations cannot be fully explained by pension systems or rational economic models alone – deep-seated sociocultural and historical factors play a crucial mediating role.

Szustak et al. (2025) emphasises that in Poland, the population has developed a cultural attitude towards thriftiness, shaped by historical experiences of economic instability, which remains a persistent factor: older generations maintain higher savings rates than younger generations. In the Polish context, households tend to favor tangible assets, particularly real estate, as the primary form of long-term savings. This preference is shaped by historical experience, which has fostered a cultural emphasis on property ownership as a secure store of value (Krupa et al., 2013; Kulpaka, 2016). Furthermore, trust in financial institutions remains relatively low in Polish society, reinforcing the tendency to prioritize physical assets over formal financial products. According to Olszewska (2023), these patterns reflect a persistent skepticism toward institutional finance and a strong material orientation in household saving strategies.

Despite the extensive development of research on household saving behavior, the number of studies specifically focused on the Polish context remains limited. This gap in the literature highlights the need for further empirical investigation into the determinants and dynamics of household savings in Poland, particularly in light of the country's unique socio-economic trajectory and transitional experience.

3. Methods

This study employs a quantitative approach to examine the relationship between household saving rates and selected macroeconomic indicators in Poland over the period 2000-2022. The analysis is based on data obtained from reliable institutional sources, specifically Statistics Poland, the World Bank database (World Bank Open Data), and the National Bank of Poland (Narodowy Bank Polski).

The dependent variable in this analysis is the household saving rate, calculated as the ratio of gross household savings to gross disposable income, adjusted for changes in pension entitlements. This indicator serves as a comprehensive measure of household financial behavior and represents the proportion of income that households allocate to savings rather than consumption.

The independent variables selected for analysis include several key macroeconomic indicators that theoretical and empirical literature identify as potential determinants of household saving behavior:

- GDP Growth Rate - representing overall economic performance and macroeconomic stability.
- GDP per capita Growth Rate - reflecting changes in individual economic well-being and living standards.
- Price Index - serving as an indicator of inflation and changes in purchasing power.
- Unemployment Rate - indicating labor market conditions and employment guarantees.
- Average NBP Interest Rate (the arithmetic mean of the NBP reference rates for the year is taken into account) - representing monetary policy stance and the opportunity cost of consumption.

The methodology used is primarily a correlation analysis using Pearson's correlation coefficients to quantitatively assess the strength and direction of linear relationships between the household savings rate and each macroeconomic variable. Statistical significance is assessed at the conventional 5% level ($p < 0.05$), with p-values indicated for each correlation coefficient.

First, a descriptive analysis is conducted to identify patterns, trends, and notable fluctuations in the variables under investigation over the observation period. Second, a correlation analysis is performed to examine the relationships between the household savings rate in Poland and each macroeconomic indicator. Third, a contextual interpretation of the statistical findings is provided, grounded in economic theory and taking into account the influence of major historical events, including Poland’s accession to the European Union (2004), the global financial crisis (2008-2009), and the COVID-19 pandemic (2020-2022).

The study period of 2000-2022 was deliberately chosen to capture Poland's economic transformation and exposure to various external shocks, providing a comprehensive view of household saving behavior under different macroeconomic conditions. This timeframe allows for the examination of both cyclical and structural factors influencing household financial decisions. The correlational approach, while not establishing causality, provides valuable insights into the systematic relationships between macroeconomic conditions and household saving patterns.

4. Results and Discussion

The household saving rate constitutes a key indicator for the household personal finance and wealth planning. It provides insight into the manner in which households allocate their income between consumption and savings. The indicator is calculated as the ratio of gross savings to gross disposable income, augmented by an adjustment for changes in pension entitlements.

Throughout the period 2000-2022, this indicator exhibited substantial fluctuations, reaching a minimum value of 0.4% in 2022 and a maximum of 12.2% in 2020 (Figure 1). The average value over the entire period amounted to 6.2%, while the median was 5.6%. These dynamics reflect the sensitivity of household saving behaviour to macroeconomic conditions, such as income uncertainty, interest rates, and fiscal policies.

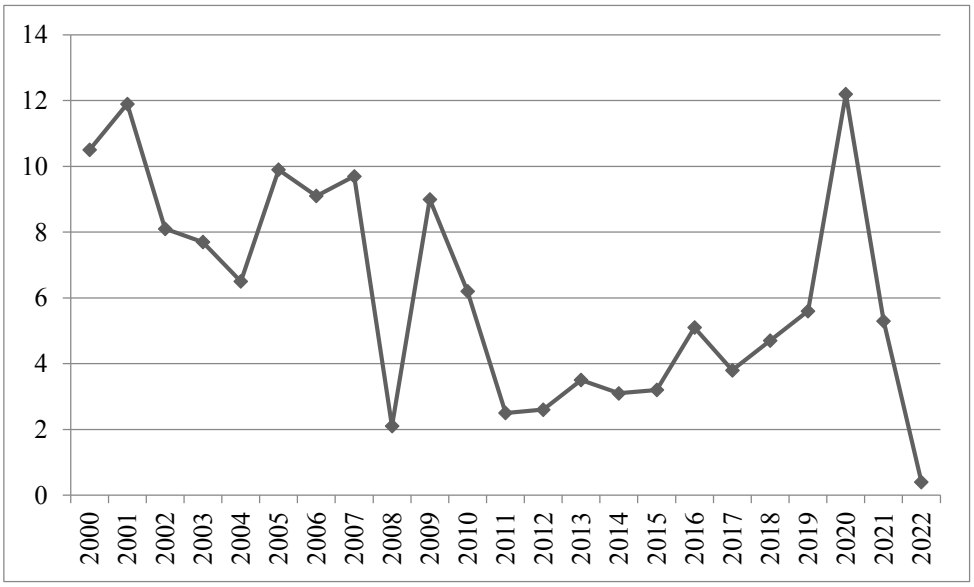

Figure 1. Household Saving Rate (%) over the period 2000-2022.

Source: own elaboration based on Statistics Poland.

The observed volatility and inconsistency in household saving behavior in Poland indicate that there are specific underlying factors and determinants influencing it. During the period under review, the Polish economy underwent historic transformations marked by significant institutional changes, the country's accession to the European Union, the consequences of the global financial crisis and the impact of the COVID-19 pandemic. These events not only affected the economy as a whole but also shaped the financial actions of individual households, creating specific behavioural patterns. In aggregate terms, the economy's response to these internal and external shocks can be seen in GDP growth fluctuations. However, it remains unclear whether changes in GDP have directly affected the level of household savings in Poland. This uncertainty highlights the need for a thorough analysis of the relationship between macroeconomic dynamics and household behaviour in the area of savings.

Table 1.
Household Saving Rate and GDP Growth in Poland (2000–2022), with Pearson Correlation Coefficient

Year	Household Saving Rate (%)	GDP Growth (%)	Pearson Correlation Coefficient	p-value
2000	10,5	4,01		
2001	11,9	2,92		
2002	8,1	1,51		
2003	7,7	3,30		
2004	6,5	4,74		
2005	9,9	6,38		
2006	9,1	6,62		
2007	9,7	5,49		
2008	2,1	2,61		
2009	9	-4,80		
2010	6,2	2,71		
2011	2,5	1,77	-0,08	0,7
2012	2,6	-0,77		
2013	3,5	-0,04		
2014	3,1	2,25		
2015	3,2	4,96		
2016	5,1	2,58		
2017	3,8	5,17		
2018	4,7	2,83		
2019	5,6	3,57		
2020	12,2	-5,30		
2021	5,3	4,03		
2022	0,4	2,85		

Source: own elaboration based on Statistics Poland and World Bank data.

A preliminary visual analysis of the data in Table 1 shows a nonlinear and inconsistent relationship between GDP growth and household savings rates. For example, in years of relatively high GDP growth, such as 2006 (6.62%) and 2007 (5.49%), the level of household savings remained fairly high, but did not exceed the maximum level for the period under review (9.1% and 9.7%, respectively). In contrast, in 2008, the level of savings fell sharply to 2.1%, despite continued positive GDP growth (2.61%).

It is noteworthy that in 2009, amid the economic downturn caused by the global financial crisis (GDP declined by -4.80%), the savings rate rose sharply to 9.0%, indicating preventive savings measures by households in the face of economic uncertainty. A similar pattern was observed in 2020, at the height of the COVID-19 pandemic, when GDP declined by -5.30% and the savings rate rose to 12.2%, the highest figure for the entire observation period.

To quantify this relationship, Pearson's correlation coefficient was calculated, which was -0.08 with a p-value of 0.7, indicating that the correlation between household savings and GDP growth during the period under review is statistically insignificant. This suggests that GDP growth alone is not a strong or reliable predictor of household savings behaviour in Poland.

GDP growth per capita is an indicator that differs from overall GDP growth, as it more accurately reflects the standard of living and economic well-being of the population. Table 2 shows the dynamics of GDP per capita growth for the period under review, which allows us to analyse whether this figure was directly related to the level of household savings in Poland.

Table 2.
Household Saving Rate and GDP per capita Growth in Poland (2000-2022), with Pearson Correlation Coefficient

Year	Household Saving Rate (%)	GDP per capita growth (annual %)	Pearson Correlation Coefficient	p-value
2000	10,5	5,76	-0,26	0,215
2001	11,9	1,26		
2002	8,1	1,95		
2003	7,7	3,59		
2004	6,5	5,15		
2005	9,9	3,31		
2006	9,1	6,27		
2007	9,7	6,82		
2008	2,1	4,37		
2009	9	2,55		
2010	6,2	3,46		
2011	2,5	5,20		
2012	2,6	1,51		
2013	3,5	0,75		
2014	3,1	4,00		
2015	3,2	4,50		
2016	5,1	3,08		
2017	3,8	5,14		
2018	4,7	6,25		
2019	5,6	4,61		
2020	12,2	-1,86		
2021	5,3	9,58		
2022	0,4	5,71		

Source: own elaboration based on Statistics Poland and World Bank data.

The data show significant variability in both indicators over the years 2000-2022. Periods of sustained GDP per capita growth, such as 2006-2007 and 2018-2019, were accompanied by moderate to high household savings rates. However, in 2008, despite relatively high GDP per capita growth (4.37%), the household savings rate fell sharply to 2.1%, indicating that other

economic or psychological factors (such as global financial uncertainty) influenced savings behaviour that year.

A particularly notable anomaly occurred in 2020, during the COVID-19 pandemic, when GDP per capita declined by 1.86% and the savings rate rose to 12.2%, likely due to precautionary measures, reduced consumption opportunities, and heightened economic uncertainty. In contrast, in 2022, GDP per capita grew significantly (5.71%), but the household savings rate fell sharply to 0.4%, the lowest level in the entire observation period, possibly reflecting a recovery in consumption after the pandemic or inflationary pressure on disposable income.

The Pearson correlation coefficient between the household savings rate and GDP per capita growth for this period is -0.26, and the p-value is 0.215, indicating a weak and statistically insignificant negative relationship. This result means that, like aggregate GDP growth, GDP growth per capita is not a reliable indicator of household savings behaviour in Poland.

So, even though GDP growth per capita in Poland is a useful indicator of how prosperous a society is, it doesn't really explain household savings patterns that well without taking into account broader contextual and behavioural factors.

Studying the impact of changes in price levels, particularly inflation, on household savings behaviour is important for understanding both macroeconomic stability and financial decision-making at the individual level. The theoretical basis for this relationship is based on the Fisher equation, introduced by Fisher (1930), which postulates that the real interest rate is equal to the nominal interest rate minus the inflation rate. According to Fisher, inflation reduces the real return on nominal savings, effectively imposing an ‘inflation tax’ on savers and potentially discouraging savings in favour of immediate consumption. Building on this concept, Tobin (1965) argued that rising inflation encourages investors and households to replace cash balances with physical assets, thereby reducing demand for real money holdings. These theoretical conclusions were supported and refined by empirical research. Juster and Wachtel (1972) and Davidson and MacKinnon (1983) investigated how inflation expectations influence households' savings decisions, while Heer and Suessmuth (2009) used several models to study the relationship between inflation and savings behaviour. Taken together, these studies show that when inflation rises faster than nominal interest rates, the associated decline in real returns may discourage saving. However, under certain conditions, such as high uncertainty or expected future inflation, households may increase their savings as a precautionary measure. Thus, the relationship between inflation and household savings is theoretically significant and empirically complex, warranting closer examination in the context of Poland's changing economic situation. Table 3 presents data on the household savings rate and the annual price index in Poland for the period 2000-2022, with the price index expressed as a percentage relative to the previous year (base year = 100). The point of this analysis is to see if changes in the overall price level, which we're using here as a measure of inflation, have had a noticeable impact on how households save over time.

Table 3.
Household Saving Rate and Price index in Poland (2000–2022), with Pearson Correlation Coefficient

Year	Household Saving Rate (%)	Price index (base year: previous year = 100)	Pearson Correlation Coefficient	p-value
2000	10,5	110,1		
2001	11,9	105,5		
2002	8,1	101,9		
2003	7,7	100,8		
2004	6,5	103,5		
2005	9,9	102,1		
2006	9,1	101		
2007	9,7	102,5		
2008	2,1	104,2		
2009	9	103,5		
2010	6,2	102,6		
2011	2,5	104,3	–0,05	0,82
2012	2,6	103,7		
2013	3,5	100,9		
2014	3,1	100		
2015	3,2	99,1		
2016	5,1	99,4		
2017	3,8	102		
2018	4,7	101,6		
2019	5,6	102,3		
2020	12,2	103,4		
2021	5,3	105,1		
2022	0,4	114,4		

Source: own elaboration based on Statistics Poland and World Bank data.

The price index for the period under review reflects several key macroeconomic events, including relatively high inflation in the early 2000s (e.g., 110.1 in 2000), a period of price stability and moderate deflation in 2014-2016, and significant inflationary pressure in 2022, when the price index jumped to 114.4, the highest value in the data set. Accordingly, the household savings rate showed noticeable volatility, but not in direct relationship to changes in the price level. For example, in 2008, the savings rate fell sharply to 2.1% despite a moderate price index of 104.2, while in 2020, amid the uncertainty associated with the pandemic, savings rose to 12.2% despite an average price index of 103.4. Pearson's correlation coefficient for the relationship between household savings and the annual price index was calculated at –0.05 with a p-value of 0.82, indicating a very weak and statistically insignificant negative correlation. This result suggests that, in the long term, changes in the general price level did not have a constant or direct influence on the savings behaviour of households in Poland.

These findings are consistent with broader theoretical perspectives suggesting that the link between inflation and savings is not linear and may depend on context.

The sharp decline in the savings rate in 2022 (0.4%), despite an unprecedented jump in the price index (114.4), may reflect households' response to pressure from rising living costs, with real income erosion reducing their ability to save. Conversely, during periods of deflation or low inflation (e.g., in 2015-2016), households did not significantly increase their savings,

suggesting that factors unrelated to inflation, such as income levels, labour market conditions or trust in institutions, play a more decisive role.

Table 4 presents data on the household savings rate and the overall unemployment rate in Poland for the period 2000-2022, as well as Pearson's correlation coefficient and the corresponding significance level. The analysis seeks to assess whether changes in the labour market have affected household behaviour with regard to savings.

Table 4.
Household Saving Rate and Unemployment in Poland (2000–2022), with Pearson correlation Coefficient

Year	Household Saving Rate (%)	Unemployment, total (% of total labor force)	Pearson Correlation Coefficient	p-value
2000	10,5	14,928	0,46	0,026
2001	11,9	18,435		
2002	8,1	20,211		
2003	7,7	19,899		
2004	6,5	18,822		
2005	9,9	17,592		
2006	9,1	13,794		
2007	9,7	9,551		
2008	2,1	7,069		
2009	9	8,131		
2010	6,2	9,578		
2011	2,5	9,576		
2012	2,6	10,031		
2013	3,5	10,293		
2014	3,1	8,971		
2015	3,2	7,475		
2016	5,1	6,141		
2017	3,8	4,867		
2018	4,7	3,835		
2019	5,6	3,267		
2020	12,2	3,155		
2021	5,3	3,268		
2022	0,4	2,811		

Source: own elaboration based on Statistics Poland and World Bank data.

The results indicate a moderately positive and statistically significant correlation between household savings and unemployment, with a Pearson correlation coefficient of 0.46 and a p-value of 0.026. This suggests that in Poland, rising unemployment is usually accompanied by an increase in household savings, and this pattern is consistent with the precautionary savings hypothesis, according to which households respond to economic uncertainty by increasing savings to protect themselves from potential income loss (Carroll, Samwick, 1997; Deaton, 1991).

In the Polish context, such behaviour was evident in years such as 2001-2002, when unemployment exceeded 18% and savings remained relatively high. Similarly, in 2009, following the global financial crisis, the savings rate recovered to 9.0%, coinciding with increased uncertainty in the labour market.

These results are consistent with the broader empirical literature emphasising the role of uncertainty about the future and the risk of income loss in shaping household financial behaviour. For example, Benito (2006) found that increased uncertainty about the future leads households to reduce consumption and increase savings in case of unforeseen circumstances. Similarly, Stephens Jr. (2004) demonstrates that both expected and actual job losses significantly affect household consumption behaviour, confirming the importance of labour market expectations in savings decisions. Gruber (1997) also emphasises how the availability of unemployment insurance helps smooth consumption during periods of job loss, suggesting that institutional mechanisms can mitigate but not eliminate the motives for precautionary savings.

It is noteworthy that the sharp increase in the savings rate in Poland in 2020 (12.2%), despite historically low unemployment (3.2%), reflects the exceptional situation caused by the COVID-19 pandemic, during which households faced unprecedented uncertainty and limited consumption opportunities. This confirms the argument that, although labour market conditions are important, subjective expectations and broader uncertainty shocks can also significantly alter savings behaviour. The decline to 0.4% in 2022, despite historically low unemployment, may reflect strong consumption recovery effects, weakening precautionary motives, and increased pressure on the cost of living due to inflation.

Thus, the positive correlation between unemployment and household savings in Poland convincingly confirms the theory that the key factor determining savings behaviour is not so much income as economic uncertainty. These findings highlight the need for policymakers to consider not only labour market indicators but also household expectations and risk perceptions when assessing savings trends and designing social protection systems.

The interest rate is one of the main factors determining household behaviour with regard to savings, both in classical and modern economic theory. According to the intertemporal choice model, interest rates influence the trade-off between current and future consumption. Higher interest rates increase the return on postponed consumption, encouraging households to save rather than spend. Conversely, lower interest rates reduce the opportunity cost of current consumption, which may discourage saving.

Theoretically, a positive relationship between nominal interest rates and household savings is expected, especially in economies where households respond to interest rate-based incentives. However, the actual effect depends on the balance between the substitution effect and the income effect: while the substitution effect encourages savings when interest rates rise, the income effect can work in the opposite direction, especially for wealthier households that already hold significant interest-bearing assets.

Given Poland's dynamic monetary policy, characterised by a sharp decline in interest rates in the early 2000s, monetary easing during the global financial crisis, and historically low rates in response to the COVID-19 pandemic, it is important to assess how changes in the average annual interest rate of the NBP (Narodowy Bank Polski) have affected behaviour.

Table 5.
Household Saving Rate and Average NBP Interest Rate in Poland (2000-2022), with Pearson Correlation Coefficient

Year	Household Saving Rate (%)	Average NBP Interest Rate (annual %)	Pearson Correlation Coefficient	p-value
2000	10,5	18,25	0,44	0,035
2001	11,9	14,30		
2002	8,1	8,28		
2003	7,7	5,88		
2004	6,5	6,08		
2005	9,9	5,15		
2006	9,1	4,13		
2007	9,7	4,63		
2008	2,1	5,54		
2009	9	3,88		
2010	6,2	3,50		
2011	2,5	4,13		
2012	2,6	4,50		
2013	3,5	3,20		
2014	3,1	2,00		
2015	3,2	1,50		
2016	5,1	1,5		
2017	3,8	1,50		
2018	4,7	1,5		
2019	5,6	1,50		
2020	12,2	0,53		
2021	5,3	1,16		
2022	0,4	4,69		

Source: own elaboration based on Statistics Poland and Narodowy Bank Polski data.

Table 5 presents the relationship between the household saving rate and the average interest rate set by the National Bank of Poland from 2000 to 2022. The Pearson correlation coefficient is 0.44, with a p-value of 0.035, indicating a moderate positive and statistically significant relationship between these two variables.

This result is consistent with standard theoretical expectations, according to which higher interest rates correlate with an increase in household savings, as households have an incentive to postpone consumption and accumulate interest-bearing financial assets. For example, in the early 2000s, when interest rates exceeded 10%, the household savings rate also remained relatively high, peaking at 11.9% in 2001. Conversely, the lowest savings rate recorded in the data set for the period under review, namely 0.4% in 2022, coincided with the recovery of interest rates from near zero during the pandemic.

However, the relationship is not perfectly linear, and several periods demonstrate divergence between interest rates and saving behavior. For instance, in 2008, despite a moderate interest rate of 5.54%, the saving rate dropped sharply to 2.1%, likely reflecting economic uncertainty and deteriorating consumer confidence amid the global financial crisis. Similarly, the sharp increase in household saving in 2020 (12.2%) occurred during a historically low interest rate of 0.53%, highlighting the dominance of precautionary motives during the

COVID-19 pandemic, when households curtailed consumption due to lockdowns and uncertainty, rather than being driven by monetary incentives.

Thus, while interest rates remain an important determinant of saving behavior, their explanatory power may be conditional on broader macroeconomic and psychological factors, such as expectations, income security, and liquidity constraints.

5. Summary

This study analysed the relationship between household savings levels and key macroeconomic indicators in Poland between 2000 and 2022, contributing to the recent literature on the financial behaviour of Polish households. The analysis revealed a number of important findings that provide a better understanding of the factors influencing household savings decisions in the context of the Polish economy.

The household saving rate in Poland demonstrated considerable volatility throughout the observation period, ranging from a minimum of 0.4% in 2022 to a maximum of 12.2% in 2020, with an average of 6.2%. This variability reflects the sensitivity of household financial behavior to changing macroeconomic conditions and extraordinary circumstances, particularly during periods of economic uncertainty.

Empirical findings showed that neither GDP growth nor GDP per capita growth showed a statistically significant correlation with household savings. This indicates that aggregate economic indicators alone are insufficient to predict household savings behaviour in Poland, highlighting the importance of other factors beyond overall economic growth.

Furthermore, inflation, as measured by the price index, did not show a significant relationship with household savings rates. This finding challenges simple theoretical predictions about the relationship between inflation and savings, suggesting that Polish households' saving decisions are not primarily driven by changes in price levels or inflation expectations.

Key empirical findings include the fact that unemployment showed a moderate positive and statistically significant correlation with household savings. This result strongly supports the precautionary savings hypothesis, indicating that Polish households respond to labour market uncertainty by increasing their savings as a protective measure against potential income loss.

The average NBP interest rate also showed a positive and statistically significant correlation with the level of household savings. This result is consistent with traditional economic theory, according to which monetary policy decisions influence household savings behaviour through the interest rate channel, although this relationship is not perfectly linear and may be mitigated by other factors.

These results may be of particular practical significance in the context of monetary policy, as they indicate that interest rate policy influences household behaviour with regard to savings, although the effectiveness of such policy may depend on labour market conditions and general economic uncertainty. The significant relationship between unemployment and saving rates confirms the relevance of precautionary saving motives in the Polish context, highlighting the importance of employment security in household financial planning. This practical result highlights the importance of stable employment and social protection systems for maintaining the financial security of households in Poland, a factor that must be taken into account in the country's social policy.

The sharp decline in the savings rate in 2008 (2.1%), despite moderate economic performance, reflects the psychological impact of global financial uncertainty. In contrast, the unprecedented rise in 2020 (12.2%) during the COVID-19 pandemic demonstrates how extraordinary circumstances can disrupt normal economic relations, with households increasing savings both out of precaution and because of reduced consumption opportunities.

The research contributes to the literature on Polish household saving behavior by providing systematic empirical evidence on the relationships between saving rates and macroeconomic conditions. The findings suggest that Polish households exhibit rational responses to economic uncertainty, particularly regarding employment security, while being less sensitive to aggregate economic growth or inflation than might be theoretically expected.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

COMPARISON OF PATH SPLITTING CONCEPTS UNDER SELECTED PROCESS MODELLING METHODS

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Purpose: The main purpose of the study is to identify and discuss the differences between the various solutions applied for process splitting under three selected popular process modelling methods, namely EPC, BPMN, and YAWL.
Design/methodology/approach: The three selected process modelling methods have been characterised in the first place based on with reference to a literature review. For each of them, the commonly used elements and the most important process modelling rules have been discussed in the paper. In the next step, four workflow patterns describing different cases of process splitting have been selected. For each of these patterns, a short abstract process has been proposed to serve as an example. And for each of the methods analysed, the respective rules of path splitting have been discussed in detail, and models have been created for the processes proposed. On such a basis, the differences between the individual methods have been identified and discussed.
Findings: The methods analysed are characterised by a very distinctive approach to process path splitting. All these methods enable modelling of cases aligned with patterns 2, 4, and 6, while the manner in which conditions are defined for patterns 4 and 6 is completely disparate in each of them. Such conditions can be defined using an event type element which occurs first in each of the paths going out of the splitting point, they can be assigned to the conditional flows going out of the splitting point, or they can be defined in the properties of the activity after which the splitting takes place. Even apparently similar concepts are approached differently under the methods analysed. Both BPMN and YALW make use of default flows. However, in BPMN, they are optional and cannot have a condition assigned to them, while in YAWL, they are mandatory and can have such a condition. Only BPMN and YAWL feature dedicated solutions for splitting in line with pattern 16.
Social implications: The article emphasises how important it is to know the rules by which models are created under the specific method in use. It also highlights the fact that the knowledge of the rules applicable to one method cannot be automatically transferred to others.
Originality/value: The identification and discussion of the differences between the methods analysed is a new and original endeavour.
Keywords: business process management, EPC, YAWL, BPMN.
Category of the paper: Research.

1. Introduction

One of popular contemporary solutions commonly employed in management is the process approach, extensively addressed in scientific papers (Brilman, 2002; Nowosielski, 2008; Witkowska, 2021). According to this approach, an organisation is primarily perceived as a set of processes implemented within it and interacting with one another – a concept which departs from focusing on positions or functions (Miller, 2011). In order to exert a genuine effect on the processes at hand, one must have good and comprehensive understanding of them. What becomes extremely important in this respect is their correct identification and subsequent description. A precise description often requires a clear and unambiguous model to be prepared. Many different concepts may come in handy in that regard. And although these concepts refer to the same body of problems and may even seem similar at the first glance, they can actually differ quite dramatically from one another.

The subject literature contains numerous studies that discuss in detail the individual methods used in process modelling. However, no studies have been found that emphasize the differences between them. As part of the conducted research, solutions related to process path splitting were compared across three selected popular process modelling methods. Within this scope, the following research question was defined: 'What are the differences in the way process path splitting is handled in popular process modelling methods?

For purposes of this study, three popular methods applied in process modelling have been chosen. These are EPC, BPMN, and YAWL.

These methods are discussed in Chapter 3. Chapter 4 presents four abstract processes corresponding to four different cases of process flow branching, along with the application of each selected modelling method to represent each process. Chapter 5 examines the similarities and differences between the analysed methods. Final conclusions are presented in Chapter 6.

2. Methodology

The three selected process modelling methods EPC, BPMN and YAWL have been characterised in the first place based on with reference to a literature review. For each of them, the commonly used elements and the most important process modelling rules have been discussed in the paper. In the next step, a comparative analysis was conducted for the selected methods. Four workflow patterns describing different cases of process splitting have been selected. For each of these patterns, a short abstract process has been proposed to serve as an example. And for each of the methods analysed, the respective rules of path splitting have been discussed in detail, and models have been created for the processes proposed.

On such a basis, the differences between the individual methods have been identified and discussed.

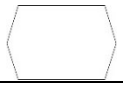
3. Literature review: Characteristics of the selected business process modelling methods

3.1. EPC

EPC models were originally developed at the end of the 20th century as part of the collaboration between SAP AG and the University of Saarbrücken. In the initial phase of development, model describing was informal in nature (Keller et al., 1992), but in subsequent years, the principles governing this process were clarified and formalised. A formal approach to flat EPC models was presented by William van der Alst in 1999 (Alst, 1999), while a formal approach to flat and hierarchical models – in the year 2002 (Nüttgens, Rump, 2002). Later on, formalised EPC model rules appeared in numerous studies (Mendling, Nüttgens, 2003; Gruhn, Laue, 2007; Mendling, Aalst, 2006).

This article focuses on flat EPC models, i.e. those which are not linked with other EPC models. In such models, a process is represented as a sequence of alternating events and functions. Events confirm the fact that specific situations have occurred, affecting how the process develops. Functions define the actions performed in the process. In a flat EPC model, there must be a start event at the beginning of each diagram-starting path and an end event at the end of each terminating path. The functions and events representing the process flow can be linked directly or via logical operators: OR, XOR, and AND. In a graphical form, EPC models are represented using EPC diagrams, where the symbols provided in Table 1 are used.

Table 1.
Graphical symbols used for the elements available in EPC diagrams

Element	Graphical symbol
Event	
Function	
XOR logical operator	
AND logical operator	
OR logical operator	

Source: own elaboration based on Szczęśniak, 2010.

One must follow a number of rules when creating an EPC diagram. According to the most important ones, all elements of the diagram must be linked with one another by arrows. Each function must have exactly one incoming arrow and one outgoing arrow. Each start event must have exactly one outgoing arrow and each end event must have exactly one incoming arrow. All other events must have exactly one incoming and one outgoing arrow. Logical operators can have one incoming arrow and several outgoing arrows, or several incoming arrows and one outgoing arrow. Functions can only be linked via arrows with events, and events can only be linked with functions. The relationships between functions and events can be effected directly or via logical operators. An example of an EPC diagram created for a very simple process has been provided in Figure 1.

Figure 1. EPC – example of a simple process diagram.
Source: own elaboration.

In the process presented in this way, tasks A, B, and C are performed in sequence.

One can find an extensive discussion on the rules applicable to creating EPC diagrams in many publications (Gabryelczyk, 1998, 2006; Szczęśniak, 2010, 2011).

3.2. BPMN

The BPMN standard was developed by the Business Process Management Initiative at the beginning of the 21st century. Version 1.0 of its first published specification dates back to 2004 (White, 2004). As used in that version, the acronym BPMN stands for Business Process Modelling Notation. In the following years, the development of BPMN continued under the Object Management Group's operations. The specification which applies at the moment is version 2.0.2 (OMG, 2013), published in 2013, where the BPMN acronym translates into Business Process Model and Notation. There are numerous extensive publications devoted to the principles of process modelling in accordance with the BPMN standard (Gawin, Marcinkowski, 2013; Piotrowski, 2014; Drejewicz, 2017; Misiak, 2023). In this section, only the generally available elements and the most basic rules relevant to the examples provided further on in the article have been discussed.

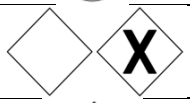
As per the specification, the process flow is represented in BPMN by means of a process diagram, where it is shown as a sequence of flow elements such as activities, events, and gateways, interlinked by arrows representing the sequence flow. Activities include tasks, sub-processes, and call activities. The most basic activity type is a task, corresponding to the simplest activity which is not represented in the model in a more detailed manner. It is possible to precisely define the specifics of tasks. In this regard, one can define manual, user, service, script, send, receive, as well as business rule tasks. Where it is necessary to present a more

complex activity, whose internal details must be described using additional activities, events, gateways and sequence flows, a sub-process is used. Sub-processes include event sub-processes, ad-hoc sub-processes, and transaction sub-processes. The last activity type is a call activity, used to indicate the place in the process where a specified process or global task is to be executed. In the examples provided further on in the article, only tasks in their most basic form are referred to, without identifying their exact specifics. Another group of flow elements are events. They represent external and internal stimuli which affect the process flow. There are many types of events recognised under BPMN. Firstly, they can be classified according to the location of their occurrence in the process. In this respect, one can distinguish between start, intermediate, and end events. Intermediate events are further broken down into those which occur in a normal flow and boundary events. Another classification criterion which may be applied is the relationship between events and triggers. One can distinguish between events without a trigger assigned, known as none events, and those linked with a trigger. The latter can additionally comprise trigger throwing events and trigger catching events, while the catching events additionally include process interrupting and non-interrupting events. Moreover, events linked with a trigger can be further classified according to the type of the trigger assigned. In this respect, one can distinguish between 12 event types. The most fundamental ones are message and time events. The examples provided further on in the paper refer only to the none-type start and end events as well as non-interrupting events linked with message triggers. Another group of flow elements are gateways. They are used to split and merge process paths. The types available in BPMN are: exclusive gateway, inclusive gateway, parallel gateway, composite gateway and event-based gateway. The last important flow element is sequence flow. Each sequence flow links exactly two flow elements, such as activities, gateways, or events, and determines the sequence in which they occur throughout the process. Sequence flow can be uncontrolled, conditional, or default. Uncontrolled flow corresponds to unconditional continuation of a specific process path. Conditional flow indicates that a given path is continued once a specific condition has been met. The chosen flow elements, used in the models discussed further on in the article, along with the graphical symbols representing them, have been provided in Table 2.

Table 2.
Graphical symbols of the selected elements used in BPMN-aligned process diagrams

Element	Graphical symbol
Task	
None start event	
None end event	

Cont. table 1.

Intermediate catching message event	
Exclusive gateway	
Inclusive gateway	
Parallel gateway	
Event-based gateway	
Uncontrolled sequence flow	
Activity outgoing conditional sequence flow	
Gateway outgoing conditional sequence flow	
Default sequence flow	

Source: own elaboration based on OMG, 2013.

An example of a BPMN process diagram created for a very simple process has been provided in Figure 2.

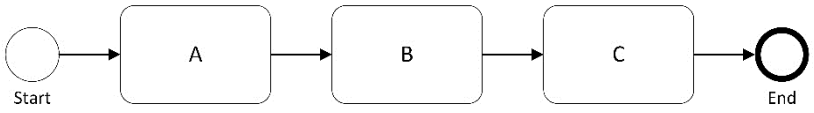


Figure 2. BPMN – example of a simple process diagram.

Source: own elaboration.

In the process presented by this diagram, tasks A, B, and C are performed in sequence.

3.3. YAWL

YAWL is a process modelling language developed in the early 21st century by the researchers working at Eindhoven University of Technology and Queensland University of Technology. The first publication discussing the assumptions and principles underlying the YAWL language in detail dates back to 2005 (Alst, Hofstede, 2005).

The rules for describing a process in YAWL are discussed in great detail in a manual rendered available after the said environment has been installed (The YAWL Foundation, 2024). According to these rules, when creating the specification, the process is described from three basic perspectives: the process execution perspective, the data perspective, and the resource perspective. Given the subject matter of this article, the process execution perspective is held particularly important. It is the only perspective where the area being described is presented in a graphical form. The simplest element it features is an atomic task, representing a basic and indivisible activity performed within the process. Another element is a composite task, representing a more complex activity which requires to be additionally defined.

If the execution of an atomic or composite task is repetitive in nature, this is represented in the model by a multiple instance atomic task or a multiple instance composite task. An additional available element is a condition, representing a point in the process where one can make a choice regarding its further course. Some special elements are the start condition and the end condition, occurring at the beginning and end of the process. The graphical symbols used to denote these elements have been shown in Table 3.

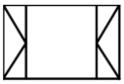
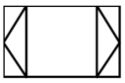
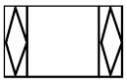
Table 3.
Graphical symbols used for the elements available in YAWL

Element	Graphical symbol
Atomic task	
Composite task	
Multiple instance atomic task	
Multiple instance composite task	
Condition	
Start condition	
End condition	

Source: own elaboration based on The YAWL Foundation, 2024.

What comes as the primary element of the specification is a network. Each specification must contain one start network, and it may additionally feature sub-networks which are used to define potential composite tasks. Each network always starts with one start condition and ends with one end condition. In between, the process is represented as a sequence of tasks linked by arrows showing the process flow direction. Additionally, there may be elements of the condition type between tasks. A condition element can have several incoming arrows and several outgoing arrows. This is not the case of tasks. In their standard form, they must have exactly one incoming arrow and exactly one outgoing arrow. However, it is also possible that decorators, as they are commonly referred to, are added to tasks. Decorators can be either joining or splitting. Adding the right decorator to a task allows it to have several incoming arrows or several outgoing arrows. There are three types of decorators: XOR, AND, and OR. Both a join decorator and a split decorator can be added to each task, and each of the decorators added to a single task can be of a different type. The graphical symbols representing an atomic task with decorators added have been provided in Table 4.

Table 4.
YAWL – graphical symbols representing tasks with decorators added

Description	Graphical symbol
Atomic task with AND decorators	
Atomic task with XOR decorators	
Atomic task with OR decorators	

Source: own elaboration based on The YAWL Foundation, 2024.

The simplest YAWL process diagram, has been shown in Figure 3.

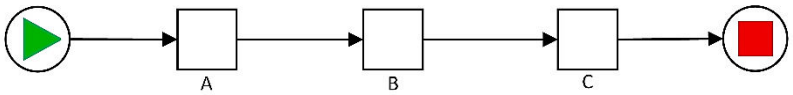


Figure 3. YAWL – example of a simple process model.

Source: own elaboration.

In the process presented by this diagram, tasks A, B, and C are performed in sequence.

YAWL comprises not only a language making it possible to describe the analysed processes with high accuracy, but also a closely related environment containing, in particular, a process editor, a task manager, and a workflow engine which enables the tasks at hand to be performed in accordance with a specification previously developed.

4. Results: Path splitting as per the chosen business process modelling methods

The respective concepts of path splitting under individual modelling methods have been discussed in the context of the workflow patterns proposed by William van der Alst's team in 2003 (Alst et al., 2003). Four of the patterns they originally postulated have been chosen to illustrate the potential cases of process splitting. This choice comprises the following:

- pattern 2 – parallel split,
- pattern 4 – exclusive choice,
- pattern 6 – multi-choice,
- pattern 16 – deferred choice.

The term *split* is used to describe a situation where the process flow diverges into several paths from a certain point. They are not specified in terms of the maximum number. However, there must be at least two. The tasks on each path are performed independently of the tasks on

the other paths. The paths can be executed simultaneously or in any order. The *parallel split* pattern means that, during execution, once the process has passed through the splitting point, all outgoing paths are always executed. In the *exclusive choice* pattern, one of the several paths diverging from the splitting point is chosen to be initiated while the process is being performed. The remaining paths stay inactive. The choice of the right path is made once it has been verified that the condition specified for it is met. Also in the *multi-choice* pattern, the path is chosen against a specific condition. However, where this is the case, it is possible to initiate several paths while the process is being performed after it has passed through the splitting point. One, several, or all paths can be initiated. The last of the patterns, known as *deferred choice*, corresponds to a case where, while the process is being performed, one of the paths is chosen to be initiated after reaching the splitting point. However, this choice is not based on a pre-defined condition that can be verified once the process has reached a specific point, but only with reference to the user's decision or the fact that a specific situation has occurred in the process. Such a decision may pertain to the choice of one of several available activities. Choosing a given activity means that the process will continue along the path which features this activity. For each of the patterns, a sample short abstract process has been proposed to illustrate a given pattern. The relevant process descriptions have been provided in Table 5.

Table 5.
Examples of abstract processes for the splitting patterns discussed

Pattern	Sample process description
Pattern 2, parallel split	The first activity performed in the process is a roll of a six-sided dice (D6). After the dice has been rolled, two activities are performed in any order: • a card is drawn from the deck, • a coin is tossed.
Pattern 4, exclusive choice	The first activity performed in the process is a roll of a six-sided dice (D6). After the dice has been rolled: • if the number rolled is less than 4, a card is drawn from the deck, • if the number rolled is greater than or equal to 4, a coin is tossed.
Pattern 6, multi-choice	The first activity performed in the process is a roll of a six-sided dice (D6). After the dice has been rolled: • if the number rolled ranges between 1 and 4, a card is drawn from the deck, • if the number rolled ranges between 2 and 3, a coin is tossed, • if the number rolled is 2 or it ranges between 5 and 6, a twelve-sided dice (D12) is rolled.
Pattern 16, deferred choice	The first activity performed in the process is a roll of a six-sided dice (D6). After the dice has been rolled, the process participant can perform one of the following activities: • draw a card, • toss a coin.

Source: own elaboration.

Where the solutions proposed under the selected modelling methods are discussed further on in the paper, the models discussed herein represent the sample processes described above.

4.1. Splitting in EPC

In EPC models, logical splitting operators are used to split a process according to patterns 2, 4, and 6 (Mendling et al., 2005). For pattern 2, this is the AND operator, while the XOR operator is used for pattern 4, and the OR operator – for pattern 6. In patterns 4 and 6, the conditions determining the choice of a specific path are introduced as events. Therefore, on each path going out of the XOR or OR split operators, an event must always come as the first element. Given that alternation of events and functions is required under EPC models, the XOR and OR operators must always follow a function in the model. The EPC models representing the sample processes have been shown in Figure 4.

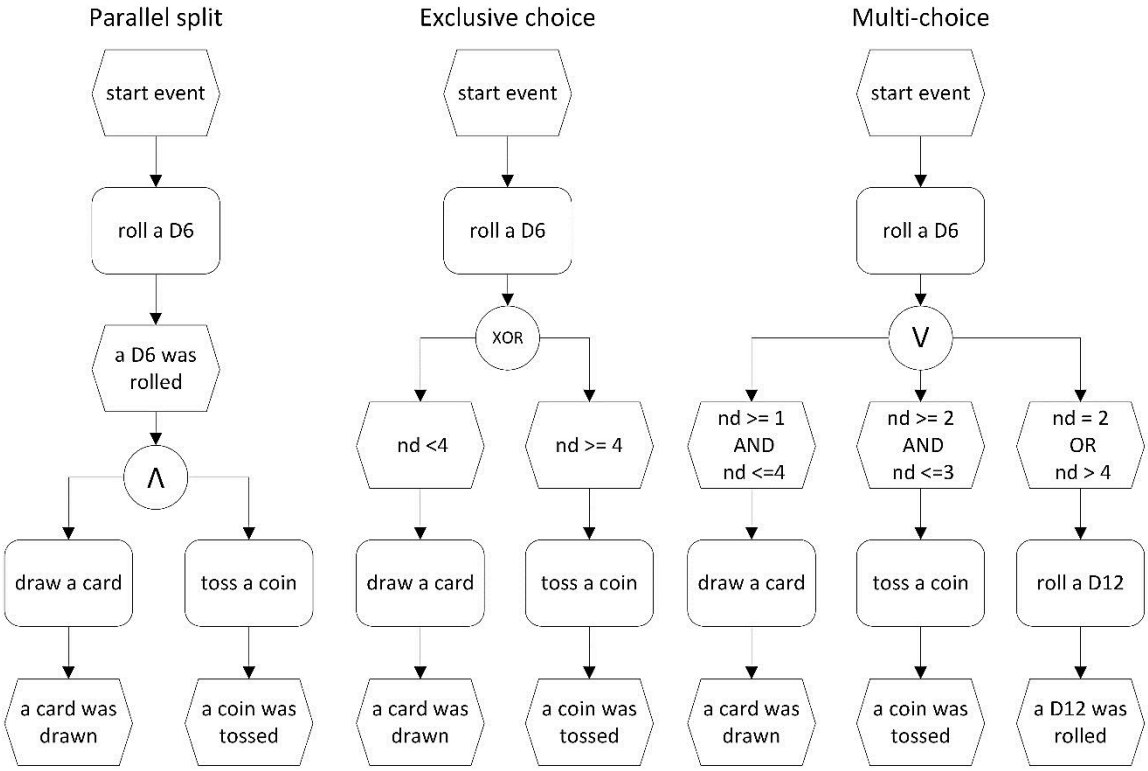


Figure 4. EPC models of the sample processes for parallel split, exclusive choice, and multi-choice. Source: own elaboration.

In the case of an exclusive choice in EPC models, there is no specific sequence in which the conditions determining the choice of a specific path, contained in the definition of individual events, are checked while the process is being performed. The person creating the model must make sure that these conditions are mutually exclusive and cannot apply simultaneously. Such a situation would generate ambiguity in the process performance and is treated as an error. In EPC models, there is no dedicated solution for the case presented under pattern 16 (Mendling et al., 2005).

4.2. Splitting in BPMN

In a BPMN-aligned process model, process splitting can be represented using adequate gateways or by means of several flows going directly out of a single activity. When using gateways in patterns 2, 4, and 6, the following types can be introduced:

- parallel gateway – for pattern 2,
- exclusive gateway – for pattern 4,
- inclusive gateway – for pattern 6.

The flows going out of an exclusive gateway and an inclusive gateway are conditional flows. These flows should be assigned conditions based on which decisions are made to activate individual paths. As in the case of EPC models, the sequence in which conditions are checked while the process is being performed is not specified either, which is why, while creating the model, one must make sure that the conditions assigned to the conditional flows going out of an exclusive gateway cannot be met simultaneously. Examples of BPMN-aligned process models for patterns 2, 4, and 6 have been shown in Figure 5.

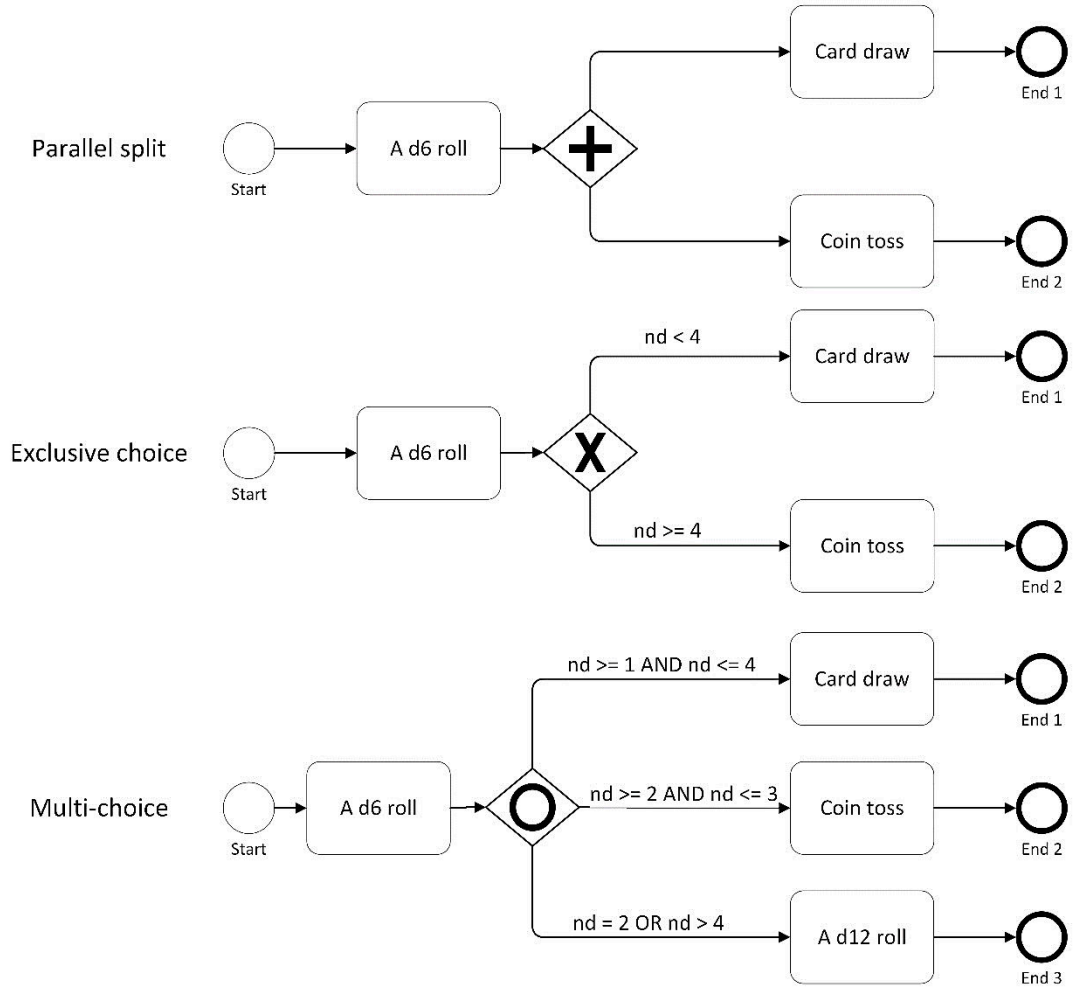


Figure 5. BPMN-aligned models of sample processes for parallel split, exclusive choice, and multi-choice – splits with gateways.

Source: own elaboration.

Where an exclusive gateway and an inclusive gateway are used, it is possible to apply a default flow. According to the BPMN specification, such a flow cannot have any conditions assigned to it. A flow path will be chosen in the case that all the conditions assigned to the other conditional flows going out of a specific gateway are not met. While it is possible to choose any one of the outgoing flows, to remove the condition from it, and to convert it into a conditional flow with the exclusive gateway, in the case of an inclusive gateway the situation becomes more complex. In order to apply exactly the same splitting rules as those defined using the exclusive gateway, having outgoing flows with conditions assigned, the default flow should be made the one whose condition cannot be met at the same time as any condition assigned to any of the other paths going out of a given gateway. In the multi-choice model shown in Figure 5, none of the flows can be converted to a default flow. However, it is possible to split the flow featuring the condition "nd = 2 OR nd > 4" into two flows leading from the gateway to the same activity. The first will feature the condition "nd = 2," while the condition assigned to the second one will be "nd > 4." The condition of the second flow cannot be met simultaneously with the condition of any of the other flows going out of a given gate. This flow can be converted to a default flow. Figure 6 depicts process models containing default flows for patterns 4 and 6.

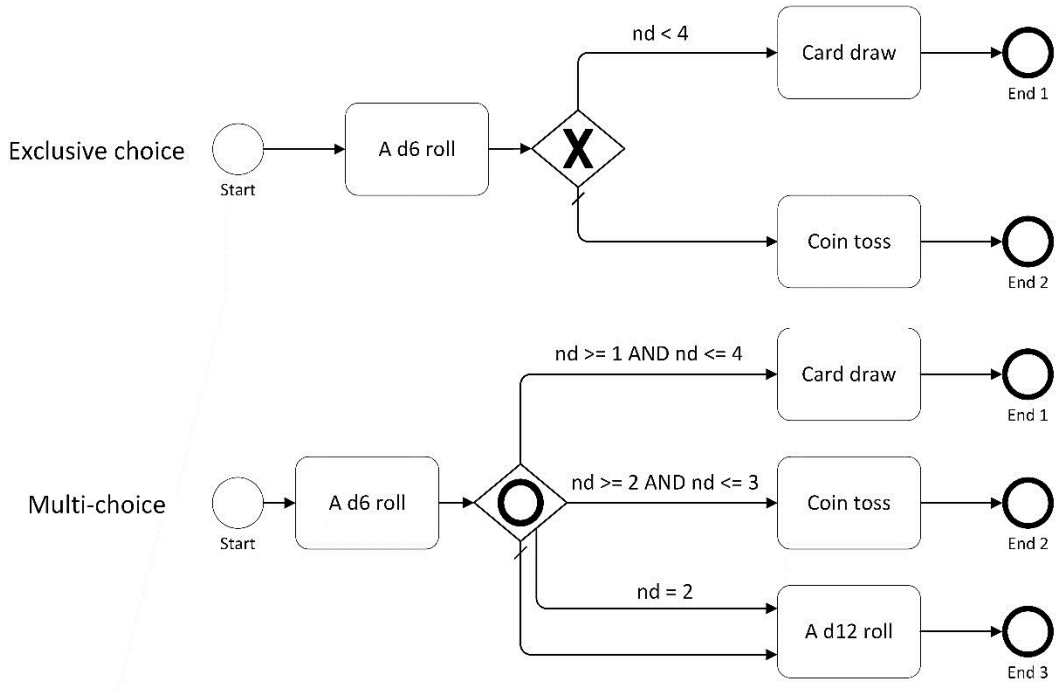


Figure 6. BPMN-aligned models of sample processes for exclusive choice and multi-choice – splits with gateways, application of default flows.

Source: own elaboration.

As aforementioned, in a BPMN-aligned process model, a path splitting can also be represented without using gateways. This being the case, several sequence flows go out directly of a single activity. A situation where these are regular flows without conditions assigned is represented as a parallel split. If these are conditional flows, inclusive splitting applies. Splitting

without gateways cannot be used to represent exclusive splitting. Examples of process models featuring splits without gateways have been shown in Figure 7.

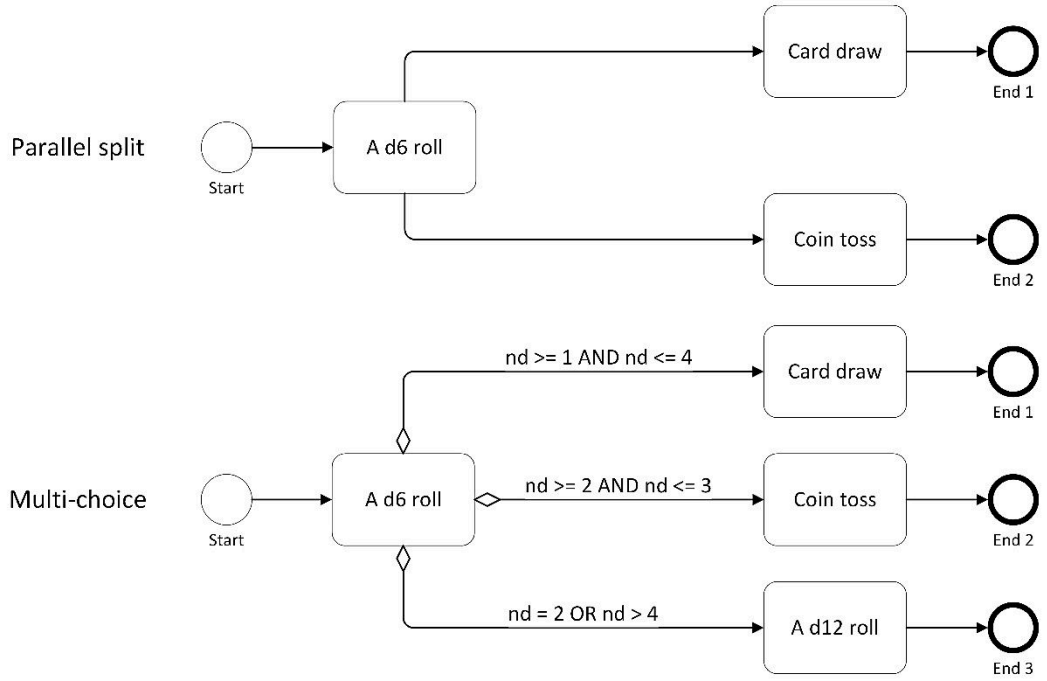


Figure 7. BPMN-aligned models of sample processes for parallel split and multi-choice – splits without gateways.

Source: own elaboration.

When splitting without gateways, one can also make use of a default flow. Such a flow is added by following the same rules as those which apply to splitting with gateways. A sample process model representing a multi-choice with splits without gateways and the application of a default flow has been provided in Figure 8.

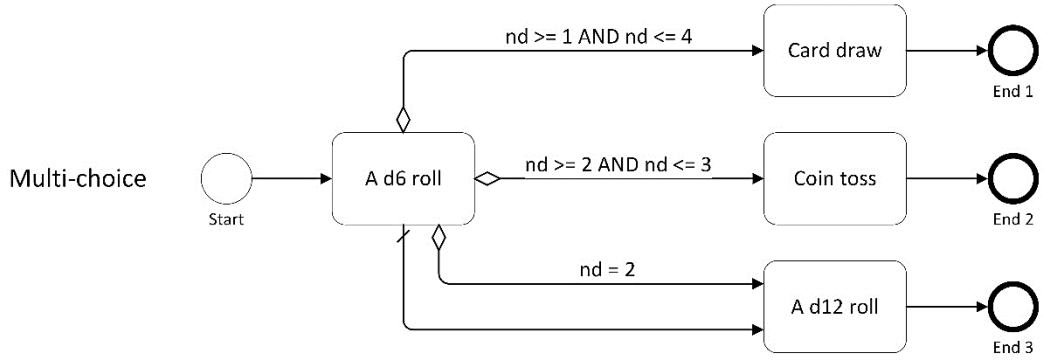


Figure 8. BPMN-aligned model of a sample process for multi-choice – splits without gateways, application of a default flow.

Source: own elaboration.

A BPMN-aligned process model makes it possible to represent splitting consistent with the *deferred choice* pattern. According to the BPMN specification, in the case of splitting which follows this pattern, an event-based gateway should be used (OMG, 2013). Such a gateway may be followed by intermediate catching events or receive tasks. Figure 9 illustrates a BPMN-aligned process model of a sample process following the deferred choice pattern.

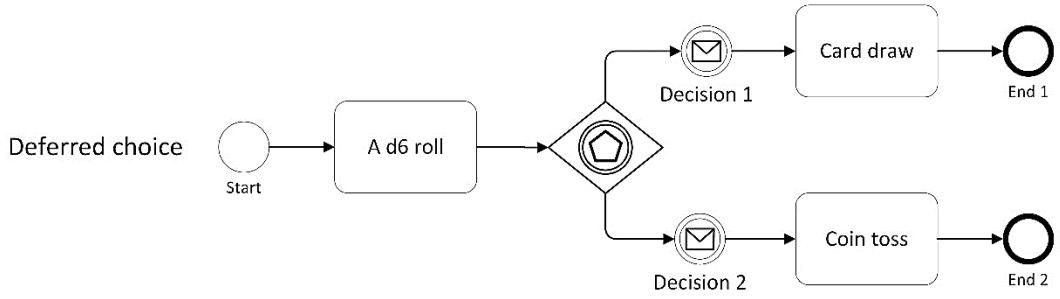


Figure 9. BPMN-aligned model of a sample process for deferred choice.
Source: own elaboration.

In this diagram the decision to choose a specific path is represented as an intermediate catching message event.

4.3. Splitting in YAWL

In YAWL, decorators are used to split process paths when following patterns 2, 4, and 6. For pattern 2, this is the AND-split decorator, while the XOR-split decorator is used for pattern 4, and the OR-split decorator – for pattern 6. They are not separate elements occurring independently in the model, but rather extensions of the tasks which are already in it. Adding a split decorator to a task makes it possible to set several outgoing arrows for it. The conditions under which the right path or paths are initiated in patterns 4 and 6 are defined within the task as one of its properties. Each condition is associated with one of the task's outgoing arrows. This association is defined by indicating the task name or condition to which the given arrow leads. The conditions for a given task are entered in successive rows of the table. Their sequence is very relevant, since they are checked while the process is being performed in exactly the order in which they are arranged from top to bottom of the table. The order in the table does not depend on the sequence of individual arrows in the model. In the case of splitting by means of the XOR-split decorator, if the condition checked has been met, the others are not to be checked. This explicitly defines the path to be initiated over the course of the process, even if the person creating the model has entered conditions that can be satisfied altogether at the same time. In the case of splitting with the OR-split decorator, all the conditions defined are always checked.

The flow whose associated condition is found in the last row of the table is the default flow. With the XOR-split decorator in use, this condition always has the value of *true* and cannot be changed. As for the OR-split decorator, one can introduce a custom condition for the default

flow. In the case that this condition has been met, the default flow is initiated along with the other flows for which the respective conditions have been satisfied. If none of the conditions are met, the default flow is initiated regardless of the outcome of the condition verification. Some YAWL models representing the sample processes following patterns 2, 4, and 6 have been provided in Figure 10. To illustrate how conditions are defined, the figure also shows tables containing them, but they are in fact internal elements of the relevant task, and these conditions are not visible in the graphical layer of the original YAWL model.

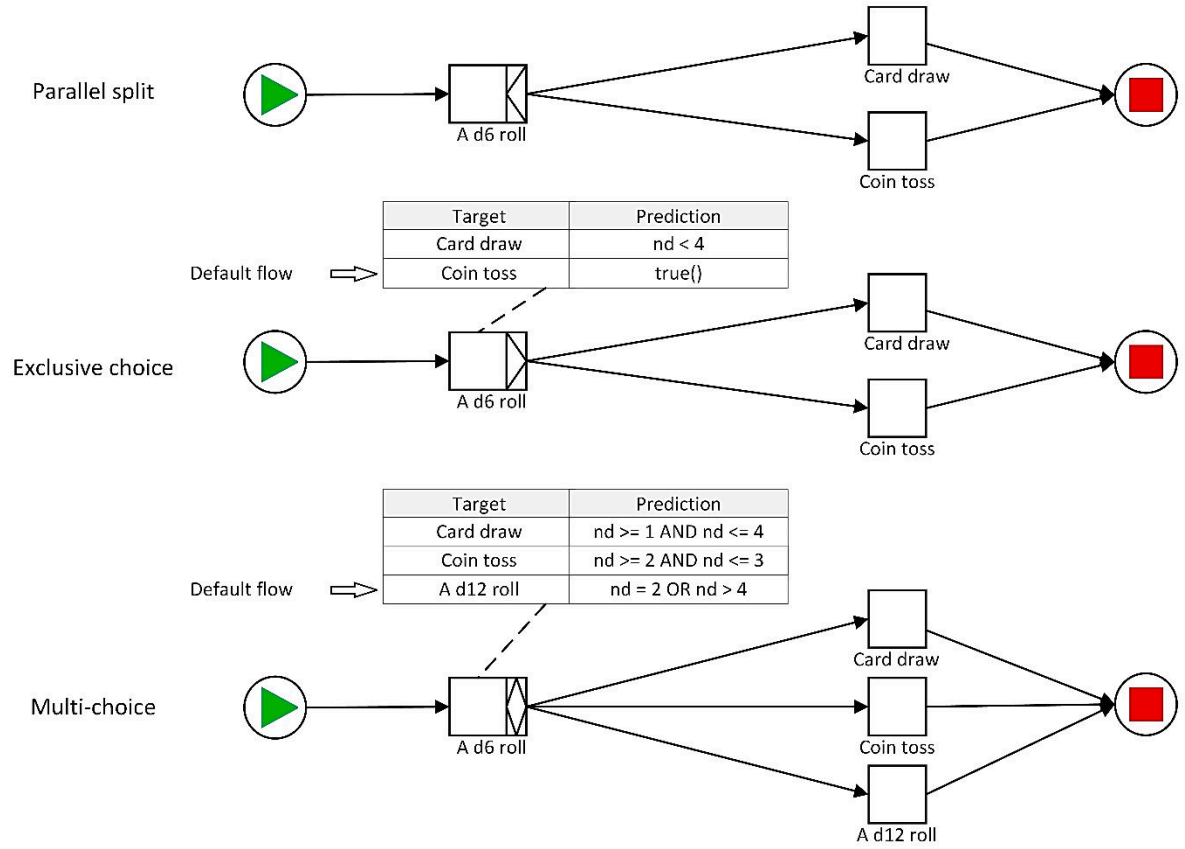


Figure 10. YAWL-aligned models of sample processes for parallel split, exclusive choice, and multi-choice.

Source: own elaboration.

In order to model a case aligned with pattern 16, the *condition* element is used in YAWL. This element can feature several outgoing arrows leading to different tasks. A YAWL-aligned model of a sample process following pattern 16 has been provided in Figure 11.

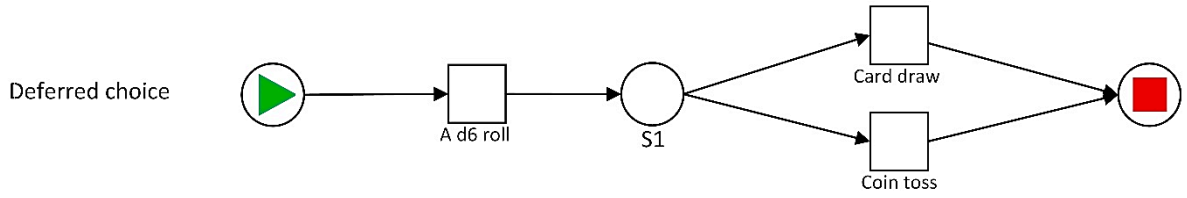


Figure 11. YAWL-aligned models of sample processes for parallel split, exclusive choice, and multi-choice.

Source: own elaboration.

While being performed, the process is stopped at S1 condition, offering users the option to initiate each of these tasks. Choosing any task makes the remainder unavailable.

5. Discussion

Each of the models analysed in the paper represents a different process splitting concept. All of them make it possible to present splitting cases described under patterns 2, 4, and 6. A dedicated solution for splitting aligned with pattern 16 is only available in BPMN and YAWL.

In the case of patterns 4 and 6, it is necessary to precisely define the conditions taken into account when choosing the paths along which the process is to be further implemented. What should definitely be highlighted is the differences in the way conditions are defined. This problem is solved in a different fashion under each of the concepts analysed. Pre-defined conditions can be presented, as in EPC, as an additional event-type element occurring first on each of the paths diverging from the splitting point. They can also be assigned to the conditional flows going out of the splitting point. Such a solution is applied in BPMN. Conditions can also be assigned to an activity from which several paths diverge, this being a solution typical of YAWL. All conditions defined in YAWL always follow a pre-defined sequence in which they should be checked while the process is being performed. Owing to this solution, where splitting is conducted in line with pattern 2, even if several conditions can be met at the same time, this does not cause any ambiguity regarding the path which should be selected. In the case of BPMN and EPC, the sequence in which conditions are checked is not defined. Those creating the process model must pay special attention to make sure that the relevant conditions cannot be satisfied simultaneously. In the case of EPC and BPMN models, the pre-defined conditions are presented in the graphical form of the model. In YAWL models, the conditions are defined within one of the activity properties, and the model's graphical layer does not provide for their presentation. When presenting splits aligned with patterns 4 and 6 by following two of the concepts in question, it is possible to define the default process flow. In BPMN, a default flow is added solely at the discretion of the person creating the model. Such a flow cannot have any conditions assigned to it. It is chosen only if the conditions assigned to the other flows have not been satisfied. In YAWL, in cases of the XOR or OR type splitting, exactly one default flow is mandatory. As for the OR splitting, what can be associated with such a flow is a condition which is checked in the same manner as the conditions associated with other flows. Therefore, the default path can also be initiated when other paths within a given branch are initiated.

6. Conclusions

The conducted research indicates that the approaches to process path splitting in the analysed modelling methods differ from one another. The identified differences include: the way conditions determining which process paths are to be executed are defined, the approach to the use of default flows, and the solutions dedicated to branching in accordance with pattern 16.

With regard to process splitting by following patterns 2, 4, and 6, BPMN offers the largest variety of possible solutions. It enables splitting with gateways, splitting without gateways, as well as using or skipping the default flow. On the one hand, this offers the greatest freedom to those creating the model, which can be perceived as a positive feature. However, on the other hand, when both creating and reading the model, one must be familiar with a greater number of rules in order to create and understand the model correctly. Both EPC and YAWL are more rigorous in this respect, admitting only one possible solution for a given case.

The research carry social implications. It emphasises how important it is to know the rules by which models are created under the specific method in use. It also highlights the fact that the knowledge of the rules applicable to one method cannot be automatically transferred to others.

The conducted research focused solely on comparing the approaches to process path splitting in three popular process modelling methods. It would be interesting to extend the study to include other aspects of modelling as well as less commonly used methods.

Acknowledgements

The research presented in the article was supported by statutory work BK-257/ROZ1/2025 (13/010/BK_25/0087).

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SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

DEMOCRACY AND THE MARKET: DO POLITICAL ELECTIONS INFLUENCE THE STOCK EXCHANGE IN POLAND?

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Purpose: Although political events do not directly impact the stock exchanges, they are widely regarded as one of the significant factors determining their volatility and dynamics. This paper aims to examine the impact of political election results in Poland—specifically presidential, parliamentary, local, and European elections—on the Warsaw Stock Exchange Index WIG.
Design/methodology/approach: The objectives are achieved using an event study methodology. This approach assesses how the stock market reacts to a specific event, such as election results, by comparing actual stock price changes around the event with predicted changes if the event had not occurred.
Findings: The results do not unequivocally confirm the thesis of a significant impact of all studied types of political elections on Warsaw Stock Exchange quotations. The strongest impact was observed in the case of presidential elections, however, its intensity varied depending on the specific elections. The impact of parliamentary elections was observed only in the 1990s. In contrast, local and European Parliament elections generally did not have a statistically significant impact on the Polish stock exchange.
Research limitations/implications: Research limitations of this study include its focus solely on the WIG index, suggesting future research could explore the impact on individual companies or other market indices, acknowledging that company-specific factors might lead to varied reactions. Additionally, the study highlights the arbitrary nature of event window selection and the potential for market reactions to differ based on broader economic or political contexts, especially in emerging markets like Poland.
Originality/value: This paper contributes to the existing literature by providing empirical evidence on the influence of various types of political elections on the Warsaw Stock Exchange in Poland, covering a substantial historical period. The findings are valuable to investors, policymakers, and academics interested in the interplay between political events and emerging financial markets.
Keywords: political election, political event, stock exchange, event study.
Category of the paper: Research paper.
JEL Class: G10, G14, G18.

1. Introduction

Financial markets constitute a crucial element of every country's economy, and their stability is a significant indicator of the nation's overall economic condition. The stock exchange plays a particularly important role in the financial system, contributing to development through the efficient allocation of capital between investors and entities seeking financing. Stable development of the stock exchange and its positive results foster the inflow of both domestic and foreign investments, which consequently affects the overall competitiveness of the economy (Mishkin, 2007).

One of the critical questions facing every voter during an election is which political party possesses the most suitable strategies for supporting economic growth and the development of capital markets. The victorious party or coalition, by implementing its program, can shape future economic outcomes through economic policy tools. Depending on their ideological orientation, different political groups may adopt varying priorities in economic policy. According to Nordhaus's (1975) political business cycle theory, left-wing parties typically focus on reducing unemployment and improving social conditions, while right-wing parties tend to prioritize controlling inflation.

Although political events do not directly impact the stock exchanges, they are widely regarded as one of the significant factors determining their volatility and dynamics (Alesina, Roubini, 1997). The aim of this paper is to examine the impact of political election results – presidential, parliamentary, local, and European – on the Warsaw Stock Exchange (WSE). Based on the literature review, we formulated the following hypothesis: "The results of political elections in Poland have a statistically significant impact on the stock market". To test this hypothesis we applied the event study methodology focusing on the rate of return of the WIG index. The study covered the period from the parliamentary elections held in 1993 to the presidential elections in 2025.

The existing body of literature robustly confirms the general influence of political events on global stock markets, as evidenced by studies across various countries and methodologies (e.g., Tomić et al., 2024; Pantzalis et al., 2000; Białkowski et al., 2008). However, despite this established interest, a significant research gap persists concerning the comprehensive and up-to-date impact of diverse political elections on the WSE, particularly within a unified analytical framework. Crucially, there are no prior studies that systematically analyze the impact of all major types of Polish elections – presidential, parliamentary, local, and European – on the WSE, utilizing a consistent event study methodology across such a broad and contemporary period (1993-2025). This study directly addresses this gap by providing a unique and comprehensive assessment of how distinct electoral events shape an important emerging market. The novelty of our approach lies in its multifaceted scope, covering a full range of election types within a single coherent analysis spanning over three decades.

Our findings hold considerable significance for a diverse audience: for investors, they offer deeper insights into market behavior around political cycles; for policymakers, they inform understanding of the economic implications of electoral processes; and for academics, they contribute robust empirical evidence to the literature on political economy and financial markets in transitioning economies.

This paper consists of six sections. After the introduction the second part provides a detailed review of the literature concerning the impact of political events on the stock exchange. The third section outlines the research methodology and the characteristics of the sample. The fourth section presents results and the next one discussion. Conclusion summarizes the paper.

2. Literature review

Impact of the political election results on the functioning of financial markets, including stock exchanges, has been the subject of numerous studies. Many analyses focus on the relationship between political changes and investor reactions, stock index volatility, and long-term trends in capital markets. Niederhoffer, Gibbs, and Bullock (1970) were among the first to conduct empirical research on the relationship between stock market and presidential elections in the United States. They analyzed changes in the Dow Jones Industrial Average (DJIA) both before and after elections, and during the nominations of 18 presidents over the period 1900-1968. Additionally, the authors examined one-day, one-week, and one-month changes in the DJIA following political events, as well as its fluctuations during a four-year presidential term. Ultimately, they found no statistically significant differences in stock market returns between Republican and Democratic administrations.

Impact of the political elections on stock markets remains a subject of ongoing interest within the academic community. Recently, this topic has been addressed by researchers such as Tomić, Vasić, and Todorović (2024), who employed an event study methodology to evaluate the impact of Donald Trump's elections on the financial sector. Their research showed that the financial sector responds to presidential election outcomes, and this response is consistent across various election cycles. Republican candidate victories resulted in positive abnormal returns within the financial sector, while Democratic candidate victories yielded negative abnormal returns in the same sector. All tests confirmed the presence of statistically significant returns in the post-election periods.

Research on U.S. presidential elections was also conducted by Kallianiotis (2025). His work focused on the effectiveness of public policy following elections and its impact on stock markets. He identified that changes in fiscal and monetary policy can trigger abrupt investor reactions, leading to periods of heightened market volatility.

Haas (2025) analyzed the influence of electoral expectations on stock market volatility in the United States. His research demonstrated that not only the elections themselves, but also their anticipated outcomes (election polls) can lead to significant fluctuations in the stock market. His findings indicate that strong market reactions are primarily observed during periods of high political uncertainty.

In the context of India, Jain and Gupta (2025) examined the reactions of the Indian capital market to the Lok Sabha elections in 2014, 2019, and 2024. Their research showed that the infrastructure and banking sectors are particularly susceptible to political changes, and the impact of the elections persists for several months following their conclusion.

Within a broader political context, the research of Zhong and Zhang (2025) provided evidence that firms with strong political connections often exhibit reduced innovation, consequently impacting their stock market valuation. During periods of administrative changes in China, the quotations of companies with close political ties demonstrate greater instability.

The study of the political impact on the stock exchange extends beyond single-country analyses to include cross-national comparisons. Pantzalis, Stangeland, and Turtle (2000) investigated stock market behavior in the context of political elections across 33 developed and developing countries, covering the period from 1974 to 1995. Their findings indicate that during political events, stock index returns were generally positive and statistically significant, with this impact being most pronounced from two weeks prior to the election week. It was also established that the positive stock market reaction to elections depends on the level of political freedom, economic freedom, and press freedom in the respective country, as well as the timing of the elections and the incumbent politician's re-election prospects.

Nippani and Arize (2005) investigated the impact of U.S. presidential elections on the stock markets of Canada and Mexico. They analyzed whether delays in announcing election results affect the stock exchanges of these countries and whether their reaction is similar to that observed in the U.S. market. The findings suggest that the stock markets in Canada and Mexico are strongly interconnected with the U.S. stock exchange. That study also demonstrates that investors in Canada and Mexico monitor U.S. presidential elections as closely as market participants in the United States.

Białkowski, Gottschalk, and Wiśniewski (2008) analyzed data from 27 OECD countries to examine whether national elections contribute to increased stock market volatility. Their findings revealed that stock prices exhibit a strong reaction to the final vote distribution, and a temporary increase in volatility occurs during the election period. It was established that the country-specific volatility component can even double in the week preceding the elections.

While the extensive literature confirms the general significance of political events on stock markets globally, a notable gap exists in comprehensive, up-to-date analyses specifically focused on the Polish context. Much of the existing research tends to concentrate on mature markets like the United States or on broader cross-country comparisons that may not fully capture the unique dynamics of an emerging market with a distinct post-communist transition history, like Poland. Existing studies often focus on one or two election types, or a more limited time frame, thereby providing an incomplete picture of the cumulative and differential effects.

According to what we were able to find, there are no prior studies that systematically analyze the impact of presidential, parliamentary, local, and European elections on the Warsaw Stock Exchange using a consistent event study methodology over such an extensive period (1993-2025), encompassing the full spectrum of Polish democratic development. With this, our study addresses a significant gap in the literature by providing a multifaceted and up-to-date assessment of how diverse political electoral events influence a key emerging market's stock exchange.

To summarize this section, the existing literature indicates that political elections are a key factor influencing stock market volatility. Their impact depends on the ownership structure of companies, investor expectations, and the specifics of economic policy in a given country. Consequently, the analysis of market reactions to political elections remains a significant area of economic and financial research. Based on the literature review, the following hypothesis has been formulated: “The results of political elections in Poland have a statistically significant impact on the stock market”.

3. Data and methods

The impact of events on stock market can be investigated using regression or event study analysis. This paper examines the influence of political election results on the Warsaw Stock Exchange (WSE) by employing the latter method. Event study analysis allows for the assessment of whether, and to what extent, stock market reacts to a specific event, such as the announcement of election results. This method involves comparing the actual changes in stock prices during a defined period around the event with the predicted changes had the event not occurred. The event study methodology, first applied by Fama et al. (1969), is widely utilized to investigate how various events affect stock prices (Mackinlay, 1997; Liu et al., 2020; Singh et al., 2024). Event study analysis has also been successfully employed to examine the impact of political events on the stock market (e.g., Bailey et al., 2005; Beaulieu et al., 2006; Sajid Nazir et al., 2014).

This paper investigates the impact of the results of presidential, parliamentary, local, and European Parliament elections (only Polish results) on the rate of return of the WIG index. The election day was defined as the event for the purpose of the methodology. The study covered the period from the parliamentary elections held in 1993 to the presidential elections in 2025. The presidential election of 1990, in which Lech Wałęsa won, took place before the establishment of the stock exchange in Poland and was therefore not included in the study. A list of the election events is presented in Table 1. In total, the study considers:

- 9 parliamentary elections,
- 13 presidential elections (including second rounds),
- 14 local elections (including second rounds), and
- 5 elections to the European Parliament.

Table 1.
Selected political elections

Parliamentary	Presidential	Local	European Parliament
19.09.1993	05.11.1995	19.06.1994	13.06.2004
21.09.1997	19.11.1995	11.10.1998	07.06.2009
23.09.2001	08.10.2000	27.10.2002	25.05.2014
25.09.2005	09.10.2005	10.11.2002	26.05.2019
21.10.2007	23.10.2005	12.11.2006	09.06.2024
09.10.2011	20.06.2010	26.11.2006	
25.10.2015	04.07.2010	21.11.2010	
13.10.2019	10.05.2015	05.12.2010	
15.10.2023	24.05.2015	16.11.2014	
	28.06.2020	30.11.2014	
	12.07.2020	21.10.2018	
	18.05.2025	04.11.2018	
	01.06.2025	07.04.2024	
		21.04.2024	

Source: own elaboration.

To verify the research hypothesis, this study investigates whether, in the period surrounding the election day, the election outcome had a statistically significant impact on WIG index return. The methodology is based on the work of Sajid Nazir et al. (2014). The study is conducted in several stages:

1) calculation of the daily rate of return of the WIG index,
2) determination of the event window and the estimation window,
3) calculation of average and abnormal returns,
4) calculation of standard deviations,
5) computation of the t-Student statistic.

In the first stage, the daily rate of return of the WIG is calculated using the following formula:

$$R_t = \frac{P_t}{P_{t-1}} - 1 \tag{1}$$

where Pt is the index value in points on day t, and Pt-1 is the index value on the previous day.

The event window, which is the period directly surrounding the occurrence of the analyzed event, is set at 2, 4, 5, 6, 8, or 10 business days (i.e., days when trading takes place on the stock exchange) before and after the election day. For example, if the elections were held on October 15th (Sunday) and the event window is 2 days, then the actual rate of return is compared with the expected rate of return (calculated based on the estimation window) during the two days before the election day (October 12th and 13th, Thursday and Friday) and the two days after the election day (October 16th and 17th, Monday and Tuesday).

The expected daily rate of return is estimated within an estimation window of 100 days. Referring to the example above, the expected rate of return is estimated starting from the day preceding the commencement of the event window, which is 100 days prior to October 11th. The estimation and event windows are presented in Figure 1. Determining the appropriate length of the event and estimation windows is crucial for obtaining reliable analysis results. Excessively short windows may fail to capture the full market reaction, while excessively long windows may be susceptible to the influence of other factors.

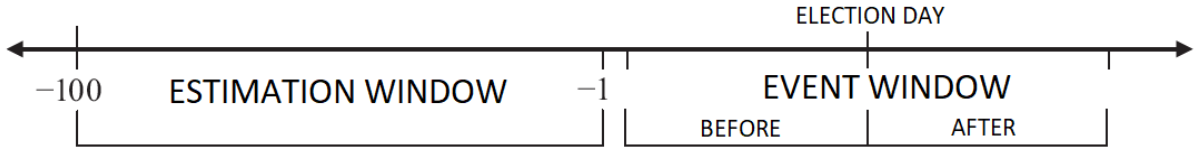

Figure 1. Estimation and event window.

The following formula is used to estimate the expected rate of return of the index:

$$\overline{R_t} = \frac{1}{T}\sum_{-100}^{-1} R_t \tag{2}$$

where T is the number of days in the estimation window, T = 100.

In the next stage, abnormal returns are calculated for each event window, defined as the difference between the actual and expected rates of return.

$$AR_t = R_t - \overline{R_t} \tag{3}$$

Furthermore, for the event window, the average abnormal return is calculated for the period before the election day and for the period after the election day.

$$\overline{AR}_{before} = \frac{\sum_{t=-n}^{t=-1} AR_{before,t}}{n} \qquad \overline{AR}_{after} = \frac{\sum_{t=1}^{t=n} AR_{after,t}}{n} \tag{4}$$

where n is the number of days in the event window. For example, if the event window is four days, then n = 4, and the average abnormal return is calculated for four days after the election day and four days before the election day.

The next stage involves calculating the standard deviations of the average abnormal returns before and after the election day.

$$\sigma_{before} = \sqrt{\frac{\sum_{t=-n}^{t=-1}(AR_{before,t} - \overline{AR}_{before})^2}{n-1}}$$
$$\sigma_{after} = \sqrt{\frac{\sum_{t=1}^{t=n}(AR_{after,t} - \overline{AR}_{after})^2}{n-1}} \quad (5)$$

Subsequently, the pooled standard error is calculated as follows:

$$pSE = \sqrt{\frac{(n_1-1)\sigma_{before}^2 + (n_2-1)\sigma_{after}^2}{n_1+n_2-2}} * \left(\frac{1}{n_1} + \frac{1}{n_2}\right) \quad (6)$$

where n_1 and n_2 represent the number of days before the election day and after the election day, respectively.

In the final stage, the t-Student statistic is computed.

$$t = \frac{\overline{AR}_{after} - \overline{AR}_{before}}{pSE} \quad (7)$$

4. Results

The results are presented separately for each type of election, in the following order: parliamentary, presidential, local, and European Parliament.

Table 2 presents the t-Student statistic for different event windows with respect to parliamentary elections. Table 3 is showing the average abnormal returns, calculated using formula 4, for the periods before and after the election day. Among the nine events studied, a statistically significant impact of the elections on the stock market was found in five cases. Furthermore, in three of these cases, this impact persisted for more than two days. In the case of the 1997 election, a statistically significant impact on stock market was observed for up to 10 days after the election day. It is worth noting that in 1997, the average abnormal return was positive in the period before the election day, but negative after the voting day. In 2001, a statistically significant impact of the voting on WIG can also be observed, but here the situation was reversed – the average abnormal return was negative before the elections and positive after the voting day. In subsequent years, parliamentary elections did not exert a statistically significant impact on stock market. In the 2005 and 2023 elections, a significant impact of the elections on stock market was found only in the shortest analyzed period, i.e. two days.

These results do not allow for an unambiguous confirmation of the research hypothesis. The impact of parliamentary election results was statistically significant for the initial period of Poland's democratization, when market reactions to political events were more pronounced. The influence of parliamentary elections on stock market in Poland was mainly noticeable in

the early 1990s, i.e., the initial period of democracy. A possible explanation for this phenomenon lies in the transformational systemic changes associated with the transition from a communist to a democratic system. During this time, society showed strong engagement in the electoral process, striving to remove politicians associated with the previous (communist) system from power. As a result, the outcomes of parliamentary elections could significantly affect investor sentiment and stock market. In subsequent years, along with the stabilization of the political system and the development of a market economy, the significance of these elections for the financial market gradually diminished.

Table 2.
Parliamentary elections, t-values for different event windows

Election date	2 days		4 days		5 days		6 days		8 days		10 days	
	t	p-val.	t	p-val.	t	p-val.	t	p-val.	t	p-val.	t	p-val.
19.09.1993	**-7,637**	**0,0084*****	**-1,915**	**0,0520***	-0,512	0,3113	-0,750	0,2353	-0,259	0,3998	-0,017	0,4934
21.09.1997	0,14	0,45	-1,07	0,16	**-1,80**	**0,05***	**-2,12**	**0,03****	**-1,74**	**0,05***	**-2,41**	**0,01****
23.09.2001	1,61	0,12	0,71	0,25	1,25	0,12	**1,57**	**0,07***	1,13	0,14	**1,77**	**0,05****
25.09.2005	**6,92**	**0,01****	1,44	0,10	0,56	0,30	0,63	0,27	-0,24	0,41	-0,96	0,17
21.10.2007	0,50	0,33	0,69	0,26	0,38	0,36	0,65	0,27	-0,03	0,49	-0,96	0,18
09.10.2011	0,41	0,36	0,41	0,35	0,87	0,20	0,77	0,23	0,72	0,24	0,06	0,48
25.10.2015	0,94	0,22	-0,76	0,24	-0,63	0,27	-0,06	0,48	-0,42	0,34	-0,74	0,23
13.10.2019	-0,65	0,29	-0,48	0,32	-0,70	0,25	-0,72	0,24	0,50	0,31	0,55	0,30
15.10.2023	**2,22**	**0,08***	0,01	0,50	-0,44	0,33	-0,53	0,31	-0,05	0,48	0,32	0,38

* significance at 0,1, ** significance at 0,05, *** significance at 0,01.

Source: own elaboration.

Table 3.
Average abnormal returns for parliamentary elections

Election date	2 days		4 days		5 days		6 days		8 days		10 days	
	before	after	before	after	before	after	before	after	before	after	before	after
19.09.1993	**0,19%**	**-8,27%**	**-2,25%**	**-6,55%**	-3,38%	-4,78%	-1,46%	-3,75%	-1,63%	-2,40%	-1,68%	-1,73%
21.09.1997	0,12%	0,21%	0,22%	-0,19%	**0,30%**	**-0,56%**	**0,36%**	**-0,49%**	**0,25%**	**-0,36%**	**0,44%**	**-0,28%**
23.09.2001	-2,02%	0,12%	-0,42%	0,41%	-0,62%	0,54%	**-0,99%**	**0,34%**	-0,78%	0,00%	**-0,91%**	**0,10%**
25.09.2005	**-0,73%**	**0,54%**	-0,77%	-0,11%	-0,24%	0,12%	-0,06%	0,31%	0,09%	-0,03%	0,16%	-0,35%
21.10.2007	-0,42%	0,52%	-0,50%	0,14%	-0,25%	0,04%	-0,29%	0,11%	-0,05%	-0,07%	0,22%	-0,25%
09.10.2011	1,14%	1,74%	0,63%	1,19%	0,20%	1,20%	0,20%	0,95%	0,31%	0,83%	0,75%	0,80%
25.10.2015	0,05%	0,19%	0,02%	-0,36%	-0,01%	-0,27%	-0,08%	-0,10%	0,06%	-0,07%	-0,02%	-0,22%
13.10.2019	0,57%	-0,10%	0,41%	0,18%	0,33%	0,05%	0,42%	0,17%	0,01%	0,22%	-0,13%	0,08%
15.10.2023	**-0,03%**	**3,03%**	0,76%	0,77%	0,97%	0,41%	0,83%	0,28%	0,62%	0,58%	0,22%	0,45%

Source: own elaboration.

Next, the results from the presidential elections are presented. The same presentation format is maintained, i.e., first, table 4 shows the value of the t-Student statistic, and then table 5 presents the average abnormal returns. Among the thirteen events, a statistically significant impact of voting results on the stock market returns can be indicated in seven of them. The presidential elections in 2000 and 2015 (first round) exerted a statistically significant impact on the rate of return of the WIG for an event window of up to 5 days. In contrast, the election in 2005 (second round), 2010, and 2015 (second round) influenced the stock market for event windows of 8 and 10 days. It cannot be unequivocally stated whether the average abnormal returns were generally positive or negative in the periods before and after the elections. The results were varied depending on the specific vote. For example, in 2000, the average abnormal returns were negative both before and after the voting. Conversely,

in 2015, in the first round, they were positive before the voting day and negative after the election day. The most recent elections, held in 2025, did not seem to exhibit a statistically significant impact on the rate of return of the Polish stock exchange.

The results of the presidential election suggest a stronger impact between election outcomes and stock market quotations compared to parliamentary elections. However, not all presidential elections exhibited a significant impact on stock market. Therefore, it cannot be conclusively confirmed that presidential elections always have a significant impact on the Polish stock market. In the case of presidential elections, the impact of elections on the stock market was more varied over time and was not concentrated solely around the first elections in the analyzed period.

Table 4.
Presidential elections, t-values for different event windows

Election date	2 days		4 days		5 days		6 days		8 days		10 days	
	t	p-val.	t	p-val.	t	p-val.	t	p-val.	t	p-val.	t	p-val.
05.11.1995	-1,73	0,11	-0,87	0,21	-0,84	0,21	-1,09	0,15	-0,78	0,22	-0,36	0,36
19.11.1995	-1,22	0,17	-0,37	0,36	-0,38	0,36	-0,13	0,45	-0,20	0,42	-0,41	0,34
08.10.2000	**-2,66**	**0,06***	**-1,67**	**0,07***	**-2,20**	**0,03****	-0,46	0,33	0,03	0,49	0,39	0,35
09.10.2005	1,34	0,16	0,40	0,35	-0,02	0,49	-0,09	0,47	-0,21	0,42	-0,22	0,41
23.10.2005	-0,08	0,47	-0,06	0,48	-0,12	0,46	0,30	0,38	**1,63**	**0,06***	1,23	0,12
20.06.2010	0,74	0,27	-0,31	0,38	-0,47	0,32	-0,46	0,33	**-1,57**	**0,07***	-0,80	0,22
04.07.2010	0,10	0,46	0,89	0,20	0,93	0,19	1,09	0,15	**1,90**	**0,04****	**1,43**	**0,08***
10.05.2015	-1,03	0,21	**-1,46**	**0,10***	**-1,67**	**0,07***	-1,31	0,11	-0,74	0,23	-1,25	0,11
24.05.2015	**-2,31**	**0,07***	-1,07	0,16	-1,20	0,13	-1,14	0,14	**-1,40**	**0,09***	**-2,01**	**0,03****
28.06.2020	0,46	0,35	1,02	0,17	1,08	0,16	1,22	0,13	0,76	0,23	0,55	0,29
12.07.2020	-0,73	0,27	0,59	0,29	0,10	0,46	0,71	0,25	-0,09	0,47	-0,22	0,41
18.05.2025	0,05	0,48	-1,27	0,13	**-1,96**	**0,04****	-0,73	0,24	-0,76	0,23	-0,71	0,24
01.06.2025	0,58	0,31	-0,14	0,45	-0,89	0,20	-0,41	0,35	0,25	0,40	-0,09	0,47

* significance at 0,1, ** significance at 0,05, *** significance at 0,01.

Source: own elaboration.

Table 5.
Average abnormal returns for presidential elections

Election date	2 days		4 days		5 days		6 days		8 days		10 days	
	before	after	before	after	before	after	before	after	before	after	before	after
05.11.1995	2,57%	0,78%	1,12%	0,27%	0,66%	-0,11%	0,63%	-0,19%	0,45%	-0,02%	0,13%	-0,07%
19.11.1995	-0,28%	-2,24%	0,07%	-0,42%	-0,10%	-0,49%	-0,32%	-0,43%	-0,30%	-0,42%	-0,07%	-0,30%
08.10.2000	**0,40%**	**-0,95%**	**-0,35%**	**-1,58%**	**-0,44%**	**-1,76%**	-0,23%	-0,75%	-0,42%	-0,40%	-0,28%	0,03%
09.10.2005	-1,77%	0,42%	-1,45%	-0,97%	-0,93%	-0,95%	-0,60%	-0,68%	-0,65%	-0,81%	-0,40%	-0,54%
23.10.2005	0,57%	0,50%	-0,28%	-0,33%	-0,10%	-0,19%	-0,22%	-0,03%	**-0,77%**	**0,33%**	-0,53%	0,18%
20.06.2010	-0,40%	0,29%	-0,13%	-0,32%	0,06%	-0,19%	0,04%	-0,16%	**0,26%**	**-0,41%**	0,08%	-0,23%
04.07.2010	0,53%	0,64%	-0,37%	0,33%	-0,30%	0,28%	-0,19%	0,38%	**-0,39%**	**0,41%**	**-0,25%**	**0,30%**
10.05.2015	0,34%	-0,12%	**0,23%**	**-0,30%**	**0,26%**	**-0,23%**	0,18%	-0,16%	0,00%	-0,17%	0,10%	-0,17%
24.05.2015	**-0,20%**	**-1,24%**	-0,20%	-0,66%	-0,11%	-0,55%	-0,09%	-0,44%	**-0,18%**	**-0,54%**	**-0,17%**	**-0,58%**
28.06.2020	-0,65%	-0,06%	-0,34%	0,69%	-0,25%	0,61%	-0,12%	0,70%	-0,04%	0,37%	0,05%	0,37%
12.07.2020	0,31%	-0,38%	-0,19%	0,17%	0,08%	0,14%	0,10%	0,50%	0,46%	0,42%	0,34%	0,25%
18.05.2025	-0,56%	-0,53%	-0,32%	-0,81%	**-0,25%**	**-0,86%**	0,15%	-0,35%	0,28%	-0,12%	-0,06%	-0,41%
01.06.2025	-1,43%	-1,02%	-0,45%	-0,56%	0,08%	-0,67%	-0,11%	-0,42%	-0,38%	-0,23%	-0,40%	-0,45%

Source: own elaboration.

Next, the analysis focuses on local elections. Table 6 presents the values of the t-Student statistics, and table 7 shows the average abnormal returns. Among the fourteen elections studied, the impact of election results on the stock market can be indicated in six of them.

However, the elections in 2006, 2010, and 2018 show a very weak impact of the elections on the stock market, occurring only for a single event window. It can be stated that only the elections in 1994, 1998, and the second round of the 2002 elections exerted a statistically significant impact on stock market, although not in all the analyzed event windows either. It cannot be stated whether the average abnormal returns were generally positive or negative in the periods before and after the elections.

The results for local election do not confirm the hypothesis of a significant impact of these elections on stock market. Statistically significant impact was observed only in a few cases, and these were not consistent over time. Possible reasons for this may stem from the lower importance of local elections compared to parliamentary or presidential elections, as well as the greater diversity of interests represented by local authorities.

Table 6.
Local elections, t-values for different event windows

Election date	2 days		4 days		5 days		6 days		8 days		10 days	
	t	p-val.	t	p-val.	t	p-val.	t	p-val.	t	p-val.	t	p-val.
19.06.1994	-0,55	0,32	0,55	0,30	0,91	0,20	1,11	0,15	**1,90**	**0,04****	**2,30**	**0,02****
11.10.1998	1,62	0,12	1,03	0,17	1,30	0,12	**1,49**	**0,08***	**2,41**	**0,02****	**2,54**	**0,01****
27.10.2002	1,38	0,15	0,95	0,19	1,29	0,12	0,17	0,43	-0,30	0,38	-0,71	0,24
10.11.2002	0,69	0,28	**1,63**	**0,08***	1,25	0,12	1,26	0,12	**1,77**	**0,05****	**1,44**	**0,08***
12.11.2006	0,42	0,36	-0,52	0,31	-1,16	0,14	**-1,40**	**0,10***	-0,61	0,27	-0,09	0,46
26.11.2006	-0,62	0,30	-0,36	0,37	-0,17	0,43	0,59	0,28	0,80	0,22	0,92	0,19
21.11.2010	0,13	0,46	**1,57**	**0,08***	1,33	0,11	0,54	0,30	0,90	0,19	1,19	0,13
05.12.2010	-0,27	0,41	-1,32	0,12	-0,57	0,29	-0,07	0,47	-0,12	0,45	-0,08	0,47
16.11.2014	0,04	0,48	-0,32	0,38	0,41	0,35	0,36	0,36	0,87	0,20	0,35	0,37
30.11.2014	0,66	0,29	-0,06	0,48	0,39	0,35	-0,16	0,44	-0,48	0,32	-0,76	0,23
21.10.2018	-0,93	0,22	-1,22	0,13	-1,59	0,07*	**-1,57**	**0,07***	-0,04	0,49	0,67	0,26
04.11.2018	-1,42	0,15	-0,81	0,22	-0,19	0,43	-0,26	0,40	0,07	0,47	-0,06	0,48
07.04.2024	-0,31	0,39	-0,44	0,34	-1,13	0,15	-1,12	0,14	-1,03	0,16	-0,99	0,17
21.04.2024	0,68	0,28	0,08	0,47	0,27	0,40	0,72	0,24	0,45	0,33	0,82	0,21

* significance at 0,1, ** significance at 0,05, *** significance at 0,01.

Source: own elaboration.

Table 7.
Average abnormal returns for local elections

Election date	2 days		4 days		5 days		6 days		8 days		10 days	
	before	after	before	after	before	after	before	after	before	after	before	after
19.06.1994	-2,12%	-6,27%	-5,15%	-2,58%	-4,98%	-1,58%	-5,18%	-1,77%	**-5,29%**	**-0,57%**	**-4,66%**	**0,12%**
11.10.1998	-2,27%	2,41%	-0,65%	1,31%	-0,32%	1,71%	**-1,00%**	**1,23%**	**-1,95%**	**1,16%**	**-1,38%**	**1,54%**
27.10.2002	-0,05%	1,55%	0,22%	0,87%	0,18%	0,86%	0,47%	0,57%	0,37%	0,22%	0,59%	0,28%
10.11.2002	-0,09%	0,20%	**-0,63%**	**0,17%**	-0,34%	0,27%	-0,20%	0,33%	**-0,12%**	**0,69%**	**0,18%**	**0,89%**
12.11.2006	-0,72%	-0,45%	-0,16%	-0,56%	0,25%	-0,55%	**0,38%**	**-0,43%**	0,31%	0,01%	-0,01%	-0,05%
26.11.2006	-0,34%	-0,43%	0,42%	0,15%	0,32%	0,21%	0,11%	0,45%	-0,10%	0,33%	-0,17%	0,24%
21.11.2010	-0,52%	-0,44%	**-0,79%**	**-0,15%**	-0,78%	-0,31%	-0,59%	-0,40%	-0,48%	-0,11%	-0,36%	0,05%
05.12.2010	0,65%	0,55%	0,75%	0,20%	0,41%	0,15%	0,16%	0,13%	0,16%	0,12%	0,04%	0,01%
16.11.2014	0,15%	0,18%	-0,04%	-0,16%	-0,14%	0,00%	-0,15%	-0,05%	-0,19%	0,00%	-0,07%	0,00%
30.11.2014	-0,04%	0,45%	0,04%	0,01%	-0,02%	0,12%	0,11%	0,05%	-0,06%	-0,21%	0,01%	-0,19%
21.10.2018	-0,19%	-1,00%	0,22%	-0,58%	0,09%	-0,90%	**0,27%**	**-0,65%**	-0,25%	-0,27%	-0,28%	0,09%
04.11.2018	1,63%	0,61%	1,13%	0,67%	0,45%	0,28%	0,33%	0,15%	-0,03%	0,01%	-0,01%	-0,04%
07.04.2024	0,33%	-0,10%	0,14%	-0,18%	0,38%	-0,31%	0,35%	-0,22%	0,26%	-0,33%	0,36%	-0,18%
21.04.2024	0,39%	0,88%	-0,10%	-0,02%	-0,03%	0,18%	-0,18%	0,31%	-0,23%	0,02%	-0,19%	0,25%

Source: own elaboration.

The final type of elections examined were the elections to the European Parliament. The findings are presented in tables 8 and 9. It cannot be stated that the elections to the European Parliament in Poland exerted a statistically significant impact on stock market. Only the 2014 elections, within the 5 and 6-day event windows, exerted a statistically significant impact on the stock market returns.

Table 8.
European elections, t-values for different event windows

Election date	2 days		4 days		5 days		6 days		8 days		10 days	
	t	p-val.	t	p-val.	t	p-val.	t	p-val.	t	p-val.	t	p-val.
13.06.2004	-0,02	0,49	-0,86	0,21	-0,41	0,35	0,34	0,37	0,31	0,38	0,38	0,36
07.06.2009	-0,38	0,37	0,24	0,41	-0,81	0,22	-0,78	0,23	-1,13	0,14	-1,22	0,12
25.05.2014	-1,32	0,16	-1,36	0,11	**-1,88**	**0,05****	**-1,51**	**0,08***	-1,02	0,16	-0,89	0,19
26.05.2019	0,51	0,33	0,24	0,41	0,62	0,28	0,66	0,26	0,18	0,43	1,23	0,12
09.06.2024	-0,37	0,37	0,22	0,42	0,11	0,46	0,32	0,38	1,07	0,15	1,19	0,12

* significance at 0,1, ** significance at 0,05, *** significance at 0,01.

Source: own elaboration.

Table 9.
Average abnormal returns for European elections

Election date	2 days		4 days		5 days		6 days		8 days		10 days	
	before	after	before	after	before	after	before	after	before	after	before	after
13.06.2004	-0,50%	-0,52%	-0,10%	-0,55%	-0,25%	-0,44%	-0,27%	-0,10%	-0,15%	-0,02%	-0,08%	0,05%
07.06.2009	0,48%	-0,23%	0,42%	0,69%	1,34%	0,29%	0,99%	0,12%	0,83%	-0,21%	0,56%	-0,55%
25.05.2014	0,98%	0,02%	0,66%	0,08%	**0,62%**	**-0,12%**	**0,49%**	**-0,04%**	0,36%	0,05%	0,42%	0,19%
26.05.2019	-0,41%	0,18%	0,23%	0,39%	0,11%	0,44%	0,07%	0,36%	0,13%	0,20%	-0,01%	0,38%
09.06.2024	-0,36%	-0,71%	-0,68%	-0,48%	-0,44%	-0,36%	-0,26%	-0,03%	-0,51%	0,11%	-0,47%	0,07%

Source: own elaboration.

5. Discussion

The obtained results do not unequivocally confirm the thesis of a significant impact of political elections on the Warsaw Stock Exchange. The most pronounced connection was observed in the case of presidential elections; however, its intensity varied depending on the specific election. These findings would partially corroborate earlier research (Szymański, Wojtalik, 2022). In contrast, the impact of parliamentary elections appears to be limited to the early period of Poland's democratization. Furthermore, local elections and elections to the European Parliament did not exert a statistically significant impact on the WSE.

The research presented in this paper corroborates the findings obtained by Nippani and Medlin (2002), indicating that presidential elections primarily exert a significant impact on the stock market. The presented research is also consistent with the findings of Floros (2008), who analyzed the impact of Greek parliamentary and European political elections on the Athens

Stock Exchange between 1996 and 2002. The author found no evidence indicating a significant impact of political factors on the performance of the Greek stock exchange, either before or after the Greek parliamentary and European elections.

It should be noted that the impact of political elections on the financial market is a complex phenomenon influenced by numerous factors, such as investor expectations, the economic situation, and the specifics of individual elections. The research presented in this paper has certain limitations:

- The study concerns the impact of political elections on the Warsaw Stock Exchange, specifically focusing on the main stock index – WIG – without examining the impact on individual companies or other indices. Companies may react differently to political events. Sector affiliation, company size, or its exposure to foreign markets can lead to varied reactions to the same events.
- The selection of the event window length is, to some extent, arbitrary. Different events may have different periods of impact on the market.
- Election results are often interpreted in multiple ways, and their impact may depend on the economic, social, and international context.
- The reactions of the Polish market to political events may differ from the reactions of more mature markets.

6. Conclusion

This paper investigated the impact of the results of presidential, parliamentary, local and European elections in Poland between 1991 and 2025 on the rates of return of the WIG index on the Warsaw Stock Exchange.

While an analysis of presidential elections suggests a stronger impact on the stock market compared to parliamentary, local, or European elections, the overall thesis of a significant influence of political elections on the Warsaw Stock Exchange isn't entirely confirmed by our findings. The strongest link was evident in presidential elections, but its strength was highly dependent on the particular election. Therefore, it's not possible to conclude that presidential elections invariably have a significant impact on the Polish stock market. The conclusions presented in this paper corroborate the findings of Nippani and Medlin (2002), who indicated that presidential elections primarily have a significant impact on the stock market.

In comparison to countries such as the United States, the United Kingdom, or Germany, the Polish capital market is relatively young and comparatively small in terms of capitalization and the number of active investors. Although political elections in Poland influence the local economy and investor sentiment, their impact on the market may be less pronounced than in

countries with more developed and globalized stock exchanges. In countries like the United States or Germany, political decisions often have a direct impact on global financial markets due to the immense scale of their economies and international capital linkages. In Poland, however, owing to the market's smaller weight in the global system, investor reactions may be more localized and short-term. Additionally, some foreign investment capital may treat Poland as a peripheral market, whereby their reactions to political changes are often more cautious and delayed.

It is worth emphasizing, however, that with the development of the capital market in Poland, the role of political factors may gradually increase — particularly concerning decisions affecting taxes, regulations, or the public sector.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

PARTICIPATORY PLANNING OF STUDENT CAMPUSES. CASE STUDIES: POLAND AND UKRAINE

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Purpose: This article analyzes participatory planning as a tool for optimizing resources and increasing users' social capital by studying the opinions of architecture students about their learning environment.
Design/methodology/approach: The authors present and analyze two participatory planning processes of student campuses in Warsaw (Poland) and Poltava (Ukraine).
Findings: The proposals of space users (in this example, students), which stem from a preliminary analysis of their needs, include specific, simple, and environmentally friendly solutions and also suggest the inclusion of space users in maintenance and care.
Research limitations/implications: The learning environment should also be a place for youth integration, recreation, and various learning activities between standard educational classes. Further research should test whether creating the above conditions in the learning environment will increase social capital and students' achievement as a particular social group.
Practical implications: Understanding the needs of young people in specific elements of the learning environment will help increase the comfort and social cohesion of students, thereby enhancing their participation in university life, which will, in turn, increase the institution's status and attractiveness to applicants.
Social implications: Practicing participatory planning skills will enhance architecture students' social awareness and increase their sense of responsibility to society. Consequently, projects created by socially conscientious architects will be of greater value to society and better address its needs.
Originality/value: Combining social theories with student-driven design practice highlights how user involvement contributes to creating inclusive and socially meaningful academic spaces. The paper provides valuable insights for researchers, educators, and campus planners.
Keywords: participatory planning, social capital, learning spaces, students.
Category of the paper: Research paper, case study.

1. Introduction

This article describes a specific, concrete case study involving students in participatory planning (a first-hand reported account). The comparison between students' perspectives and professional architects' approaches is a subjective observation, likely stemming from the author's analysis, and thus constitutes an original insight (Figure 1).

Figure 1. The participatory planning process in SGGW (Poland): a) description of the event, 9.11.2024 (author: Witold Hebanowski); b) the working group is analyzing architectural concepts, 1.07.2025; c) discussion between participants and one of the architects behind the winning concept (Karol Lange) on taking into account the results of participatory planning and the expectations of the space's users, 1.07.2025 (photos: Polina Vietrova).

Source: documentation of the Academy of Young Architects, The Other Space Foundation project; coordinator: Polina Vietrova (Department of Architecture, Institute of Civil Engineering, SGGW, Poland).

Modern practices of planning new and improving existing public spaces increasingly include participatory planning with existing and potential users of the space to maximize the adaptation of the project proposal to users' needs. At the same time, young people are rarely involved in this process (Costa et al., 2023; Rexhepi et al., 2018). However, as the example of this study shows, young people are quite good at identifying the problems and needs of the analyzed space and proposing simple, sustainable, and environmentally friendly solutions, unlike professional architects, who think more globally at the level of the whole object, focusing on standards and calculations, students at the user level notice every important detail to them.

This research topic exemplifies the practices used by the authors within their teaching activities. In 2017, Polina Vietrova, the Head of the Architecture Department at the Trostianets City Council in the Sumy Region, invited a group of National University of Poltava Polytechnic (NUPP) students, led by their teacher Pavlo Vasyliev, to carry out a student practicum in Trostianets city (Sumy Region). The students showed great enthusiasm and created several concepts for city facilities proposed by the mayor. In 2018, the next step was to cooperate in implementing the project in Ukraine with the support of Polish Aid (Vietrova, 2019). Architecture students assisted in the participatory planning of public spaces in the Poltava and Sumy regions. To prepare for working with residents, the students attended a three-day training program.

The training program covered key aspects of mediation, project proposal preparation, and participatory planning process management. One of the test sites was the university's yard, where students proposed interesting and innovative solutions to improve the quality of this public space based on analysis, surveys, and an open workshop. The architecture students noted the importance of interacting with space users, something they had never done before when developing educational projects.

This experience convinced the organizers and participants that involving architecture students in participatory planning practices has many advantages. It establishes social connections and helps create more meaningful architectural projects that better meet users' needs (Table 1).

Table 1.
Student involvement in the transformation of learning spaces is practiced in both universities

	Type of Involvement	**NUPP***	**SGGW****
1	Direct involvement - active young people take part in various activities aimed at improving public spaces.	Municipal Architectural Practice in Trostianets (2016)	Participation in the city program "Droga na szóstkę" in Warsaw (2025).
2	Architectural competitions - involvement in conceptual design to find the most interesting, innovative, and creative ideas for the spatial development of the campus or its components.	- Rethinking the NUPP library space (2019). - Transformation of non-residential premises of the university into an invincibility center and student hub (2021).	- Concept for the revitalization of the SGGW Water Center (2024). - Design and model of the Innovative Pavilion "MAKIETERRA" (2025).

Note.
* NUPP – National University Poltava Polytechnic (Ukraine),
** SGGW – Warsaw University of Life Sciences (Poland).

At the same time, the authors' experience with participatory planning shows that in the process of co-creation, participants strengthen their social contacts and actively cooperate on future activities. To verify how social capital has grown, the results of the planning workshops were evaluated by distributing a short questionnaire among workshop participants with questions about their feelings and observations regarding indicators of social capital growth: changes in the level of mutual trust within the team cohesion, team competence, synergy in work, and mutual support.

The present study set out to examine the level of social capital as an incidental outcome of participatory spatial planning — a dimension often underexplored.

2. The theory of social capital

The article engages with several theoretical frameworks originating from the field of social sciences. The first framework discussed is the theory of social capital. It is a complex concept that draws on several academic disciplines, including sociology, economics, and political

science. The development of this concept has been most significantly influenced by the academic work of Pierre Bourdieu, James Coleman, and Robert Putnam, whose key publications appeared during the 1980s and 1990s. (Leenders, 2014, p. 1762). The earliest articles referring to social capital already addressed issues related to the functioning of educational institutions. Lyda J. Hanifan, regarded by Robert Putnam as the first author to define the concept of social capital (Farr, 2004, p. 7), served as a superintendent of schools in West Virginia. In his concept, he combined the issues of civic engagement, carried out especially around rural schools, with the quality of social life, emphasizing that social ties play a key role in building well-functioning local communities (Hanifan, 1916). James Coleman's work also demonstrates a strong link between educational research and the development of the theory of social capital. The starting point for James Coleman's later findings was his research on educational inequalities in the United States, which resulted in the Equality of Educational Opportunity report. Drawing on the collected data, Coleman argued that it was not school resources but rather social influences – particularly the stability of the family background and the surrounding social environment – that played the most crucial role in shaping students' academic achievement (Gamoran, Long, 2007, pp. 24-25). The idea of the importance of social capital was further developed by Coleman in the article "Social Capital in the Creation of Human Capital" (Coleman, 1988). Coleman emphasized, in particular, that "the social capital of the family is the relations between children and parents (and, when families include other members, relationships with them as well). That is, if the human capital possessed by parents is not complemented by social capital embodied in family relations, it is irrelevant to the child's educational growth that the parent has a great deal, or a small amount, of human capital" (Coleman, 1988, p. 110).

Contemporary articles on social capital and education also focus primarily on its impact on the learning process. The examined issues include the influence of social capital on educational attainment, progression through the education system, and students' engagement with institutional structures. In this context, researchers emphasize that social capital, manifested through emerging networks of relationships, community engagement, and support from family and peers, can significantly influence students' motivation, access to resources, and ability to achieve success within the educational system (Gentry et al., 2025; Soria, Stebleton, 2013; Oyefuga, Shakeshaft, 2023). The discussed topic also included the impact of students' participation in volunteer activities on the development of social capital. A study conducted by Soria (2023) on a sample of 8,964 students from 69 colleges and universities indicates the existence of a positive and statistically significant correlation between students' participation in community service and the development of their social capital. However, the strength and significance of the correlation vary depending on students' ethnic background and socio-economic status. A qualitative meta-synthesis conducted by Boat et al. (2024) based on 33 scientific articles highlights that participation in organized activities, such as extracurricular programs and youth development initiatives, positively supports the social capital development

of high school and college students. However, the extent and effectiveness of this support vary depending on organizational features, as well as the social groups to which the students belonged.

While the theory of social capital emphasizes the importance of social networks for educational achievement and highlights the benefits of building social relationships for civic engagement, in the context of the proposed study, a complementary perspective can be found in the spatial dimension of these interactions — particularly through Henri Lefebvre's concept of the production of space. The central premise of Lefebvre's theory is the conviction that space is (re)produced and represented and that power relations and social inequalities are embedded in spatial configurations and expressed through them. Henri Lefebvre explains the concept of the production of space by referring to a conceptual triad of space: perceived, conceived, and lived. The mutual relations between these dimensions mean that each coexists with the others, influences them, and co-creates the dynamic process of the social production of space (Hammond, 2019, p. 31) (Table 2).

Table 2.
Theoretical frameworks - comparisons and meanings

Theory	Key Contribution	Reference to the Study of Student Participation
Henri Lefebvre – Production of Space	Space is not neutral – it is socially produced through practices, representations, and experiences (triad: perceived, conceived, lived).	Students co-create the campus space through actions, projects, and symbolic meanings – they co-produce the space.
Social Capital (Putnam, Coleman)	Community, trust, norms of cooperation, and engagement are elements that enable collective action and the effective functioning of institutions.	Thanks to mutual trust and cooperation, students are able to act for the common good (e.g., green campuses).
Olson – Collective Action	People do not always engage in collective action unless there are incentives, social norms, or a shared identity.	Student participation is an example of how, despite potential barriers, individuals engage because they feel empowered and part of a group.
Ostrom/Trumbull	Cooperation is possible without coercion as long as social norms, trust, and moral legitimacy of actions are present.	Students act not only out of self-interest but because they feel their actions are right and necessary (e.g., inclusive spaces for all).

In the context of participatory campus co-design, which is the subject of this article, student initiatives not only constitute an adaptation to the existing space but actively co-produce it through three interrelated dimensions:

1. Perceived space – everyday practices of use, such as movement, rest, or social interaction.
2. Conceived space – formal designs and concepts developed during workshops and architectural competitions.
3. Lived space – symbolic, emotional, and identity-related meanings associated, for example, with the idea of a free library or a relaxation zone with a water feature.

The interaction of these three dimensions reinforces social cohesion and a sense of spatial identity, integrating Lefebvre's theory with the concepts of social capital developed by Coleman and Putnam.

Student participation in campus co-design processes can be interpreted as a form of collective action in the sense developed by Mancur Olson (1965), in which individuals cooperate even though traditional cost-benefit logic does not always support such engagement. In this context, the role of social capital – including trust, shared norms, and a sense of belonging (Coleman, Putnam) – is crucial in fostering motivation to act for the common good. At the same time, in Lefebvre's (1991) terms, such engagement represents a form of spatial co-production, in which practical use (perceived space), formal design (conceived space), and emotional-symbolic meaning (lived space) intersect. As Czech (2016, pp. 77-79) argues, contemporary reinterpretations of Olson's theory emphasize the importance of social embeddedness, cultural context, and shared moral legitimacy in enabling collective action—dimensions that are clearly visible in student-led campus initiatives.

3. Methods

The article analyzes the three stages of participatory planning that were conducted in both case studies:

- questionnaire (survey of students and other users of the space - staff, teachers),
- analysis of the existing area (advantages and disadvantages) in the format of a workshop,
- working on ideas and presentation of results (workshop).

The project used qualitative and action research methods, including open-ended surveys, design workshops with students, observation, and photographic documentation. Data focused on participants' needs, emotions, and proposals, analyzed through Inductive Thematic Analysis and a comparative study of Poland and Ukraine. The interpretation was further grounded in theoretical perspectives from Lefebvre, Putnam, Ostrom, and Olson (Table 3).

Table 3.
Methodology

	Description
Study type	Qualitative research with elements of action research
Research techniques	- Open-ended questions on the survey (n = 60 – Poltava, about 50 – SGGW) - Design workshops with architecture students - Participatory observation, photographic documentation
Data type	- Open-ended questions only - Qualitative data: needs, emotions, proposals – frequency analysis of selected topics
Analytical approach	- Inductive Thematic Analysis (Braun, Clarke, 2019) - Comparative Study (PL/UA) - Theory Reference: Lefebvre, Putnam, Ostrom, Olson

3.1. Participatory planning of the Territory of National University «Yuri Kondratyuk Poltava Polytechnic» (NUPP, Ukraine)

Based on the previous findings (Vietrova, 2019; Vietrova et al., 2022), the design concept was developed for the gradual transformation of a mono-space (recreation and transit areas) into a multifunctional environment that would facilitate the efficient use of the area by students and staff, technical staff, and university guests. It's become the starting point for larger-scale changes.

Essential achievements include the launch of a tradition of dendrological renovation of the territory, creating green areas, organizing open-air lectures, and integrating environmental initiatives. An open-space event was the arrangement of open-space classrooms in 2023, implemented with the support of the Japanese government. It was equipped with furniture made according to the principles of recycling and eco-design.

Fundraising activities are underway to create a space where students will feel so comfortable that they will not want to leave the university in their free time.

Given the significant experience of involving young people in university and city initiatives, the master's educational program for urban planning was updated in 2023. Particular attention was paid to improving the discipline "Heuristic Methods of Urban Planning Design", which added meaningful modules on public engagement processes, competitive design, and the organization of open discussions (Borodych et al., 2022).

The practical basis of the discipline was the development of concepts for the spatial development of individual university territories. The key requirements for the work are teamwork, analytical research (surveys, SWOT analysis), the use of informal design methods, and modeling of the user engagement process (Vasyliev, 2022).

3.2. Survey of NUPP case (Ukraine)

The study area covers a part of the university's inner courtyard. Its distinctive feature is the conditional division into three functional zones: transit, educational–recreational, and sports. During on-site observation, students identified the sports zone as the most underutilized. This zone was formed as a result of the revitalization of a former parking area, yet a portion of it currently remains unused, presenting the potential for further development and functional enhancement.

The next stage involved conducting a SWOT analysis of the area, followed by a brainstorming session focused on ideas for optimizing the space. An essential part of the concept development was incorporating the perspectives of the direct users of the space — students, faculty, and technical staff of the university.

The user survey was anonymous, which ensured the comfort of respondents and allowed them to express their opinions more openly. A total of 60 people completed the survey within 3 days. Master's students majoring in Architecture and Urban Planning proposed questions with

multiple-choice answers based on a preliminary analysis of the space (for example, “What do you use this space for?” and “What areas would you like to see in this space?”). At the same time, participants had the opportunity to add their ideas if they thought something had been missed (for example, “What would make you come here and stay?” or “What do you currently dislike about this space?”).

Figure 2. The participatory planning process in NUPP (Ukraine): survey, workshop (photo: Diana Semenets), and students’ proposals.

Source: Archive of discipline “Heuristic Methods of Urban Planning Design”, coordinator: Pavlo Vasyliev (Educational and Research Institute of Architecture, Civil Engineering and Land Management, NUPP, Ukraine).

The study's main objective was to identify the functions that university users consider most relevant, as well as to find out their needs and expectations about how they plan to use this space in the future.

3.3. Working on ideas and presentation of results, NUPP case (Ukraine)

The next step was to hold a workshop based on the collected data. The event involved students of different specialties who were randomly divided into three teams. The participants were assigned two main tasks: dividing the common area into functional zones, which made it possible to confirm the survey results, and dividing the desired space elements (places for recreation, mini-games, food zones) into separate areas.

The limited time for each task (5-10 minutes) encouraged participants to generate innovative ideas using heuristic methods quickly. The proposals presented were highly diverse and often differed significantly from the study results and initial analysis (Figure 2). It allowed us to gain a deeper understanding of the vision of the needs of different categories of university users to make final decisions and further develop the concept based on the results.

3.4. Participatory planning of the Water Center at Warsaw University of Life Sciences (SGGW, Poland)

At the Warsaw University of Life Sciences, workshops were held with Architecture program students directly in the Water Center space. The SGGW Water Center was built in 2010 by Piotr Fornalczyk and Marcin Pisarski as a laboratory subordinated to the Faculty of

Civil and Environmental Engineering. The building now supports the research activities of the Institute of Civil Engineering and the Institute of Environmental Engineering. In 2024, classes for Architecture students began to be held here, and the issue of modernizing the Center to meet new needs arose.

The participatory planning was conducted with the Other Space Foundation and consisted of a questionnaire, workshops, and an exhibition (Figure 3).

Figure 3. The participatory planning process in SGGW (Poland): survey, workshop (photo: Polina Vietrova), and concepts, 2024.

Source: documentation of the Academy of Young Architects, The Other Space Foundation project; coordinator: Polina Vietrova (Department of Architecture, Institute of Civil Engineering, SGGW, Poland).

Three teams of teachers and students majoring in Architecture and Landscape Architecture worked on the project proposals in a closed architectural competition format. All three proposals took into account the results of participatory planning.

3.5. Survey of SGGW case (Poland)

The questionnaire was intended to include those space users who did not participate in the workshops and duplicated questions that were important input for generating ideas: The results of the survey were presented during workshops with space users – 1st year architecture students and potential applicants – members of the Academy of Young Architects, which 30 people attended.

The questionnaire included an assessment of the space's quality and open-ended questions about the problems and needs of the building's users.

Since the questions in the questionnaires were mostly open-ended and specific, Manifest Coding was used to analyze the responses. The more often a certain word or phrase was mentioned, the higher priority was given to this result in the summary of results. For example, out of 38 answers, "What do you like/appreciate most about the Water Center? How important is it?" The word 'space' was mentioned 22 times in the meanings of 'a lot of space' and 'open space.' From this, we conclude that students appreciate the large, spacious atrium. It is worth preserving it. Along with space, 'the lake' was most often mentioned (8 times - the element that students value most in the space around the building), and 'light' in the context of large windows in classrooms and the atrium (7 times).

In the question "What don't you like and what would you like to change at the Water Center?" the word 'the fountain' was leading (out of 39 answers, 11 participants noted it as unnecessary or requiring rethinking and integration of water in another form into the space of the Water Center). When describing the negative aspects of the place, students often used different wording, so Latent Coding was used in the analysis of the answers. The answers were sorted according to the themes of 'Fullness of space' (where the keywords were 'atmosphere', 'climate of the place', 'more life', 'comfort', which were described in terms of their negative perception or lack of), 'Convenience of stay' (this included access to food, convenience of the workplace and places for recreation).

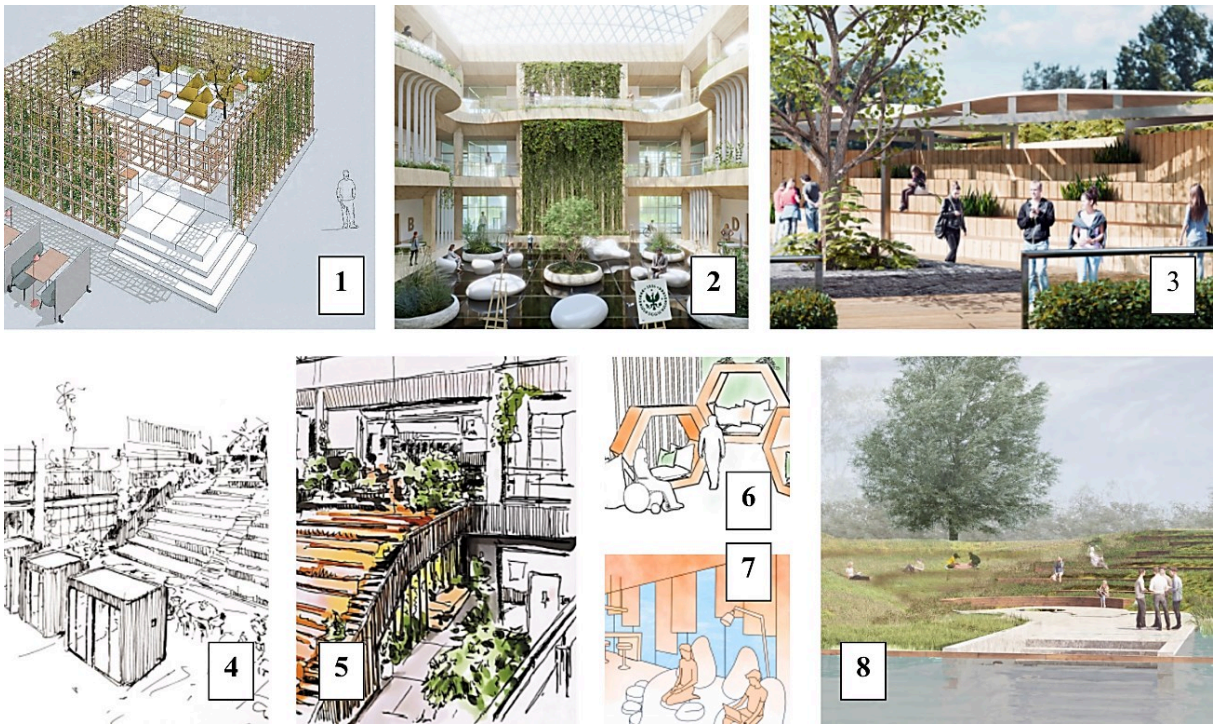
When asked, "What do you think is missing from the Water Center? What is not enough? Where could the features you suggested be added?" a 'cafeteria' (or canteen) was mentioned 18 times, 6 times an alternative was suggested - a microwave and 'someplace to eat'. "A place to sit in the corridor", 'ottomans,' and 'sofas' were mentioned 14 times in the survey; 3 more people specified the need for seating in the corridors as places for integration and adapted places for individual work, including a laptop, were mentioned 2 times.

When comparing the answers of male and female respondents, no significant differences were noticed. Users mostly noticed similar things and proposed similar solutions in terms of space. The exception was the issue of food - among men, the word 'cafeteria' was mentioned only once and in the general sense of its absence. In contrast, female respondents mentioned the Water Center's inadequacy in meeting their nutritional needs 9 times (lack of a cafeteria, small selection of food in the vending machine).

The survey results were presented at the beginning of the participatory planning workshops at the Water Center and influenced the selection of priority topics for planning.

3.6. Working on ideas and presentation of results (SGGW, Poland)

During the second workshop, 1st-year students of Architecture and AMAiA members, based on the results of the questionnaire and the answers on the flipcharts, developed specific proposals for changing the space of the Water Center. They generally referred to soft changes that did not interfere with the load-bearing structures but complemented the space with various functions. The workshop participants were divided into thematic groups: ‘Greening’, ‘Education/Science’, ‘Water in Center’, ‘Events/exhibitions’, and ‘Chillout’. Each group considered a specific function as a priority and offered their ideas for its development. The flipcharts prepared by the groups were also placed in the exhibition, and videos of the groups' presentations were distributed among the teams that participated in the closed competition for the Water Center space revitalization project (Figure 4).



1, 8 – I prize, team leader: Langie, K.; 2, 3, 6, 7 – II prize, ex aequo, team leader: Golański, M.; 4, 5 – II prize, ex aequo, team leader: Stefańska, A.

Figure 4. Excerpts from competition entries for the competition "Concept for the modernization of the Water Center building and its surroundings" (SGGW, Poland, 2025).

Source: Official Website of the Institute of Civil Engineering SGGW (Department of Architecture, Institute of Civil Engineering, SGGW, Poland).

The 'Water in Center' group proposed replacing the inactive fountain with a space that would serve the Center's guests during various events – a presentation space with a small water installation as a relaxation element and a symbol of the place. The Education/Science group suggested adding a free library – a place where books can be freely exchanged and read directly in the space. This book space also allows quiet independent work or a small group meeting. It was emphasized that some subjects, such as descriptive geometry, require the teacher to use a traditional blackboard, and it is still worth having such a place in the learning space, despite modern technology allowing everything to be demonstrated on screens.

4. Results and discussion

The data collected from case studies at Poltava Polytechnic (Ukraine) and the Water Center at the Warsaw University of Life Sciences (Poland) show that, despite apparent differences in infrastructure and aesthetics, students in both locations share strikingly similar expectations toward learning environments. They consistently express a need for spaces that go beyond formal instruction – spaces where they can meet, unwind, work independently or in groups, and spend time between or after classes (Table 4).

Table 4.
The emotional and symbolic meaning of space

Location	Aspect	Quotation
NUPP (Ukraine)	Need for appropriating the space (identity building)	"It's not just a square - it should be our place, with our character"
NUPP (Ukraine)	Space of community and creativity (student activities, experiments)	"The spirit is missing, but we can create it"
SGGW (Poland)	A symbol of wasted potential (fountain - aesthetics vs function)	"Beautiful but lifeless - it's a bit like a metaphor for this place"
SGGW (Poland)	Experienced regeneration space (pond - a place for rest)	"Here you can reset, have a moment with nature"
SGGW (Poland)	Lack of identification with the space (coolness and formality of interiors)	"It's like it's not for us, it's just for show"
Both locations	A space experienced, not just designed	"We want a space where you can feel that you belong"

Source: own study based on the survey's results.

Students' suggestions reflect more than just practical concerns. Their input reveals that they see the campus not only as a functional site for education but also as a social and symbolic environment that helps shape relationships, identity, and a sense of belonging.

This aligns with Lefebvre's (1991) notion of space as socially produced and co-created rather than passively consumed. The emotional and symbolic value students assign to campus spaces confirms that space is experienced as a lived reality — essential for identity-building and collective meaning-making.

To better understand the patterns in these responses, the data were analyzed using inductive thematic analysis (Braun, Clarke, 2019). This approach focused entirely on the perspectives of participants rather than testing any predefined hypotheses. A comparative summary of key findings is presented in the Table 5.

Table 5.
Main student observations regarding campus spaces – a comparative overview

Category	Poltava Polytechnic (UA)	Water Center, Warsaw University of Life Sciences (PL)
Assessment of aesthetics and overall impression	Harsh, visually underdeveloped space lacking atmosphere: "A lot of emptiness, no atmosphere, everything kind of gray"	Aesthetic, but "cold" and not suited to everyday life: "It's nice, but cold and uncomfortable"
What students value	Open space, potential for transformation, experimental activities: "This place has potential - you can do something really our here"	Natural light, spaciousness, pond, unique character of the building: "I like the space and the light, but something doesn't feel right here, I don't feel comfortable"
Functional problems	Lack of shade, uncomfortable benches, minimal functional diversity: "There is nowhere to sit in the shade, everything is hard and uncomfortable"	No cafeteria, cold temperature, uncomfortable seating, underused space: "There's nowhere to eat, there's no microwave, and it's cold inside like a basement"
Needs and suggested changes	Chill zone, food zone, relaxation, and event areas, pavilions: "Let's make a chill zone with poufs, tea, and board games"	Cafeteria, bean bags, spaces for integration and creative work: "Just add some poufs, heat, and a buffet, and you immediately want to stay"
Identity and emotions	Low identification, need to appropriate the space	Desire to "domesticate" the space, to give it character and a sense of life

Source: own study based on the survey's results.

Despite differing aesthetic and functional contexts, students at both campuses express similar needs: they seek comfortable spaces that support everyday presence (Table 6).

Table 6.
Empirical findings and interpretation

Empirical finding (with examples from the study)	Interpretation in light of theory	Theoretical source
Students engaged in the design process without formal incentives or rewards. In Poltava, they organized workshops without the involvement of teachers, while in Warsaw, they participated in two planning stages (survey and workshops) as well as an architectural competition	Contrary to the logic of individual self-interest, collective action is made possible through intrinsic motivation, social norms, and group identity	Olson (1965); Ostrom/ Trumbull
Students proposed concrete, low-budget, and functional solutions: 3x3 m recycled pavilions, hammock chillout zone, food zone, and space with a microwave	These proposals reflect a high level of spatial responsibility and the development of social capital – actions for the common good	Putnam, Coleman
Students assigned emotional and symbolic meaning to space. In Warsaw, the fountain became a symbol of lost potential, while the pond area served as a space for calm and "energy recharging"	Space is not merely a physical structure, but something lived and experienced – a lived and co-created space	Lefebvre (1991)
Workshop activities led to the formation of integrated teams of students from different fields. In Poltava, thematic groups worked together on 'Greening,' 'Events,' and 'Education' zones	Such activities strengthen social ties within academic micro-communities, support integration, and increase engagement	Coleman, Soria (2023)
Students emphasized that space should support not only learning, but also rest, social interaction, and inspiration. Space should "recharge energy", "encourage group work", and "create atmosphere"	The university as a space of relationships - a place of social and cultural learning. This fosters civic attitudes and a sense of responsibility	Hanifan (1916), Hammond (2019), Czech (2016)

Source: own study based on the survey's results.

This reinforces Hanifan's (1916) and Hammond's (2019) argument that social infrastructure is as vital to educational environments as physical infrastructure. The students' emphasis on 'energy recharging' and informal gathering spaces reflects the role of everyday social interaction in fostering social capital.

The findings demonstrate that student participation in campus planning operates on functional, emotional, social, and symbolic levels. In both cities, these activities reflect key aspects of classical social theory, particularly the importance of co-creating space to foster identity, engagement, and collective responsibility.

Architecture students, in particular, envision learning spaces rich in sensory and spatial diversity — combining natural elements, access to books, zones for both individual and group work, and informal settings with localized lighting and comfortable furnishings. Such environments not only support academic productivity but also enhance well-being and creative collaboration.

Despite the differences in campus architecture, students from Poltava and Warsaw formulate very similar expectations of academic space.

They expect a space that supports daily functioning at the university, not limited to lecture halls.

The space should allow for rest and regeneration (‘energy recharging’), social meetings and integration, informal conversations with lecturers and students of other majors, creative and teamwork, a quiet place for individual work, and spending time outside of classes (e.g., waiting between classes). For students, campus space is not just a teaching infrastructure but a place of social life – it shapes their relationships, sense of belonging, and academic identity. Often, there is a need to “domesticate” the space – to give it warmth, coziness, and everyday functions (e.g. sofas, bookcases, buffet, microwave, plants) (Figure 5).

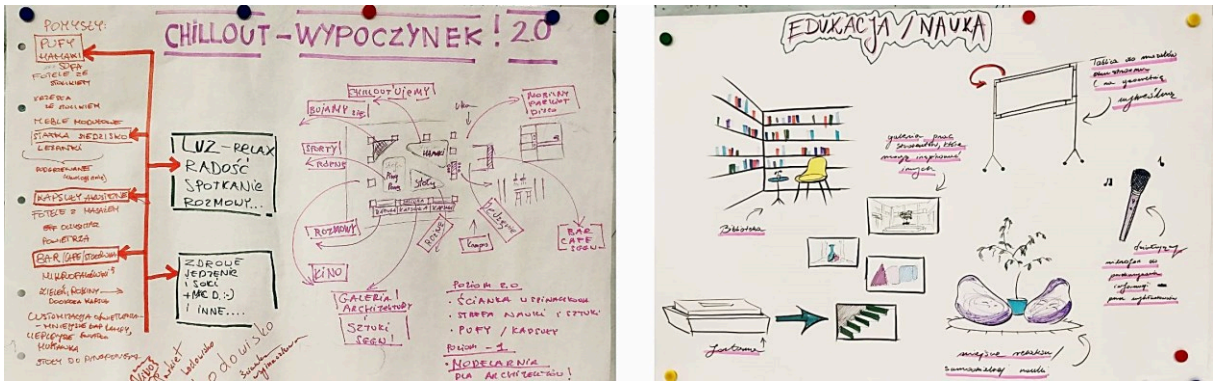


Figure 5. The Participatory Planning Process in SGGW (Poland): concepts (photos: Polina Vietrova).

Source: documentation of the Academy of Young Architects, The Other Space Foundation project; coordinator: Polina Vietrova (Department of Architecture, Institute of Civil Engineering, SGGW, Poland).

Considering the results of the groups' work, which aimed to describe elements of a space for relaxation and effective learning, we see that the participants' expectations combine elements of a standard educational space with other types of leisure and individual learning. These elements include a space for reading books and comfortable poufs for relaxing and informal communication in small groups.

When assessing the impact of participatory planning on its participants, significant progress in some areas was noted in social capital indicators. One participant noted that the most positive impact was seen in the assessment of increased cohesion and mutual support at the Poltava workshop. Mutual trust, synergy, and team competence also showed positive results. Conversely, workshop participants in Warsaw reported the greatest growth in team competence and the least change in team trust. The authors assume that mutual trust within the teams was well-established before because the participants were students who had previously taken classes together (Figure 6).

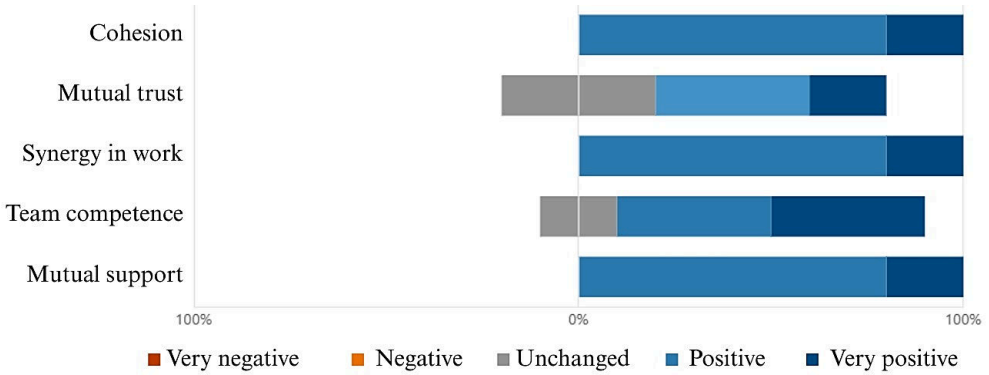


Figure 6. The Participatory Planning Process in SGGW (Poland): Post-evaluation. Changes in social capital indicators after workshops, according to participants' perceptions.

Table 7 summarizes the main indicators used for evaluation, associated coding categories, and representative quotes that illustrate each dimension of social capital expressed by participants during or after the workshops.

Table 7.
Indicators of Social Capital and Representative Participant Quotes

Indicator of Social Capital	Description / Code	Representative Quote from Participant
Mutual trust	Expression of increased interpersonal or institutional trust	"I felt like my ideas were really heard for the first time"
Cohesion	Sense of unity, shared goals, or solidarity	"We quickly became a team, even though we didn't know each other before"
Team competence	Recognition of team's growing ability to solve problems together	"Together we came up with better solutions than I expected"
Synergy in work	Value emerging from collaboration greater than sum of parts	"Someone would suggest an idea, and others would improve it — like puzzle pieces"
Mutual support	Willingness to help, empathize, or rely on each other	"Whenever someone got stuck, others jumped in to help"

These findings correspond with previous studies that emphasize the role of participatory planning in fostering social capital and inclusive environments. For instance, Putnam (2000) highlights that collaborative civic activities strengthen trust and mutual engagement within communities. Similarly, Hou (2010) and Manzini (2015) argue that co-creation in urban settings enhances social cohesion and empowers citizens. The observed increase in trust and team synergy among workshop participants aligns with Dovey's (2016) concept of emergent place-making through collective spatial practices. Our study reaffirms these claims and adds empirical evidence from the Ukrainian and Polish contexts, where participatory methods are still emerging in academic planning practices.

An overview of other examples of participatory planning of student campuses in different countries worldwide reveals that students also strive to diversify the existing space of the learning environment. We see a natural need for flexibility in solutions and the ability to change spaces for specific needs or functions. For example, lecture halls should be able to accommodate students in smaller groups for discussions or practical tasks in teams, combining teaching methods for better assimilation of the material. At the same time, large spaces

themselves are problematic in that they generate significantly more noise and distract students, while also allowing for greater flexibility in work and the possibility of interaction with different groups. When designing a prototype learning space with no restrictions on the existing form, participants often illustrate their ideas using rounded shapes and avoid right angles (Casanova et al., 2023).

The outdoor spaces of universities should combine the functions of rest and recreation, providing a complete reset between lectures, including the need for some solitude (a break from constantly being with peers), as well as the ability to create flexible spaces for different needs and groups of visitors during mass events.

In the discussion "Re-designing Universities: Social Learning Space" (Oxford Brookes, 2006), such forms of the learning environment, which include a combination of educational and social functions, are defined as "Social Learning Space". These places should meet the basic needs of students without distracting them from the learning process and provide them with a level of comfort that can compete with what they can get in other social and catering establishments. Such spaces are designed to keep students in the academic environment, promoting the expansion of academic contacts and interactions.

In all the examples proposed by participants in participatory planning, it is suggested that spaces be created to facilitate the implementation of different scenarios tailored to the needs of a specific user or group. All this involves diverse interaction and socialization and, at the same time, the availability of minimal personal space, which, according to some student comments, is too small in lecture rooms (Table 8).

Table 8.
An overview with insights into the processes of participatory planning of university spaces

Place of event	**Place of planning/ event/ organizer**	**The driving question**	**Phases**	**Instruments and methods**	**Insights**
Kingston University London (Casanova et al., 2023)	The learning space prototype (cube) / Department of Education and Distance Teaching, CIDTFF and LEAD, Universidade Aberta	What are the insights into the perceptions of students and teachers regarding the learning space and their role in it?	Workshop: Introduction, discussion, redesigning of the prototype.	Sandpits - design-driven focus groups (teachers and students separately).	Students appeared to be more focused on the functional aspects of the space, while teachers were more concerned with the conceptual perspectives. Students want more space on the desks than is allocated in lecture rooms - for a notebook, tablet, calculator; more distance between students for a comfortable perception of the lecturer.
Peking University, Beijing, China (Co-created Campus, 2020)	The outdoor area adjacent to the dormitory / the landscape architecture department	-	Participation in three rounds of design review.	voting to support the project: following the consideration of students' comments, the project garnered a greater degree of support.	Post-maintenance: some flaws not previously considered are compensated for by students spontaneously during use.

Cont. table 8.

Seoul Eunro Elementary School, Republic of Korea (Baek, 2023)	Redesigning of school building / the User Participation School Design Promotion Plan / Seoul Metropolitan Office of Education.	-	Planning: Announcing plans, SEES renovation decision, KEBID Workshop. Design: Expert selection, Expert discussion.	1st workshop with students, teachers, and parents to search for priorities (nature, safety, and comfort), 2nd workshop with teachers and parents (zoning plan), 3rd workshop with teachers: the detailed plan.	In the user collaboration design process, it is necessary to divide the roles of experts into planning, generalization, and design realization. Since participants cannot discuss and decide on the design like experts, the presence of experts to educate participants, create a forum for discussion, and select different creative opinions is paramount.
Royal Institute of Technology, Stockholm, Sweden (Pannone et al., 2019)	The campus yard / Placemaking Week / Master of Urbanism Studies program.	How can we create a space that encourages people to discuss the future of public space on campus?	Immersing, Planning, Designing, Executing.	Tactical urbanism event, using 160 buckets, provided visitors with seating, enclosure, and fun. Permanent installation: board for writing proposals.	Clear communication and collaboration are key between the private, public sectors, and the local population. Designers, architects, and urban planners often overlook aspects that impact the execution and longevity of the space, focusing too much on the physical environment.
Department of Music of the University of Jyväskylä, Finland (Lundström et al., 2016)	Former dining room space for a shared thematic student open space / A participatory workshop charrette method / Department	How does the final product meet the users' needs that were conceptualized during the charrette?	Visioning and concept design, technical design, construction, premises in use.	Coded data of the survey produced three main categories of user needs: infrastructural, practical, and emotional.	The framework highlights the user needs that are relevant to the users yet widely neglected in the current practices of construction projects. Collaboration provides a positive impact on the resulting premises, even though every single part of the project may not be successful.
Oxford Brookes University, England (2006)	Learning spaces / Discussion / The Reinvention Centre, University of Warwick and Oxford Brookes University's	How can we change existing spaces? How can we make these new spaces work?	Introduction, Discussion Focus Groups, Plenary.	Discussions in thematic working groups.	"Students in the discussion favored small, enclosed spaces (contrary to what we have learnt from other spaces) and wanted bookable spaces." "Students were very happy with self-policing - if it's your mess you clean it up."

Joint planning increases responsibility for and a sense of belonging to the space, which improves comfort and is vital for young people who are often outside their permanent place of residence for the first time and far from their parents and friends.

However, the observed formation of micro-communities, along with the development of mutual trust, synergy, and collaborative competence, suggests that these effects are not incidental but rather intrinsic to participatory spatial practices. In line with Putnam (2000) and Coleman (1988), such dynamics point to a virtuous cycle: participatory design fosters social capital, which in turn strengthens engagement and enhances the long-term sustainability of the spatial outcomes.

Future research should analyze the impact of such a space on increasing learning efficiency and improving students' cognitive skills.

5. Conclusions

The activities carried out in this study demonstrate that student participation in campus spatial planning is not only feasible but essential if the aim is to create environments that support both education and social relationships. Students are competent spatial users – they are capable of diagnosing weaknesses and proposing realistic, functional, and sustainable solutions. Their perspectives offer an often-overlooked yet valuable source of design knowledge. Educational space plays a critical role in shaping a university's social capital: areas for integration, relaxation, activity, and symbolic expression support the development of academic communities and promote civic values. Participatory spatial planning aligns with the broader theoretical frameworks of the social production of space (Lefebvre) and the collective action potential of empowered communities (Olson, Ostrom).

However, the study is not without its limitations. The sample size was modest and focused on two specific institutional contexts, which may limit the generalizability of the findings. Furthermore, the qualitative nature of the data lacks the statistical depth that might be expected for more policy-oriented recommendations. These limitations point to the need for further research using mixed methods and broader comparative frameworks across different types of campuses and cultural contexts.

Despite these limitations, the study offers several important insights. It highlights the capacity of students to act as co-designers of their environments and demonstrates how participatory processes foster social capital and emotional investment in academic space. One key lesson is that students need spaces more attuned to their everyday needs than traditional standards currently accommodate. The cross-case comparison reveals a striking similarity in spatial expectations across different national settings, suggesting that the demand for integrative, comfortable, and identity-affirming educational spaces is widespread and translatable.

The findings contribute new knowledge to the fields of campus planning, educational design, and participatory urbanism by showcasing how bottom-up input can lead to more responsive and inclusive environments. Practically, the results may inform future participatory processes in both the design of new academic spaces and the retrofitting of existing ones. More broadly, they advocate for a shift in design culture: from designing *for* students to designing with them. This paradigm shift has the potential to produce not only more adaptive and functional learning environments but also to foster agency, responsibility, and long-term engagement within academic communities.

Acknowledgments

We express our gratitude to the Other Space Foundation and President Witold Hebanowski. Thanks to him, the authors of this article began incorporating participatory planning into their work with students. We would also like to thank Polish Aid for supporting the 'Development of modern local government: Space/Planning/Participation' project (implemented in Ukraine in 2019) and the Education Office of the Warsaw City Hall for supporting the Academy of Young Architects.

Special thanks to the proactive and tireless students of the Warsaw University of Life Sciences – Julia Wlodarska, Zuzanna Wojcehowska, Olivia Pikulska, Kornelia Wiernicka, and of the National University "Yuri Kondratyuk Poltava Polytechnic" – Vlada Patsula, Diana Semenets, Andrii Yefremenko, and Alisa Pasko, whose dedication, creativity, and curiosity have contributed significantly to the success of this work. We are also grateful to the management of our educational institutions for their ongoing support of student and community participation in planning public and academic spaces. Thanks to your support, architecture students can independently study and analyze user needs, delve into the local context, and design better, higher-level architecture.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

ETHICAL ASPECTS IN MANAGING NEUROATYPICAL EMPLOYEES: A MANAGEMENT PERSPECTIVE

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Purpose: The considerable presence and steadily increasing proportion of neurodivergent individuals within contemporary societies, together with the relatively underdeveloped state of ethics-oriented research in the field of management and quality sciences, has prompted the author to articulate two research objectives. The first objective concerns identifying and analyzing the ethical considerations raised in the extant literature with regard to neurodiversity, with particular emphasis on the management of neurodivergent employees. The second objective aims to articulate research questions that explore managerial perceptions of the ethicality of neurodivergent employees' behavior and the ethical dimensions of their treatment in the workplace.
Design/methodology/approach: In order to accomplish the objective of the article, a scoping literature review was conducted, and methodological assumptions together with research questions were formulated to serve as the basis for the development of a questionnaire for the Author's own empirical study addressed to organizational managers. An approach to the topic grounded in the respect for the dignity, autonomy, and agency of neurodivergent individuals was adopted and criteria of ethical competencies - considered significant from the perspective of the challenges of the contemporary economy - were also incorporated.
Findings: Scoping literature review showed that early research perspectives in medicine and social sciences contributed to the stigmatization of neurodivergent individuals. Contemporary studies highlight the strengths of neurodiversity and ethical dimensions of inclusion, yet, research within management and quality sciences remains scarce.
Research and practical implications: The intended outcome of the planned empirical research is, in part, to address the clear research gap identified in the scholarly literature and, in practical terms, to enable the formulation of recommendations for organizational stakeholders to ensure the integration of ethical considerations in neurodiverse workplaces. The proposed research agenda may also serve as a stimulus for further exploration in this area.
Social implications: Results of the planned empirical research might positively influence public attitudes and affect quality of life neurodivergent individuals.
Originality/value: The originality of the present study is associated with the linkage of themes: neurodiversity and the ethicality.
Keywords: neurodiversity, neurodivergence, ethicality, human resource management (HRM).
Category of the paper: Conceptual paper.

1. Introduction

The term *neurodivergence* refers to the naturally occurring neurological diversity (*neurodiversity*) within the human species (Jaarsma, Welin, 2012; Blackburn, 2023) and encompasses, inter alia, autism spectrum disorder, attention-deficit/hyperactivity disorder (ADHD), attention deficit disorder (ADD), Tourette's syndrome, and learning difficulties (Baumer, Frueh, 2021). In the present article, the terms *neurodiversity*, *neurodivergence*, *neurological difference and neurodevelopmental difference* will be used interchangeably. It is estimated that the prevalence of neurodivergent conditions currently extends to as much as one-fifth of the global population (Doyle, 2020) and continues to rise dynamically. This trend is exemplified by the number of autism diagnoses, currently estimated at 1 in 100 children in Europe and 1 in 54 in the United States (polskiautyzm.pl, 2020; Wright, 2020), compared to only 0.05% in the 1980s. However, this growing representation in society has not been accompanied by a commensurate increase in public awareness regarding the characteristics of neurodivergence. One of the most critical consequences of this lack of awareness is the unjust perception of neurodivergent individuals as unethical or lacking empathy (Stenning, 2021), which in turn may result in reluctance to employ them (Bernard et al., 2023). In light of these considerations, it has been deemed essential to identify the issues addressed within the scholarly discourse on the ethicality of neurodivergent individuals, as well as to explore how, from a managerial perspective, the ethicality of their conduct and their treatment within organizations is understood. To achieve these objectives, the Scoping Review of the literature was undertaken, and methodological assumptions for the Author's own empirical research on the subject matter were developed.

2. Neurodivergence and Ethicality – A Scoping Review of the Literature

The review of the theoretical foundations was undertaken in accordance with the rigor of of methodological research procedures (Czakon, 2011; Ćwiklicki, 2020). To ensure methodological transparency and analytical robustness, a scoping review approach was used. This method has been recognized as particularly suitable for synthesizing knowledge in emerging or underexplored domains and for systematically identifying research gaps (Ćwiklicki, 2020). The structured research procedure adopted in this study is presented in Figure 1.

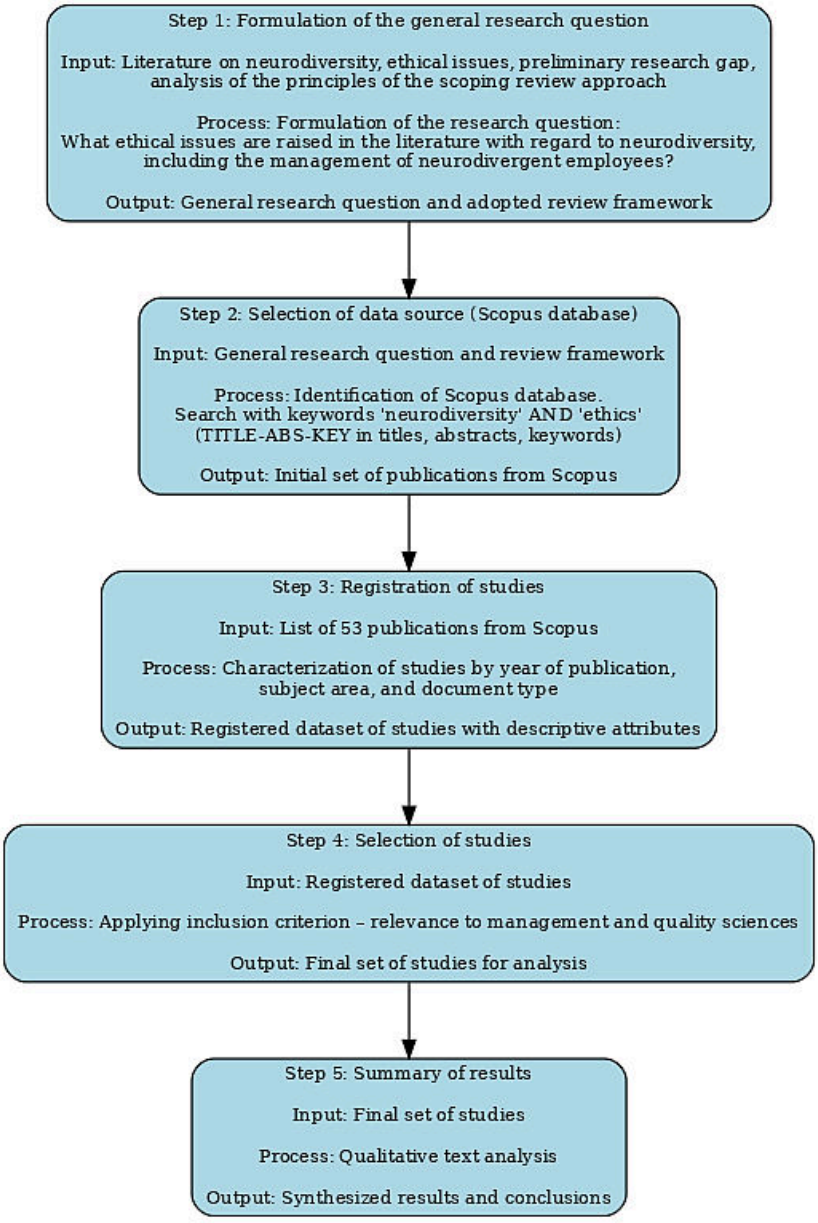

Figure 1. Procedure of the Conducted Scoping Review of the Literature.
Source: (Ćwiklicki, 2020).

The starting point of the adopted procedure was the formulation of a broadly framed research question aligned with the first objective of the study, which is considered characteristic of the scoping review approach. Furthermore, in articulating the research question, the requirement of employing "defined concepts, including the context and discipline that allow for the precise specification of the intended meaning of terms" was satisfied (Ćwiklicki, 2020, pp. 60-61). The Scopus database was selected due to the high quality of its indexed resources (Rollnik-Sadowska, Grabińska, 2024). The literature search was conducted using the keywords *neurodiversity* and *ethics*, combined with the Boolean operator (AND) within titles, abstracts, and keywords (TITLE-ABS-KEY). This procedure yielded a total of 53 documents, of which as many as 43 were published from 2022 onwards. This outcome underscores both the topical relevance of the issue and the dynamic increase in scholarly interest. An analysis of the thematic

distribution of results indicates that the largest share (23.9%) falls within the field of medicine, followed closely by social sciences (21.1%). Psychology ranks third, accounting for 13.8% of the publications, while the remaining subject areas are represented only sporadically. This distribution further substantiates the appropriateness of the scoping review as the chosen method of analysis (Ćwiklicki, 2020). The majority of the retrieved works were journal articles (56.6%), followed by book chapters (13.2%) and reviews (13.2%). The studies identified through the search were subsequently examined for their relevance to the focus of this article, particularly in relation to management and quality sciences, based on their keywords and abstracts. The qualitative content analysis of the selected texts is presented below, preceded by a definitional framing of the concept of neurodiversity and a characterization of the current state of research in the discipline.

The concept of *neurodiversity* - with reference to the equality-oriented notion of "neurological pluralism" promoted by online communities of individuals on the autism spectrum - was first introduced by the Australian sociologist J. Singer in her correspondence with the journalist H. Blume. In 1998, Blume subsequently wrote in *The Atlantic*: "Neurotypicality is just one type of mind, and when it comes to working with advanced technology, it may in fact be an inferior type (...); neurodiversity may be as crucial for the human race as biodiversity is for life itself; who can determine which type of mind is best suited to a particular situation?" (Silberman, 2021, p. 441). At present, the concept of neurodiversity extends beyond the autism spectrum to encompass other neurodevelopmental differences, such as attention-deficit/hyperactivity disorder (ADHD), Tourette's syndrome, dyslexia, dyspraxia, dyscalculia, among others. As a perspective on neurological and neurodevelopmental differences, this concept - contrary to the medical model - emphasizes the strengths of neurodivergent individuals, grounded in the conviction that they should not be regarded as "deficits or dysfunctions, but rather as naturally occurring forms of cognitive mechanisms characterized by specific advantages that contribute to technological and cultural development" (Silberman, 2021, p. 23).

In the management and quality sciences literature, a shortage of research devoted to neurodiversity has been identified, particularly with regard to the employment of neurodivergent individuals in organizations (Whelpley, Perrault, 2021), as evidenced by the limited scope of existing studies on neurodiversity (Doyle, McDowall, 2021). This may be associated with the extremely low employment rates of neurodivergent individuals in organizations (Krzemińska et al., 2019), primarily linked to difficulties in sustaining long-term employment (Mellifont, 2019). The unemployment rate among people on the spectrum has remained persistently high, reaching as much as 90% in both the European Union and the United States (Gerhardt, Lainer, 2011, p. 39). Scholars have also pointed to the insufficient adaptation of human resource management practices to the specific needs of these individuals (Wehman et al., 2016). This concern is particularly evident in relation to tailoring leadership styles to the individual needs of employees on the autism spectrum (Austin, Pisano, 2017),

as well as management practices directed toward individuals with learning difficulties (Sumner, Brown, 2015). Empirical findings suggest that this phenomenon is largely attributable to employers' limited awareness and the challenges they encounter in recruiting and retaining autistic employees. It has been emphasized that sustaining satisfactory employment among individuals with autism necessitates the provision of an environment characterized by diversity, psychological safety, and inclusive leadership (Muhammad et al., 2023; Vogus, Taylor, 2018, pp. 514-516). The literature suggests that a strong culture of organizational identification can pose challenges to the implementation of diversity practices, since deep engagement with the organization is often linked to a diminished willingness to recognize and acknowledge the need for such initiatives (Guisard et al., 2025). With respect to the leadership, empirical studies conducted among employees of Australian public sector organizations have indicated that emotional engagement and sustained participation in neurodiversity initiatives are, among other factors, contingent upon the perceived support of supervisors (Spoor et al., 2021). Direct insight into the experiences of both autistic individuals with an employment history and individuals who have managed autistic individuals in the workplace demonstrates, in the context of relations between these two groups, the importance of managerial support (Whelpley et al., 2021). At the same time, it has been shown that for first-line managers "adjustments deemed essential to support neurodiverse employees require a myriad of hidden, complex, time-consuming and often emotionally draining interactions with disabled employees, the employee's wider team, HRM and occupational health (OH) practitioners" (Richards et.al., 2019, p. 1903). Case studies demonstrate that top management support for neurodiversity practices enhances the capacity to achieve competitive advantage (Whelpley, Perrault, 2021). Despite the widespread recognition of the importance of workforce diversity, management practice continues to lack coherent and systematic actions in this area. While 95% of CEOs report an intended focus on diversity, equity and inclusion (DEI) in the coming years, evidence shows that 40% still lack a DEI strategy, and 25% have yet to implement DEI objectives (Hawkins, 2022). It is also worth emphasizing that a conceptual model has been developed which articulates how cognitive characteristics associated with neurodiversity (i.e., sensitivity and attention to detail, pattern recognition, visual thinking, and the need for structure and routine) may lead to task-based leadership behavior and traces the influence of such behaviors on both leader and follower outcomes (Roberson et al., 2021). In light of the unique psychological profiles of neurodivergent employees, and the challenges they experience in terms of social interaction and organizational integration, researchers have explored the potential use of digital technologies (Walkowiak, 2021). With respect to the ethical dimensions of treating neurodivergent individuals, attention has been given to the risks of stereotyping (Whelpley et al., 2021; Priscott, Allen, 2021), the prevention of workplace harassment (Mellifont, 2020), and the need to provide adequate support (Richards et al., 2019).

Beliefs regarding the ethicality of neurodivergent individuals are, among other factors, informed by neurocognitive theoretical explanations, including the theory of mind, according to which autistic individuals are assumed to possess deficits that hinder their ability to understand others' perspectives (Hens et al., 2019). Extending the theory of mind hypothesis, some scholars have argued that individuals with autism display difficulties not only in interpreting the mental states of others but also in recognizing their own (Baron-Cohen et al., 1985, Frith, Happe, 1999). For a considerable period, research on autism was dominated by the belief that autistic individuals were even devoid of emotions (Mundy, 2009). Within this line of thought, the following view was also expressed regarding the inability of autistic individuals to achieve a "full life": *the absence of theory of mind dramatically affects the ability of the autistic individual to live a full life regardless of societal intervention* (Barnbaum, 2008).

It is worth noting that claims derived from the theory of mind do not differentiate among individuals across the full autism spectrum, assuming instead that they share identical deficits. In contrast, theories positing that individuals diagnosed with autism are incapable of experiencing emotions or empathy have been challenged both by autistic individuals themselves (Pentzell, 2013, as cited in Hens et al., 2019), and by psychologists who distinguish multiple forms of empathy (Blair, 2005; Bollard, 2013, as cited in Hens et al., 2019). For example, according to the Empathy Imbalance Hypothesis (EIH) in autism, autistic individuals score low on cognitive empathy while simultaneously achieving very high scores on affective empathy - making them so sensitive to others' feelings that they may, at times, shield themselves from them (Smith 2009, as cited in Hens et al., 2019). Similarly, the "double empathy problem" highlights the bidirectional mismatch between autistic and non-autistic individuals in the cognitive and communicative domains, leading to a breakdown of reciprocity and mutual understanding (Milton, 2012). It should therefore be acknowledged that the relationship between empathy and autism is complex and that autistic individuals vary in their empathic capacities in much the same way as neurotypical individuals do (Praslova, 2021). Furthermore, in light of recent research, neurodivergent individuals - particularly those on the autism spectrum - demonstrate emotional lability, which underscores the necessity of providing emotional support (Prizant, Fields-Meyer, 2017), thereby challenging earlier claims that they lack emotional expression.

Contemporary scholarship also challenges the assumption that there exist objective criteria for evaluating individual quality of life, advocating instead for the adoption of autistic individuals' own perspectives and for granting them the right to define life achievements and subjective well-being as meaningful from their standpoint. Consequently, the quality of life of these individuals should be assessed, at least in part, in terms of the extent to which lived experience aligns with personal aspirations. This approach is grounded in the recognition of dignity, agency, and respect for all individuals, including the neurodivergent (Pellicano, Heyworth, 2023) and, in the Author's view, constitutes an expression of the ethics of their treatment.

Beyond the unfounded assumption of a lack of empathy and emotionality among autistic individuals, other stereotypes concerning neurodivergence remain deeply entrenched. One mechanism that reinforces the negative perception of neurodivergent individuals is the pathologization of their strengths and positive attributes. Praslova (2021) refers to the results of a study in which autistic participants, unlike their neurotypical counterparts, behaved with consistent ethicality regardless of whether they were being observed. The moral consistency of autistic participants was interpreted as a moral deficit - a pathology. Objections raised by the autistic community led to revisions of the research report, although much of the "pathologizing language" remained.

In light of numerous irregularities in the conceptualization of the ethicality of neurodivergent individuals, the literature highlights the legitimacy of establishing a distinct research domain within philosophy, referred to as the ethics of autism. Within this domain, scholars advocate for addressing ethical questions concerning, among others (Hens et al., 2019):

- understanding autism not as a disease or disorder but as a neurological identity or personality trait, and embracing and valuing the worldview of autistic individuals,
- considering whether only autistic individuals can truly define the scope and aims of autism research, and consequently how social practices can be organized to adequately understand them,
- recognizing the value of autistic testimony and its influence on policy formation, including the experiences of individuals who do not rely on verbal communication,
- taking into account the cultural representation of the term "autism" its meaning, and its portrayal in media, literature, and art,
- addressing the globalization of the concept of autism and the transfer of its Western interpretation into other cultural contexts,
- examining the rights and responsibilities of parents in connection with a child's autism diagnosis, as well as the scope of interventions aimed at improving the child's functioning,
- ensuring social justice that reflects the complexity of autism and entails practical support from social, economic, political, educational, and labor market institutions,
- assessing the ethical implications of the heterogeneity of autism concepts with regard to granting autonomy in light of social justice assumptions and the idea of paternalism.

According to its proponents, this program of the ethics of autism may be informed by insights from the more established literatures on disability ethics, bioethics, the philosophy of psychiatry, moral psychology, metaethics, normative ethics, as well as social and political philosophy, in addition to public health, medicine, and the social and behavioral sciences. At the same time, the ethics of autism cannot be reduced to a case study in which insights from these other fields are simply applied; rather, it requires the direct participation of autistic individuals and active engagement with them (Hens et al., 2019).

In characterizing autistic ethics, Stenning (2020) draws on Greta Thunberg's autobiography *No One Is Too Small to Make a Difference* (2019) and Temple Grandin's *Animals in Translation* (2005). In her work, she emphasizes that autistic ethics extend not only to other human beings but also to animals and non-human entities, while simultaneously cautioning against the risk of perceiving autistic individuals as somehow closer to nature (Stenning, 2020, as cited in Nygren, 2023). Building on this perspective, Nygren (2023) argues that the autistic orientation toward more-than-human relations can be interpreted both as an act of resistance and as an alternative mode of expressing empathy.

Current scientific research in the field addressed by this article also engages with the ethical dimensions of early autism care (Vanaken et al., 2024), emphasizing the necessity of direct insight into the lived experiences of autistic individuals and their close relatives, and the value attributed to such experiences for advancing knowledge about the condition. In this literature, autism is portrayed as a developmental phenomenon, which entails recognizing the multilayered meanings of the condition in relation to how it is experienced and perceived by individuals on the spectrum. Aligning explanatory models with the experiences of autistic persons may help to prevent various ethical dilemmas (Hens, 2021). Conversely, studies designed and interpreted exclusively from neurotypical assumptions - without incorporating the perspectives of neurodivergent individuals - may hinder the understanding of autistic cognition and impede their employment opportunities (Bernard et al., 2023). Within autism research, ethical frameworks have been proposed to guide the evaluation of specific intervention goals (Ne'eman et al., 2023). Furthermore, scholars argue that avoiding moral dilemmas requires a redefinition of autism, grounded in the recognition of autistic experience as central (Bervoets, Hens, 2020). Research linking ethics and neurodivergence has also examined how mothers' orientation toward an "ethics of care" influences their understanding of experiences of violence perpetrated by a neurodivergent child (Holt, 2024, p. 824). Within the management and quality sciences literature, however, these issues have been shown to be almost entirely overlooked. These considerations further reinforce the legitimacy of addressing the ethical aspects of managing neurodivergent employees in empirical research.

3. Methodological Assumptions of the Planned Empirical Research

Based on the analysis of the relevant literature, an exploratory gap was identified that necessitates the conduct of empirical research. This gap concerns managerial perceptions of the ethicality of neurodivergent employees' conduct, as well as the ethicality of their treatment in the workplace. The planned study will therefore not evaluate the employer's ethical behavior but rather the perception of employee ethicality as seen through the eyes of organizational managers.

Given the preliminary stage of research on the ethics of neurodivergent individuals, as well as the scarcity of studies in management and quality sciences that address the concept of neurodiversity, it was deemed necessary to situate the research questions within the well-documented domain of diversity management. Diversity management is understood as a process of "continuously discovering people and their contributions, as well as the value they can bring to the organization and society" (Gross-Gołacka, 2018, p. 10). This assumption is based on the premise that managers - who are presumed to have greater awareness of other dimensions of employee diversity such as age, origin, or culture - will find it easier to situate issues of neurodivergent employees' ethicality in this broader context. Furthermore, it was considered important to determine which dimensions of workforce diversity managers encounter in practice and on what basis they infer employee neurodivergence (formal diagnosis, observation of employee behavior). In this regard, managers whose teams do not include neurodivergent employees will also be invited to participate in the study. For these respondents, the questionnaire will include a brief description of neurodivergent conditions. Their perspectives may also prove valuable, offering insights into the state of awareness, prevailing beliefs, and perceptions of neurodivergent employees' ethicality.

Taking these premises into account, the following research questions were formulated:

1. In the opinion of organizational managers, does employee ethical conduct in professional and personal life depend on dimensions of diversity?

This question refers to whether managers perceive differences in ethicality depending on dimensions of diversity such as age, gender, origin, race, religion, culture, gender/sexual identity, and neurodivergence (autism spectrum, ADHD, learning difficulties, dyspraxia, Tourette's syndrome, etc.).

Having contextualized neurological differences alongside other dimensions of workforce diversity, a key step in understanding managerial perceptions of neurodivergent employees' ethicality is to verify whether, in their opinion, particular conditions influence the development of ethical competencies, and if so, how.

2. Do managers perceive neurological difference as influencing the development of employees' ethical competencies? If so, which differences (autism spectrum, ADHD, dyslexia, dyscalculia, dysgraphia, dyspraxia, Tourette's syndrome, etc.) and in what way?

The literature identifies the support of human dignity and the development of all individuals as a fundamental ethical principle in the treatment of neurodivergent persons. Dignity is described as "the value of values" and is considered central, inalienable, inherent, and permanently attributed to every human being (Mazurek, 1995, p. 754). The unconditional respect for dignity should underlie the motivation to employ neurodivergent individuals; without it, the business case for diversity is insufficient. In this context, a lack of workplace integration violates the principle of fair treatment (Praslova, 2021). Moreover, direct accounts of autistic individuals emphasize their declared empathic respect toward others - often grounded

in experiences of being outsiders - and their orientation toward equal treatment: *there is an autistic tendency to value all people equally* (McCowan et al., p. 372). Drawing on these insights, two further research questions were formulated:

3. In the managers' opinions, does an employee's neurological difference influence their respect for the diversity of coworkers? If so, which conditions (autism spectrum, ADHD, dyslexia, dyscalculia, dysgraphia, dyspraxia, Tourette's syndrome, etc.) and in what way?
4. Do managers perceive that an employee's neurological difference requires a different managerial approach compared to other employees? Does this raise an ethical dilemma related to ensuring equal (fair) treatment of all employees?

According to insights from the literature, responsibility occupies a central place in the moral experience of every human being and is, in a sense, equated with humanity itself (Galarowicz, 1993, as cited in Furmanek, 2013). Responsibility is seen as evidence of maturity, involving the understanding of the consequences of one's actions, bearing their outcomes, fulfilling duties to the best of one's ability, and acting with courage but above all prudence (Tischner, as cited in Furmanek, 2013). It may therefore be considered crucial for the proper performance of professional responsibilities. At the same time, as other scholars note, theories of moral responsibility do not sufficiently explain why autistic individuals, unlike neurotypical persons, are sometimes exempted from responsibility for actions that transgress social or legal boundaries (Stout, 2016). In seeking explanations, researchers have pointed out that autism is often framed as a deficit in cognitive and emotional functions, which are central to theories of moral responsibility (Hens et al., 2019), and that the theories themselves may be flawed (Richman, Bidshahri, 2018). In light of these considerations, the following research question was posed:

5. According to managers, does an employee's neurological difference affect their sense of responsibility? If so, which conditions (autism spectrum, ADHD, dyslexia, dyscalculia, dysgraphia, dyspraxia, Tourette's syndrome, etc.) and in what way?

Direct insight into the perspectives of autistic individuals reveals their particular openness, honesty, strict adherence to rules, and pursuit of social justice, all of which are recognized as expressions of integrity: *Such actions are grounded in our prevailing sense of honesty and fairness* (McCowan et al., p. 372). This dimension is captured in the following research question:

6. In managers' views, does an employee's neurological difference influence their honesty? If so, which conditions (autism spectrum, ADHD, dyslexia, dyscalculia, dysgraphia, dyspraxia, Tourette's syndrome, etc.) and in what way?

The ethical values embedded in these research questions - dignity, responsibility, and honesty - simultaneously represent criteria of ethical competencies recognized as vital in the context of the challenges of the contemporary economy (Raś et al., 2024).

Perceptions of neurodivergent employees' ethicality, however, do not exhaust the broader issue of the ethical dimensions of managing such employees in the workplace. The literature has drawn attention to the unethical treatment of atypical individuals in both historical and contemporary contexts, where norms established by and for non-autistic communities have led to the stigmatization and exclusion of neurodivergent persons as consumers, advocates, and citizens, thereby depriving them of human rights (Dawson). Against this backdrop, it is equally crucial to determine how managers perceive the ethics of treating neurodivergent employees by their colleagues. The corresponding research question is as follows:

7. According to managers, what constitutes the ethics of how neurologically different employees (autism spectrum, ADHD, dyslexia, dyscalculia, dysgraphia, dyspraxia, Tourette's syndrome, etc.) are treated by other employees within the organization?

These questions do not exhaust the full scope of ethical issues in managing neurodivergent employees but, as intended by the Author, serve as a point of departure for further inquiry and analysis in this area.

4. Conclusion

Early literature on autism and neurodivergence, particularly from the 1980s and 1990s, was dominated by deficit-oriented frameworks, often emphasizing presumed limitations in empathy, responsibility, and social functioning. These perspectives contributed to the stigmatization of autistic individuals and reinforced managerial practices that pathologized difference. Over time, however, scholarship has shifted toward recognition of neurodiversity as a dimension of human variation, informed by autobiographical accounts, critical disability studies, and organizational diversity research. Contemporary studies highlight the ethical dimensions of inclusion, focusing on dignity, agency, and fairness in the treatment of neurodivergent employees. Yet, despite the growing visibility of neurodiversity in psychology, medicine, and the social sciences, research within management and quality sciences remains scarce. This gap underscores the need for systematic inquiry into managerial perceptions of the ethicality of neurodivergent employees and the ethical frameworks that shape organizational practices in increasingly diverse workplaces.

The originality of this study lies in linking two highly topical yet insufficiently explored themes within the field of management and quality sciences: neurodiversity and the ethics of employee conduct. The joint treatment of these issues has been pursued through a Scoping Review of the literature and the formulation of research questions addressing managerial perceptions of the ethicality of neurodivergent employees and their treatment within organizations. The Author's contribution thus consists in systematizing the existing findings

from various disciplines on the ethical aspects of neurodivergence and situating them within the perspective of organizational management.

Acknowledgements

The article presents the results of the Project no. 058/ZJP/2025/POT financed from the subsidy granted to the Krakow University of Economics.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

ANALYSIS OF ECONOMIC EFFECTS AND POSSIBILITIES OF REDUCING CO_2 IN AN INDUSTRIAL THERMAL TREATMENT SYSTEM

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Purpose: The purpose of this article is to present the possibilities for the metallurgical industry to reduce burning gas consumption and thus reduce CO_2 emissions, which is a very important aspect at the moment.
Design/methodology/approach: This article presents the potential for reducing CO_2 emissions (in industrial burner systems for metallurgical heat treatment furnaces), which is currently highly desirable technologically and economically. The obtained results are the result of preliminary numerical modeling and subsequent laboratory tests.
Findings: The study determined that solutions that increase the preheat temperature of the combustion air supplied to the burners will have the greatest impact on reducing CO_2 emissions. Other elements also contribute to reducing CO_2 emissions, but on a comparative scale, they have less significant limitations and will not be considered in this publication.
Originality/value: For many years, recuperator-type air heaters have been used, and material particles discharged with exhaust gases have been observed to accumulate on their surfaces. These particles, bonding with the recuperator surface, increase thermal resistance, which results in a decrease in the heat transfer coefficient and reduced combustion air preheating. The originality of this topic is shows the extent to which this phenomenon affects the achieved combustion air preheating.
Keywords: reduction of CO_2 emissions, recuperator, compact gas burner regenerator, environmental protection.
Category of the paper: research paper.

1. Introduction

In the analysis of gas-fired furnaces, CO_2 emissions are primarily related to the amount of gas burned. For large industrial facilities (e.g., metallurgical furnaces 15-20 meters long and powered by 20-40 burners), switching to electricity, which is considered environmentally friendly, is either impossible or uneconomical.

Important parameters that also influence the reduction of CO_2 emissions are the excess air coefficient in the combustion process and the pressure in the furnace, which causes the exhaust gases to be expelled through leaks or by drawing in external air, changing the technological parameters and the burner system must cope with such disturbances – which usually results in excessive combustion of the gas fuel and is associated with excessive CO_2 emissions.

The presented parameters (air excess coefficient and pressure in the furnace chamber) influence the reduction of CO_2 emissions from the combustion of gas fuel in the burner by approximately 5-10%.

A recuperation system based on a tubular heat recovery unit is significantly more effective in reducing CO_2 emissions. It is simple and inexpensive compared to other type this systems. However, this solution only works effectively at the initial stage of installation (providing the highest heating). This is because in this type of heat recovery unit, the tubes are exposed to pollutants in the exhaust gases, which settle on them and reduce the heat transfer coefficient. This phenomenon results in a lower combustion air preheating temperature. This results in increased fuel combustion to maintain the furnace's process temperature (Puszer et al., 2021; Tomeczek et al., 2021; Gitzinger et al., 2010).

According to literature sources, tubular recuperators (metal or ceramic) enable heating of combustion air (i.e. recovery of thermal energy from exhaust gases) up to 500-600°C with an exhaust gas temperature of 1200°C.

The basis for process efficiency is achieving the highest possible combustion air preheating temperature, i.e., recovering as much thermal energy as possible from the exhaust gases. This reduces the amount of fuel supplied to the technological process and, consequently, CO_2 emissions.

The best solution for metallurgical furnaces fueled by gas burners is the use of regenerative systems. This type of solution can provide a much higher level of combustion air under the tree, resulting in a significant reduction in the chemical energy of the fuel and a significant reduction in CO_2 emissions (Ankel et al., 1987; Hasegawa et al., 2000; Fukushima et al., 2002; Georgiew, 2007).

Burner regenerators are characterized by an alternating fluid flow direction (exhaust gases - air) and are therefore not subject to such significant deposition of pollutants and reduction of the thermal energy transferred to the heated air.

With the appropriate design of burner regenerators, it is possible to obtain air heating close to (approx. 7-10% less) the exhaust gas temperature.

2. Sediments in the heat recovery system – tubular heat recovery unit

The main problem in heat recovery systems is the formation of a layer of deposits on the outer surface of the pipes, which affects the performance of these devices, i.e., increasing the resistance to exhaust gas flow in extended pipe bundles and decreasing the air preheat temperature.

The results of the tests on recuperators and the developed relationships, which allow for determining the thermal parameters of recuperators that are systematically contaminated during their operation, can be used in diagnostics and in the design of their structures for industrial furnaces.

The economics of recuperator use depends on properly solving design and operational challenges that contribute to achieving high efficiency. Recuperators constructed from extensive tube bundles are used in the exhaust gas ducts of industrial furnaces. The intensive heat flow from the exhaust gases through the tube walls allows for high-temperature heated combustion air and significant fuel savings. Exhaust gases discharged from the working spaces of metallurgical furnaces carry very fine dust, primarily particles of insulating materials and scale, which settle on the outer surface of the recuperator tubes (Figure 1a). The extent of this phenomenon depends on the type of insulating materials used, the tube bundle configuration, and the geometry of the exhaust gas extraction system. This significantly increases heat flow resistance and reduces the heat flux transferred in the recuperator (Fukushima et al., 2002; Georgiew et al., 2007; https://www.fivesgroup.com/energy-combustion). In the case of bundles with small inter-tube spacing, there is also a significant increase in exhaust flow resistance (Figure 2b).

a) b)

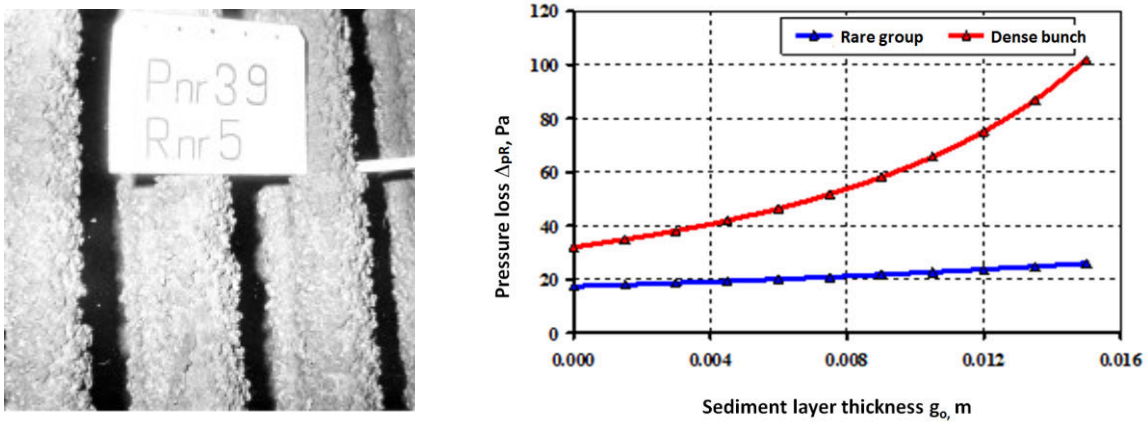

Figure 1. Recuperator pipes with deposits: a) recuperator pipes; b) exhaust gas pressure loss.

Dust in the exhaust gases positively affects the intensity of radiative heat flow in the recuperator, but the systematically growing layer of deposits from the beginning of the recuperator's construction increases the thermal resistance of the contaminated wall and,

as a result, lowers the temperature of the heated air (Figure 2). This phenomenon ultimately leads to a deterioration of the energy and economic parameters of the furnaces and causes difficulties in their operation.

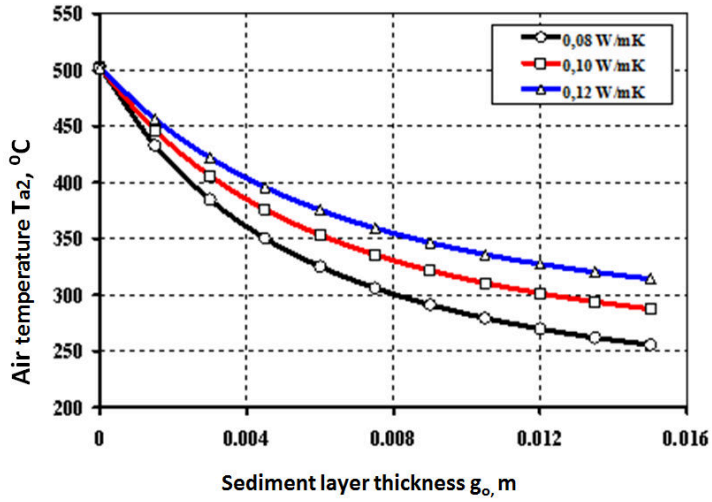

Figure 2. Temperature of heated air T_{a2} in the recuperator with deposits.

Proper design of substrate and combustion product flow systems requires accurate calculations of their temperatures and pressure losses in recuperators. The impact of deposits on heat transfer and gas dynamics in recuperators intended for long-term operation should be considered in the design calculations for these devices. Identifying the parameters of deposits deposited on recuperator tubes allows for more reliable calculations of these devices.

During the tests, it was found that the exhaust gas flow in the exhaust gas channels is characterized by significant disturbances, causing instability of the measured pressure values. The results of tests on laboratory tubular recuperators and metallurgical furnaces, as well as the analysis of various data on pressure losses in recuperator tube bundles, allowed us to determine the relationship for determining the resistance number λ_{fr}.

$$\lambda_{fr} = 2{,}1 \cdot K_p^{-0,1} \cdot Re_s^{-0,1} \tag{1}$$

for pipe bundles with parameters S_1/d_z and S_2/d_z of 1.5-3.5, in which the pipe bundle design parameter K_p is determined as:

$$K_p = \frac{S_1 \cdot S_2}{d_Z^2} \tag{2}$$

and it depends on the outer diameter of the pipes d_z and their spacing within row S_1 and between rows S_2.

Determining the resistance number λ_{fr} (1) is necessary to determine the exhaust gas pressure loss in the recuperator Δ_{psR} (Figure 1).

3. Heat flow studies

The scale of the phenomenon of the build-up of a layer of deposits impairing heat transfer was identified by measurements in several dozen recuperators of pit furnaces.

Operational measurements of the effects of long-term operation of recuperators have shown a very significant effect of increasing the thickness of the deposit layer on lowering the temperature of the heated air. Changes in heat transfer conditions and gas dynamics on the exhaust side of pipes with increasing thermal resistance of deposits significantly influence changes in the heat transfer coefficient k.

Practical experience with these devices shows that a significant drop in air temperature of approximately 100°C occurs after approximately 1.5 years of operation. Measurements of the heat recovery units in the flue gas ducts allow us to determine the average thickness of the deposit layer on the pipes of the considered heat recovery units after approximately 3-4 years of operation at 4-6 mm.

The analysis of the collected source information and the results of the recuperator tests allowed us to determine the dependence of the change in the ratio of heat transfer coefficients $n_k = k/k_{rn}$ on their operation time t for the considered cases of using these devices in heating furnaces

$$n_k = e^{-C \cdot t} \tag{3}$$

in which for recuperators of pit furnaces C=0.28 yr^{-1}, and for recuperators of pusher furnaces C=0.12 yr^{-1}. Measurement data of recuperators allow determining the changes in the ratio of the thermal resistance of the pipe wall ro with a layer of deposits of thickness so to the thermal resistance r_m of a clean metal wall of thickness s_m, occurring over time (0). Assuming for calculation purposes $r_m=s_m/\lambda_m=0.0002$ m^2K/W, the relationship was established

$$\frac{r_o}{r_m} = C \cdot t \tag{4}$$

in which: for recuperators of pit furnaces C = 74 yr^{-1}, for recuperators of pusher furnaces C = 48 yr^{-1} and $r_o = (s_m/\lambda_m) + (s_o/\lambda_o)$.

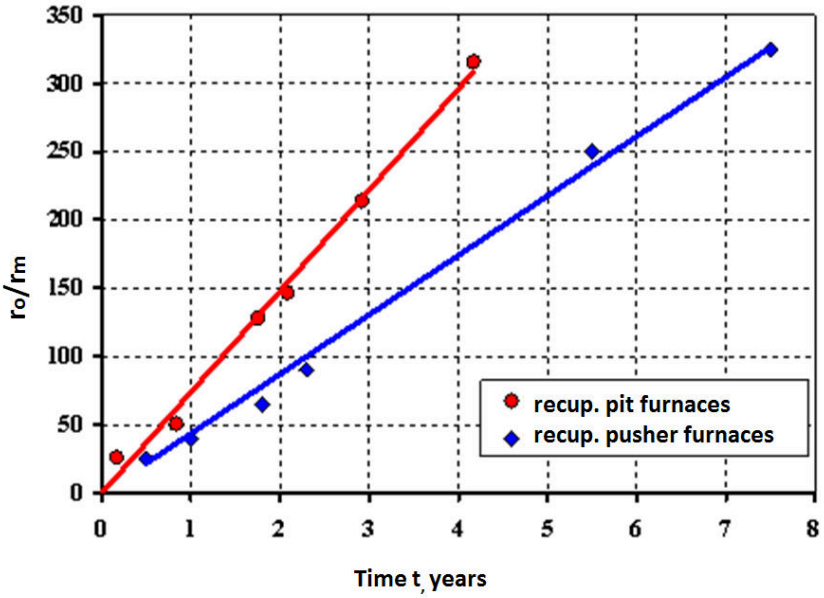

Figure 3. Thermal resistance measurements of pipes with deposits.

The physical properties of the solid and gas components of the porous sediment layer show that their thermal conductivity increases with temperature and density. Taking this trend into account, a relationship was formulated for calculating the thermal conductivity coefficient λ_O of the sediment (5).

$$\frac{\lambda_O}{\lambda_g} = \left[1 + 0{,}018\left(\frac{T_o}{T_n}\right)^{0,8}\left(\frac{\rho_o}{\rho_{ng}}\right)^{0,78}\right] \tag{5}$$

where: λo is the density of the sediment layer at temperature T_o expressed in K.

For calculation purposes, the gas parameters under standard conditions were assumed:

λ_{ng} = 1.3 kg/m^{3}N, λ_g = 0.0234 W/mK, and T_n = 273 K.

The given equations (4) and (5) can be used to calculate recuperators for metallurgical heating furnaces, such as pusher furnaces. For the assumed service life of these devices, the thickness and conductivity coefficient of the deposit layer λo deposited on the tube surface can be determined. Their values can be varied depending on the relative distances between the tube bundle elements (e.g., tube rows or modules), assuming in equation **Błąd! Nie można odnaleźć źródła odwołania.** that the initial element is C = 60 yr^{-1} and the final element is C = 36 yr^{-1}. For pit furnace recuperators, the given C parameter values can be increased by 25%.

4. Summary of problems related to sediment in the recuperation system

The design problem is to calculate the exhaust gas flow resistance in the extended tube bundles and determine the exhaust gas pressure losses. An important issue is to determine the heat flow and thermal conductivity of the deposits based on measurements of the deposit layer thickness and parameters, as well as to identify the temperature drop due to air heating.

A tubular heat recovery unit is a relatively simple structure. As the name suggests, it consists of a bundle of tubes made of various types of steel or ceramic. Ceramics can achieve higher air heating rates, but contamination deposited on the tube walls makes cleaning this structure very difficult, potentially damaging the structure, which in such cases would result in very high repair costs.

5. Burner regenerators system

In industrial heating furnaces with gas-fired burners, the most important control parameter is the process temperature. Due to high energy prices, efforts are being made to reduce gas fuel consumption by optimizing the efficiency of heating devices. One way to reduce gas fuel consumption is to optimize control processes 1 and 11. Using effective combustion air preheating methods is one way to significantly reduce fuel consumption in metallurgical thermal processes.

Regenerative systems are the most efficient, considering the temperature of the heated air. The latest burner designs can achieve air heating temperatures above 1100ºC, with exhaust gas temperatures reaching 1200ºC.

Currently, modern multi-burner furnace firing systems use individual air preheaters for each burner. One possible solution involves attaching these preheaters to the burners (0) or using individual regenerators housed in a single housing with the burner (https://www.fivesgroup.com/energy-combustion; https://www.bloomeng.com; Manatura, Tangtrakul, 2010; Wnęk, 2014).

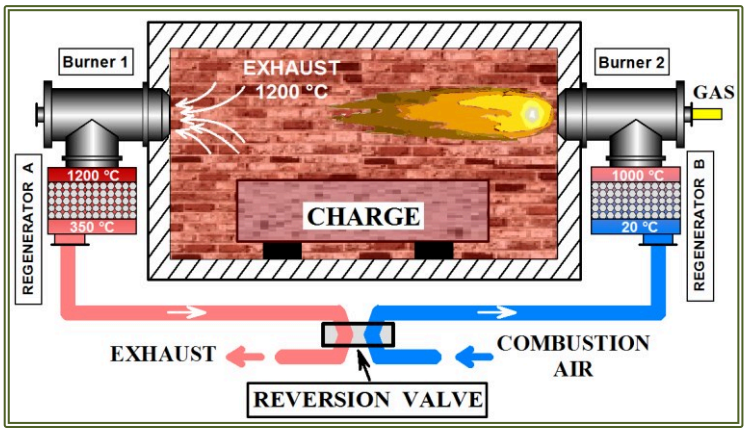

Figure 4. Operation diagram of compact regenerative burners.

6. Computer-aided regenerator selection

The scope of the work involved determining a set of ceramic materials suitable for producing regenerative packing, and one of them was selected (0). The regenerator's design parameters were selected based on, among other things, the assumed burner power, and the geometric dimensions of the regenerative packing structure were determined with a view to intensifying heat transfer. The heat regenerator packing structure was selected for a low-power burner of 20-50 kW, fueled by natural gas, assuming an excess combustion air ratio of 1.05-1.1 (air flow rate of approximately 26-68 kg/h). Numerical modeling using proprietary Reg-Optimum software was used to determine the key structural dimensions of the regenerator packing (Wnęk, 2012).

The solution had to meet the following criteria: large heat transfer surface, minimum mass, and the highest possible ratio of heat transfer surface to volume (A/V)→ max. A solution that meets these criteria guarantees the possibility of achieving high combustion air preheating temperatures, thus reducing gas fuel consumption and limiting CO_2 emissions.

Table 1.
Properties of the regenerative filling material

Lp.	Regenerator material	Density ρ, kg/m^3	Thermal conductivity coefficient λ, W/(m K)	Specific heat capacity c_p, J/(kg K)	Volumetric heat capacity ρc_p, MJ/(m^3 K)	Diffusivity k·10^7, m^2/s	Melting point, ^{0}C
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	Aluminum trioxide	1900	0.6	500	0.95	6.6	2040

7. Research station

Experimental studies were conducted on a stand enabling analysis of the operation of one regenerator section (0, 0). The stand consisted of: a compact and metered regenerator, a heating chamber, a hot and cold fluid flow measurement system, and air supply and exhaust gas discharge systems. The measurement, control, and regulation system was managed by an industrial controller with I/O modules and a proprietary program written in the industrial LabView programming environment.

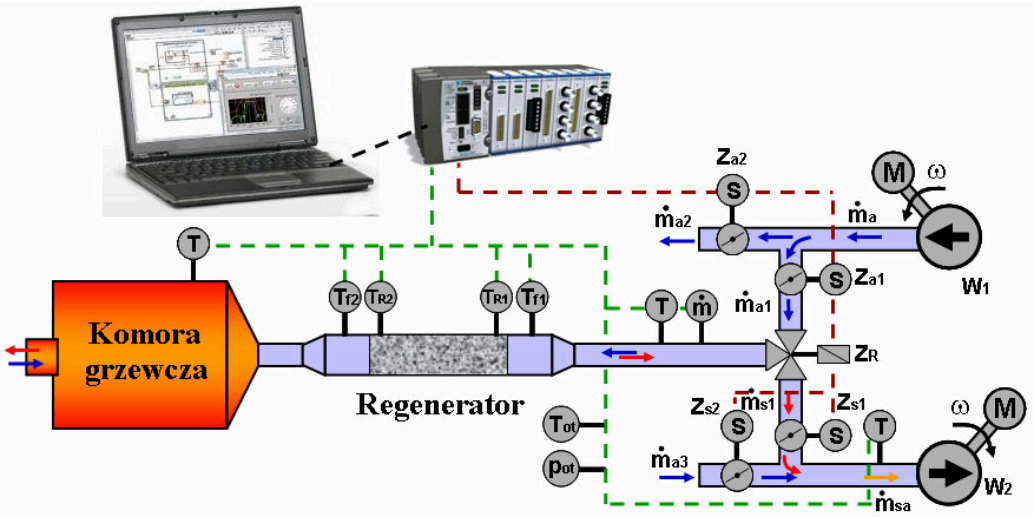

Figure 5. Schematic of the regenerator characteristics testing stand.

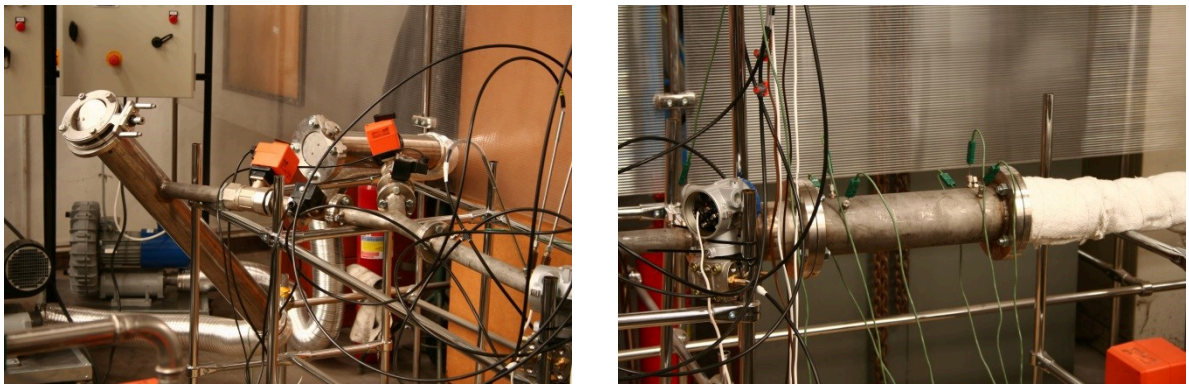

Figure 6. Gas burner regenerator test stand.

8. Research object

A regenerator made of Al_2O_3 (0) was used in the bench tests. The designed regenerator consisted of several segments, each 12 mm thick and 90 mm in diameter, with 325 circular flow channels each 3 mm in diameter.

The mass of the entire regenerative filling for the developed structure was approximately 3.7 kg and the coefficient (A/V) = 1320 m^2/m^3 (0) is comparable to the best solutions in the industry and presented in the world literature.

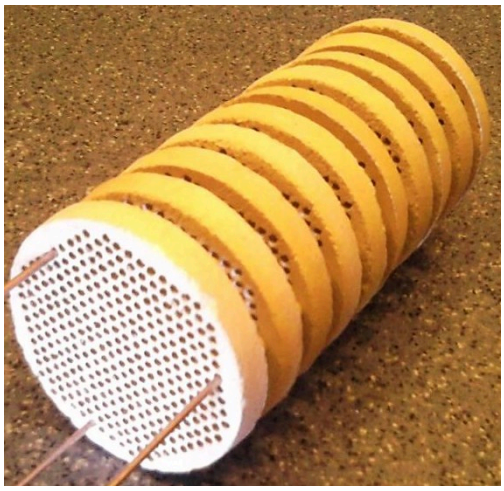

Figure 7. Ceramic filling of the burner regenerator.

9. Economic and environmental effects of using a regenerative system in industry

Selecting the right material for the regenerator fill to achieve high heated air temperatures is crucial. It is well known that increasing combustion air temperature leads to reduced fuel consumption and, at the same time, reduced CO_2 emissions.

The ability of a regenerator constructed from the selected material to achieve high air preheating (approximately 1100°C for exhaust gases at 1200°C), confirmed in bench tests, allows for significant savings in fuel consumption and, consequently, increases the efficiency of the heating furnace. An additional benefit is reduced CO_2 emissions, which is a very important environmental aspect.

The use of modern regenerative burners with the demonstrated combustion air preheating capabilities in a metallurgical heating furnace (with a capacity of 8.5 MW) resulted in a reduction in fuel consumption by over 30%, resulting in significant annual savings and avoiding the emission of over 4400 Mg of CO_2 per year, which has a significant and positive environmental impact (0).

Based on the test results, the regenerator's quality was assessed. The relative air preheating coefficient was calculated based on the air temperature at the regenerator outlet. It can be seen that it is approximately 95% – the average coefficient for a recuperation system is typically in the range of 30-40%. A high combustion system efficiency of approximately 86% was achieved. All obtained regenerator quality results indicate that the regenerator under consideration is an interesting solution, capable of significantly reducing fuel consumption and CO_2 emissions (https://enerad.pl/gaz-dla-firmy-jaka-taryfe-i-oferte-wybrac/).

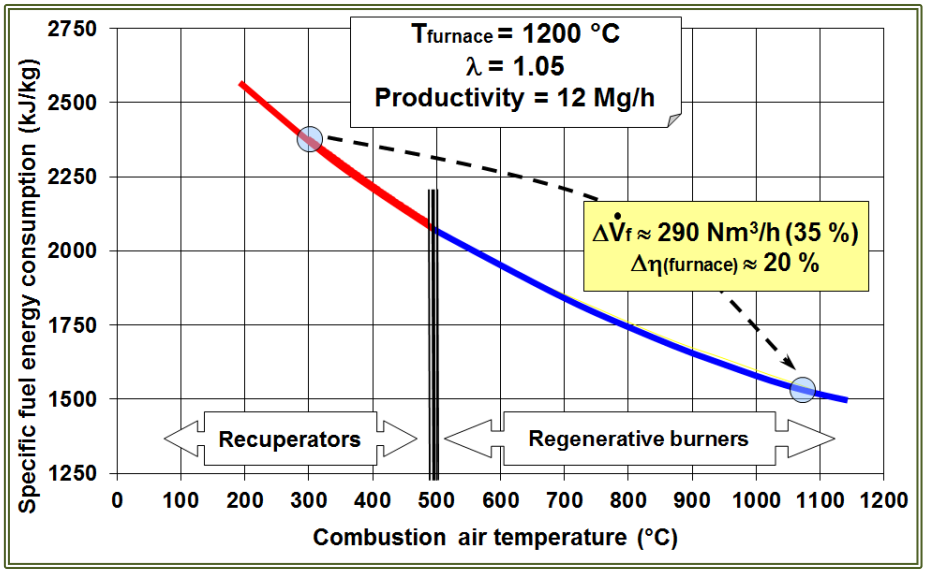

Figure 8. The fuel consumption as a function of the air preheat.

10.Conclusions

- A tubular recuperator is a simple solution for heating combustion air. However, the heating temperatures achieved differ significantly from the exhaust gas temperature, resulting in relatively low fuel consumption and, therefore, carbon dioxide emissions.
- Tubular heat recovery units can be difficult to clean due to the deposition of contaminants in the exhaust gases. It is easier to clean a heat recovery unit with a steel pipe system, but with a ceramic system, it is very difficult and can be damaged, which can result in high repair costs.
- Burner regenerators (individual and compact) are a much more efficient energy recovery system compared to a recuperative system. This solution allows for a much higher combustion air preheating temperature, which, for a well-designed regenerator, significantly approaches the exhaust gas temperature.
- Regenerators, due to their alternating operation, are not subject to such significant pollution as recuperators, it could be said that they are self-cleaning.

- Using a regenerative system allows for very high air heating temperatures, which significantly reduces fuel consumption and CO2 emissions (without changing the technological parameters of the process). This is a very attractive solution from an environmental perspective.
- Selecting the design parameters of the regenerator filling is not easy and computer support is necessary.
- Regenerators for low-power burners (up to 50 kW) were considered.
- The regenerator quality was checked. A relative fuel economy factor of approximately 0.5 was recorded. Relative air preheating factor and combustion system efficiency were achieved at levels of 95% and 86%, respectively. All factors achieved very high and satisfactory values. These values guarantee significant fuel savings and a reduction in CO_2 emissions.
- Using a regenerative system allows for very high air heating temperatures, which significantly reduces fuel consumption and CO_2 emissions (without changing the technological parameters of the process). This is a very attractive solution from an environmental perspective.
- Based on simulation tests, it was determined that the material intended for filling the regenerator should have properties that meet the following conditions: volumetric heat capacity $\rho c_p > 1$ MJ/(m^3 K), diffusivity k = (2-10)·10-7 m^2/s.
- The computer-aided selection of the regenerator design parameters indicated a solution that, in bench tests, confirmed the high temperature of the heated combustion air and thus reduced gas fuel consumption and a significant reduction in CO_2 emissions.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

INTERRELATIONSHIPS BETWEEN SELECTED INNOVATION DIFFUSION MODELS USING SYSTEM DYNAMICS

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Purpose: The aim of this publication is to identify the distinguishing features of innovation diffusion models. This objective will be achieved based on five innovation diffusion models found in the literature: the logistic curve, the Bass model, the source model, the contact model, and the contact-source model.
Methodology: System dynamics modeling using AnyLogic and AnyLogic Cloud will be applied for this purpose. To describe and compare the models, a series of simulations was carried out, which allowed us to answer six research questions concerning, among other things, changes in model characteristics under different coefficient values, the population of potential users, and the initial number of innovative technology adopters.
Findings: The outcome of this work is a more accurate understanding of diffusion models, which are usually presented as mathematical equations. This may serve as a useful tool for those involved in marketing and development activities in the process of creating organizational strategies.
Originality/value: This study introduces a novel application of system dynamics to compare and mathematically characterize five innovation diffusion models, focusing on how parameter variations influence their behavior. The approach offers fresh insights into model similarities, differences, and applicability, providing a stronger foundation for their practical use in research and management.
Keywords: simulation modeling, system dynamics, innovation diffusion models, mathematical descriptions of innovation diffusion.
Category of the paper: Research paper.

1. Introduction

Innovation plays a key role in the development and competitiveness of firms in a changing market environment. It is defined as the introduction of novelties or changes and encompasses not only advanced technologies but also various industries (Aslam et al., 2023; Szafranowicz, 2019). Three interrelated concepts can be distinguished: invention (absolute novelty), innovation (implementation of the invention), and imitation (dissemination of innovation) (Wasilewska, 2012). Contemporary approaches to innovation, such as open innovation, enable firms to draw from external sources of knowledge, thereby increasing their competitiveness. Innovation affects companies by enhancing their ability to adapt and survive in dynamic markets (Niedzielski, Henhappel, 2015). The introduction of innovation may also improve market position through collaboration with other entities (Karaś et al., 2021).

Innovation diffusion refers to the process by which new ideas, technologies, or practices spread within and across organizations over time, typically through communication channels among members of a social system (Dearing, Cox, 2018; Rogers, 1983). In organizational contexts, successful diffusion can lead to improved performance, competitive advantage, and greater adaptive capacity as innovations are adopted and integrated into operations (Hassan et al., 2024; Steiber et al., 2021). Diffusion is not always straightforward—it may be hindered by technological, social, and learning barriers as well as institutional and contextual factors such as infrastructure or organizational culture (MacVaugh, Schiavone, 2010; Vargo et al., 2020).

Innovation diffusion is essential for disseminating new technologies, practices, or ideas across societies and organizations, enabling progress and the tackling of complex challenges in many industries and domains. The process is relevant in numerous sectors, including healthcare, industry, mining, and the public sector (Cai et al., 2022; de Vries et al., 2018; Fichter, Clausen, 2021).

The diffusion process can be modeled under different assumptions—deterministic, stochastic, or chaotic—depending on the chosen approach and level of detail. Classical models, such as the Bass model, portray diffusion deterministically using differential equations to forecast the number of adoptions over time, assuming predictability and the absence of randomness in consumer behavior (Cai et al., 2022). In reality, diffusion is typically shaped by diverse random external and internal factors, including changes in preferences, competitive actions, and unforeseen market events. As a result, stochastic models are used to better capture variability and uncertainty in these processes (Singhal et al., 2019). In more complex analyses, innovation diffusion may exhibit features of deterministic chaos, where small initial changes lead to large differences in outcomes. Such systems can combine elements of randomness with deterministic chaos—sometimes described as “evolutionary chaos” (Silverberg, Lehnert, 1993).

Both mathematical and qualitative descriptions of innovation diffusion models exist in the literature. Classical models are formally expressed through differential and statistical equations, yet their assumptions and interpretations often have a qualitative character, describing social processes, actor roles, communication channels, or implementation barriers (Guidolin, Manfredi, 2023; Mahajan, Peterson, 1985). Contemporary approaches increasingly emphasize the importance of social context, service ecosystems, and institutions. This provides theoretical and qualitative frameworks that go beyond single actors or simple flows of innovation and focus on complex interactions and institutional change (Vargo et al., 2020). In practice, qualitative studies are leveraged to analyze the target market for an innovation, identify key factors affecting diffusion, and select appropriate mathematical models for subsequent quantitative analysis (Frenzel, Grupp, 2009).

Deterministic mathematical models—especially those based on differential equations—are widely used to describe innovation diffusion and form the foundation of many analyses in this field. They make it possible to capture general trends associated with the spread of innovation in society, often assuming population homogeneity and process predictability. In practice, deterministic models are applied to forecast adoption of new products, plan marketing strategies, and assess the effectiveness of undertaken actions (Guidolin, Manfredi, 2023; Karmeshu, Jain, 1997; Mahajan, Peterson, 1985).

The relationships presented by Bass, Rogers, and Moore, as well as earlier models such as the logistic curve, remain relevant and are frequently used. They are applied to forecasting and describing the pace of diffusion of selected technologies, new organizational or marketing methods within enterprises and in consumer markets, across sectors such as logistics, commerce, and manufacturing (Fant et al., 2023; Fuhua, 2009; Kang, 2021; Klincewicz, 2011; Pratiwi et al., 2022; Yang, Williams, 2008).

Despite the broad use of these models and the possibility of developing new ones tailored to specific diffusion contexts, it is difficult to find compilations that present their interrelationships and differences. Proper comparison and identification of the areas where individual models are most useful facilitate choosing the model that most accurately reflects reality. This should be crucial for those tasked with forecasting product diffusion in the market—and thus revenues from sales.

Innovation diffusion can therefore be described in a deterministic manner, very often using a mathematical formulation. The literature includes a range of mathematical models that depict this process and enable forecasting of the future outcomes of actions undertaken by an enterprise.

In this publication, we attempt to detect and define the relationships between five selected mathematical models describing innovation diffusion: the logistic curve, the Bass model, the source model, the contact model, and the contact–source model (Bradley, 1999; Fant et al., 2023; Kot et al., 1993). This will help to identify differences as well as the strengths and weaknesses of each model and to justify their selection for particular product groups.

The objective will be achieved using simulation modeling in the system dynamics convention with the AnyLogic software.

2. Methods

The five innovation diffusion models outlined in the previous section must be carefully analyzed in order to specify the differences and similarities in their functioning. The appropriate approach for analyzing these models is one consistent with their structure. Since the structure of innovation diffusion models is expressed in the form of differential equations, the method employed here is fundamentally based on the analysis of differential equation systems—namely, the System Dynamics (SD) modeling method. This choice follows from the fact that innovation diffusion concerns social systems, and the analysis is performed at a high level of generality over long periods of time. In the scientific domain, the accepted method for analyzing such systems—long-term, strategic-level, applied to large populations, and described in terms of differential relationships—is system dynamics (Borshchev, Filippov, 2004; Grigoryev, 2021; Größler et al., 2008; Lidberg et al., 2020).

System dynamics modeling combines both qualitative and quantitative approaches. To represent a system as faithfully as possible through a model, it is first necessary to identify, by means of causal loop diagrams (CLDs), the interdependencies among the factors influencing the system, and then transform them into a quantitative stock-and-flow diagram (SFD) (Harmoza, 2006; Ong et al., 2022; Poles, 2013; Walters et al., 2016; Wang et al., 2024).

Causal loop diagrams (CLDs) illustrate only the mutual influences among the system's elements. They indicate the direction of influence and whether it is reinforcing or diminishing. Furthermore, when constructing such diagrams, feedback loops emerge that determine whether a given closed cycle of relationships is reinforcing, balancing, or stabilizing (Gładysz, Santarek, 2017; Größler et al., 2008).

The purpose of stock-and-flow diagrams (SFDs) is to represent the system as a set of relations between stock and flow objects. Stocks reflect the size of a given population (e.g., inventory levels, waste, raw materials in production), while flows represent the transitions between them. Flows can either remain constant over time or vary depending on the current parameters of the system (Grobel-Kijanka, 2016; Poles, 2013).

The approach adopted in this study is grounded in the well-established theory of innovation diffusion, originally developed by Rogers, in which the mechanisms of social influence and adopter categories (innovators, early adopters, early majority, late majority, laggards) play a central role (Rogers, 2003). The literature emphasizes that the diffusion process is not merely the outcome of individual consumer decisions but depends on feedback loops within the social and market system. Classical models, such as the Bass model, provide a mathematical

formalization of these interdependencies and are widely applied to describe the dynamics of adoption of new products and technologies (Bass, 1969).

System Dynamics (SD) offers a framework that enables the interpretation and extension of these concepts by explicitly representing causal structures. The diffusion process can be conceptualized in terms of feedback loops: a reinforcing loop (the role of interpersonal communication and the "word-of-mouth" effect), which drives adoption growth, and a balancing loop, associated with market saturation and the depletion of potential adopters. The SD formalism thus allows not only for replicating the classical adoption curves but also for examining shifts in loop dominance over time, which extends theoretical analysis beyond static models (Sterman, 2000; Forrester, 1961).

System Dynamics constitutes an appropriate and theoretically grounded paradigm for modeling innovation diffusion at a strategic, aggregate level.

This integration is supported by the following arguments, derived from the literature:

Modeling social systems: as noted by Grigoryev (2021) and Größler, Thun, and Milling (2008), SD is particularly useful for modeling complex social systems characterized by nonlinearities, feedback loops, and delays. The innovation diffusion process, as a social phenomenon, fits this description precisely, as it involves interactions among user populations, the influence of communication, and imitation effects.

Long-term and strategic analysis: SD is recommended for long-horizon analyses, where the focus lies on aggregate trends rather than individual-level behavioral details (Borshchev, Filippov, 2004; Lidberg et al., 2020). This is consistent with the aim of classical deterministic diffusion models (e.g., Bass, logistic), which describe macroscopic adoption trends over time rather than microscopic, stochastic decisions.

Representation of causal structures: the foundation of SD is the identification and formalization of feedback loops that govern system behavior (Sterman, 2000; Gladysz, Santarek, 2017; Größler et al., 2008). In the context of diffusion, this corresponds to positive feedback ("imitation" – more users attract additional ones) and negative feedback ("market saturation" – a shrinking pool of potential adopters slows growth). The transformation of diffusion equations into Stock-Flow Diagrams constitutes a direct operationalization of this theory, enabling visualization and simulation of causal structures.

Integration of qualitative and quantitative perspectives: SD provides a framework that combines qualitative system understanding (through Causal Loop Diagrams – CLDs) with quantitative simulation of system behavior (through Stock-Flow Diagrams – SFDs) (Poles, 2013; Walters et al., 2016). This approach aligns with the dual (qualitative–quantitative) character of diffusion research, described in the Introduction (Guidolin, Manfredi, 2023; Mahajan, Peterson, 1985).

Moreover, an additional advantage of SD lies in its capacity to integrate demand- and supply-side processes within a single model. Unlike purely operational approaches, SD makes it possible to capture the interactions between social influences and resource constraints,

production capacities, or marketing strategies. The literature emphasizes that such an extension enhances the analytical potential of diffusion models, enabling the study of policies supporting innovation introduction under conditions of complex causal interdependencies (Peres, Muller, Mahajan, 2010). Our study follows this tradition, employing System Dynamics not only as a computational tool but also as a conceptual framework for examining and interpreting diffusion processes.

The objective of this publication is to investigate the interrelationships among the most frequently cited innovation diffusion models in the literature—namely, the logistic curve, the Bass model, the source model, the contact model, and the contact–source model (Fant et al., 2023; Kot et al., 1993; Tao, Deyong, 2012). This will be achieved by transforming the differential equations characterizing the flows in each diffusion model into simulation models using system dynamics. The implementation is carried out in the AnyLogic simulation environment. The figure below (Figure 1) shows the stages of implementation that were carried out during the work.

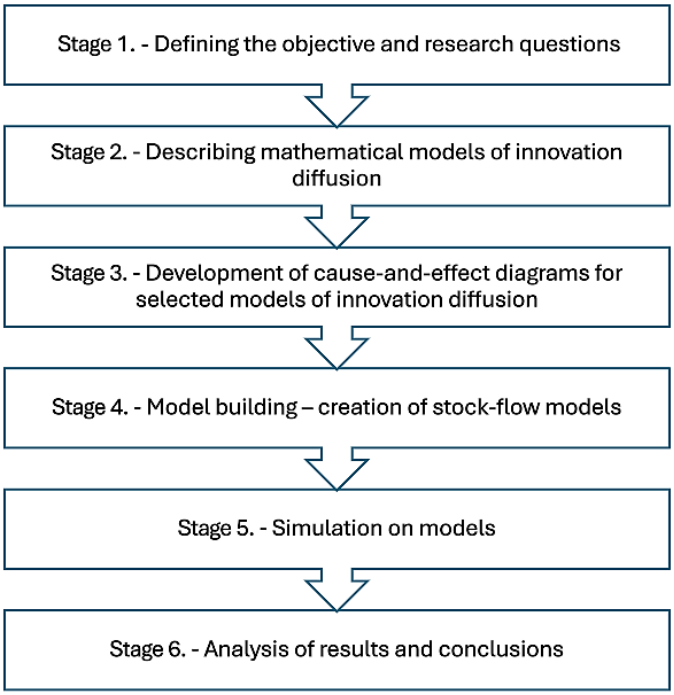

Figure 1. Stages of system dynamics application in building and comparing innovation diffusion models.

Source: authors' own elaboration.

To compare the operating principles of different models and to gain insight into the properties arising from the application of each in practice, the following research questions were posed:

1. How do increases and decreases in the initial parameters of the models affect the total diffusion time?
2. How does the size of the recipient population affect the total diffusion time?
3. How does the initial number of users affect the total diffusion time?

4. Is it possible to determine such initial parameters for the analyzed models that the total diffusion time becomes identical?
5. How do diffusion times vary across Rogers' adopter categories in the averaged models?
6. In which of Rogers' adopter categories does the maximum diffusion rate occur in the averaged models?

Answers to the above research questions will be obtained through the analysis of results from specific simulation scenarios. Each scenario of initial parameter change will be conducted separately for the given models, with the corresponding outcomes recorded. Importantly, in a given scenario only one variable will be tested for its effect on the entire system, while all other conditions remain unchanged (*ceteris paribus*).

It is also important to recognize the limitations inherent in this modeling approach. By applying system dynamics in this way, only models with constant initial parameters—unchanging throughout the simulation—can be analyzed. In practice, population behaviors and the effectiveness of innovation promoters' actions may evolve over time and may be either dependent or independent of the promoter. These dynamics are not accounted for in the constructed models and may therefore affect the final results. Furthermore, the obtained relationships are subject to errors resulting from rounding in the AnyLogic software as well as from the numerical methods used to solve differential equations.

Integration algorithm ("choice of solver") and step size ("discretization step size") – by default, SD models in AnyLogic employ the Euler algorithm with a fixed time step. Variability in the step size or an excessively large step may lead to integration errors and numerical artifacts (e.g., oscillations, instabilities), as emphasized both in the AnyLogic documentation and in SD literature. As Grigoryev (2021) notes in the AnyLogic manual, the choice of integration method (Euler vs. Runge-Kutta) and step size (dt) can significantly affect simulation accuracy, particularly for "stiff" or highly dynamic systems. In our study, all models were run with a fixed time step of dt = 0.001 day. Given the diffusion time scale of several tens of days, this value was deemed sufficiently small to ensure result stability and to minimize discretization error for these specific models.

Numerical stability – simple diffusion models, such as the logistic curve or the Bass model, are generally numerically stable for the parameter ranges considered and when using a sufficiently small step size. Nevertheless, it is worth acknowledging this as a potential limitation, especially in extreme scenarios (e.g., very high values of parameters r, p, q), which could theoretically result in instability. In our simulations, no such behavior was observed, suggesting that the chosen parameter ranges and step size were appropriate.

Rounding error – this limitation is typical of all computer simulations and was noted explicitly. Its impact on the qualitative results presented in this paper (curve shapes, parameter relationships) is negligible, though it may have nonzero significance in highly precise, absolute numerical comparisons across different simulation runs.

AnyLogic provides a range of integration methods. The optimal choice depends on the research objective. For models with slowly varying parameters over time, without sharp peaks in the data, and when predicted trajectories are described by C1-class curves, Euler integration is sufficient and represents a sound compromise between speed and accuracy. It is often applied in systems where large errors arise from aggregation, measurement inaccuracy, simplifications, or incomplete information. Conversely, in physical-system models and simple conceptual models—particularly those involving oscillations or rapid value changes—the Runge-Kutta (R-K) method is frequently preferred.

For most models of social systems, both integration methods (Euler and R-K) tend to produce comparable results.

To summary - the dynamic diffusion models developed for this study were solved using the following methods: differential equations with Euler integration, algebraic equations with Newton's method, and mixed equations with a combination of R-K and Newton's method. The following numerical parameters were adopted: for values close to zero, where relative precision is not feasible, an absolute tolerance of 1E-5 was applied; the relative accuracy guiding the solution of equations with variable step methods was set at 1E-5; the time-step precision for determining switching points during equation solving was set at 1E-5; and a fixed time step of 1E-3 was used for the R-K method.

The results are subject to numerical error, whose magnitude depended on the selected algorithm (Euler) and time step (dt = 0.001 day). Employing more advanced methods (e.g., R-K) could potentially increase accuracy but at the cost of longer computation times. For the purposes of this study—a comparative analysis of model behavior—the adopted configuration was deemed fully sufficient.

3. Results

Between the stage of developing models within the system dynamics framework and conducting specific simulations, it is important to verify the consistency and variability of the models depending on the input data provided.

A useful tool for this purpose is the AnyLogic Cloud computing environment, which enables the creation of experiments. Within the experiment settings, one can specify the ranges and step sizes (iterations) of the input parameters for which simulations will be executed (Grigoryev, 2021). As a result, it is possible to obtain dependency plots displaying all iterations of the simulations, thus allowing the assessment of how input parameters influence the generated outcomes.

Table 1 below presents the differential equations characterizing the flow magnitude per unit of time for the selected innovation diffusion models. Based on these equations, the flows and other elements characteristic of system dynamics were reconstructed.

Table 1.
Descriptions of flows in the analyzed innovation diffusion models

Model name	Equation	Equation number
The Logistic curve	$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$ where: N – population size at time t, t – time, r – growth rate coefficient – describes the combined effect of factors influencing the diffusion of innovation, K – environmental capacity.	(1)
The Bass model	$\frac{dN(t)}{dt} = p[m - N(t)] + \frac{q}{m}N(t)[m - N(t)]$ where: N(t) – number of users using the technology at time t, t – time, m – maximum number of technology users, p – innovation coefficient - reflects the probability that consumers will decide to adopt a new product regardless of the influence of other users or under the influence of external factors such as advertising or marketing activities, q – imitation coefficient - measures the influence of existing users on the decisions of potential buyers. Consumers are more likely to make a purchase decision when they see that others have already done so.	(2)
The source model	$\frac{dy}{dt} = k(n - y)$ where: y – number of users using the technology at a given time, t – time, n – size of the population under consideration, k – proportionality coefficient - describes the rate or intensity of innovation adoption through the use of marketing and advertising activities.	(3)
The contact model	$\frac{dy}{dt} = ay(n - y)$ where: y – number of users using the technology at a given time, t – time, f – effectiveness of persuading supporters of innovation, l – number of contacts of a given person per unit of time, $a = \frac{fl}{n} = const.$	(4) (5)
The contact-source model	$\frac{dy}{dt} = ay(n - y) + k(n - y)$	(6)

Source: authors' elaboration based on (Fant et al. (2023); Kot et al. (1993); Tao, Deyong (2012)).

The following subsections present the results for the developed models under various criteria.

For example, using the Bass model, the dependencies arising from changes in the parameters of innovation (p) and imitation (q) are illustrated (Figure 2a and Figure 2b). The plot demonstrates that changes in initial parameters significantly affect the shape of both the cumulative distribution function and the probability density function. In practice,

this reflects the impact of different activities supporting the diffusion of innovation. Beyond the number of such activities, the financial resources allocated—for instance, to product advertising campaigns in the media—also play a crucial role. This implies that the diffusion of innovation proceeds at different times and with varying intensity in a given unit of time.

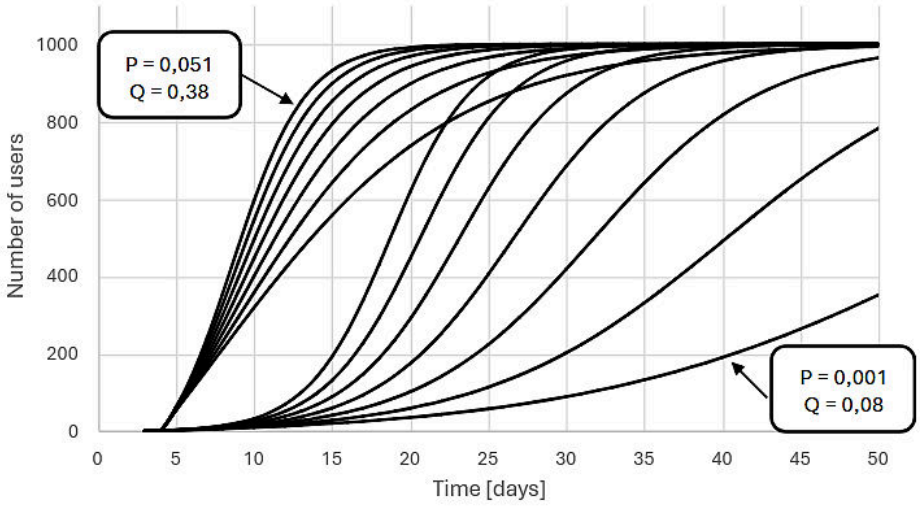

Figure 2a. Cumulative distribution curve of the Bass model under varying input parameters (N = 1000, Np = 1, p ∈ <0.001; 0.1> step 0.05, q ∈ <0.08; 0.4> step 0.05).

Source: authors' elaboration using AnyLogic Cloud.

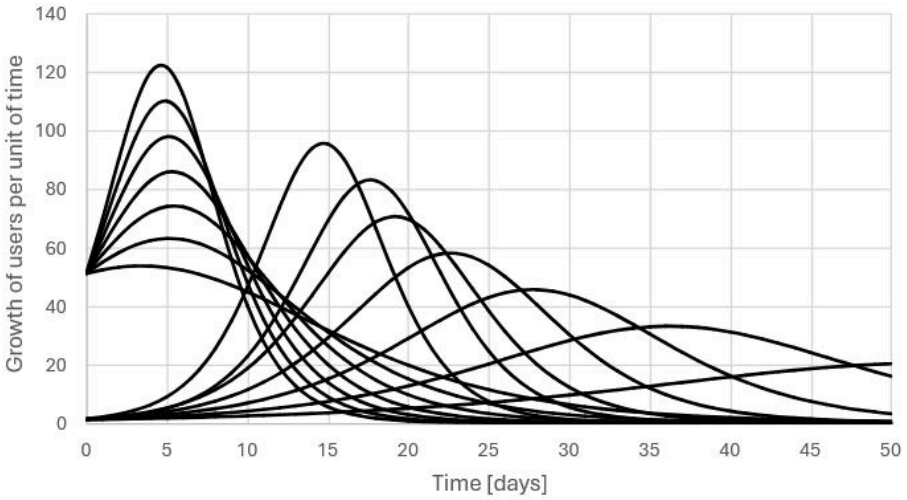

Figure 2b. Probability density curve of the Bass model under varying input parameters (N = 1000, Np = 1, p ∈ <0.001; 0.1> step 0.05, q ∈ <0.08; 0.4> step 0.05).

Source: authors' elaboration using AnyLogic Cloud.

The remaining diffusion models were analyzed in a similar way. Figures below (Figure 3a and 3b) present the cumulative distribution and density curves depending on the changes in initial parameters. In practice, these correspond to changes in the intensity of undertaken actions or in the size of the analyzed population, as specified in Table 1.

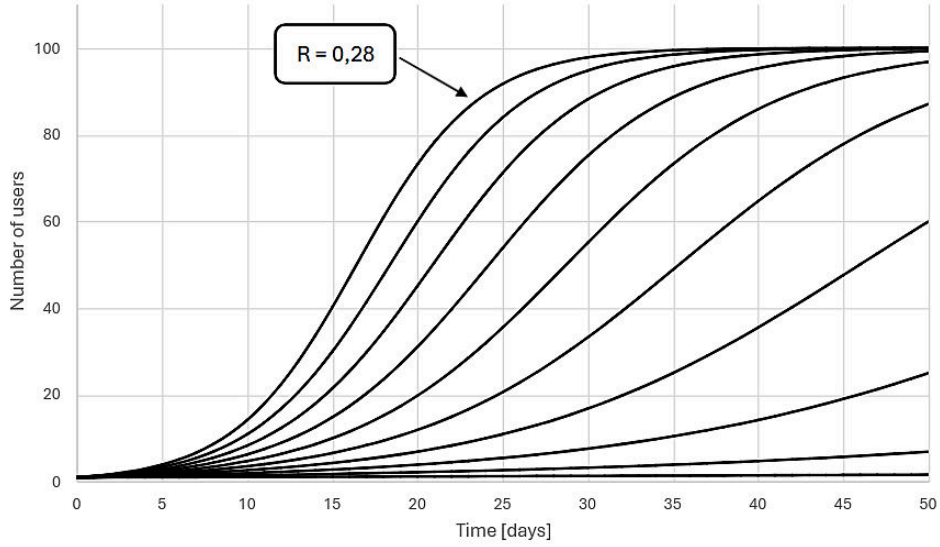

Figure 3a. Cumulative distribution curve of the logistic curve model under varying input parameters (N = 100, Np = 1, r ∈ <0.012; 0.28> step 0.03).

Source: authors' elaboration using AnyLogic Cloud.

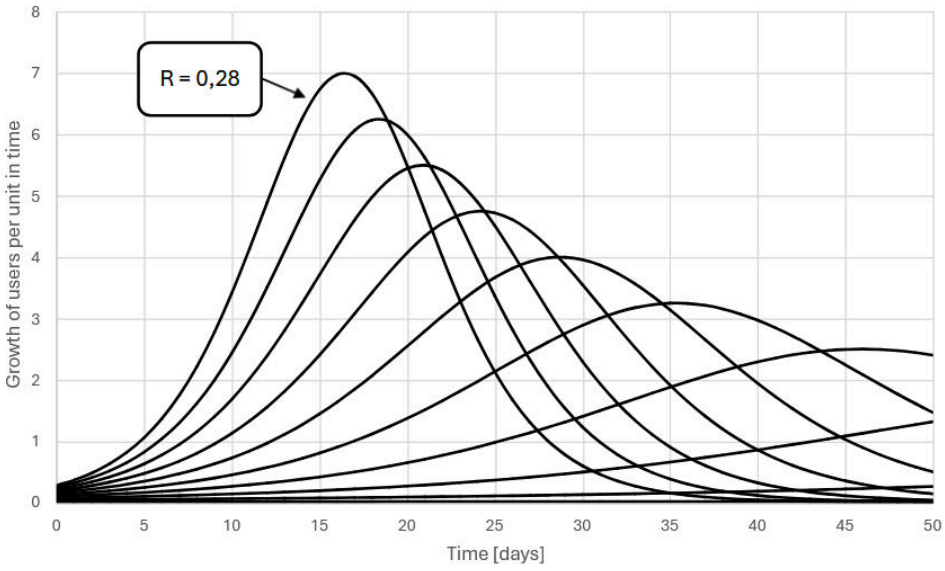

Figure 3b. Probability density curve of the logistic curve model under varying input parameters (N = 100, Np = 1, r ∈ <0.012; 0.28> step 0.03).

Source: authors' elaboration using AnyLogic Cloud.

Observing the above relationships (Figure 3a and Figure 3b), it can be clearly stated that in the logistic curve model, the higher the growth rate coefficient, the faster the diffusion of innovation occurs, and the moment when it is strongest occurs sooner.

The figures below (Figure 4a and Figure 4b) show changes in the source model of innovation diffusion in terms of changes in the proportionality coefficient.

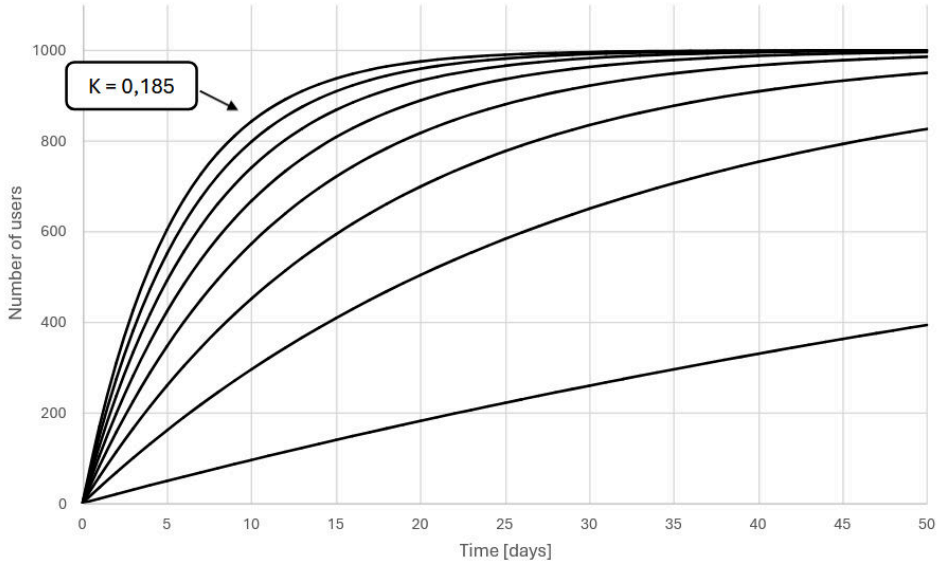

Figure 4a. Cumulative distribution curve of the source model under varying input parameters (N = 1000, Np = 1, k ∈ <0.01; 0.185> step 0.025).

Source: authors' elaboration using AnyLogic Cloud.

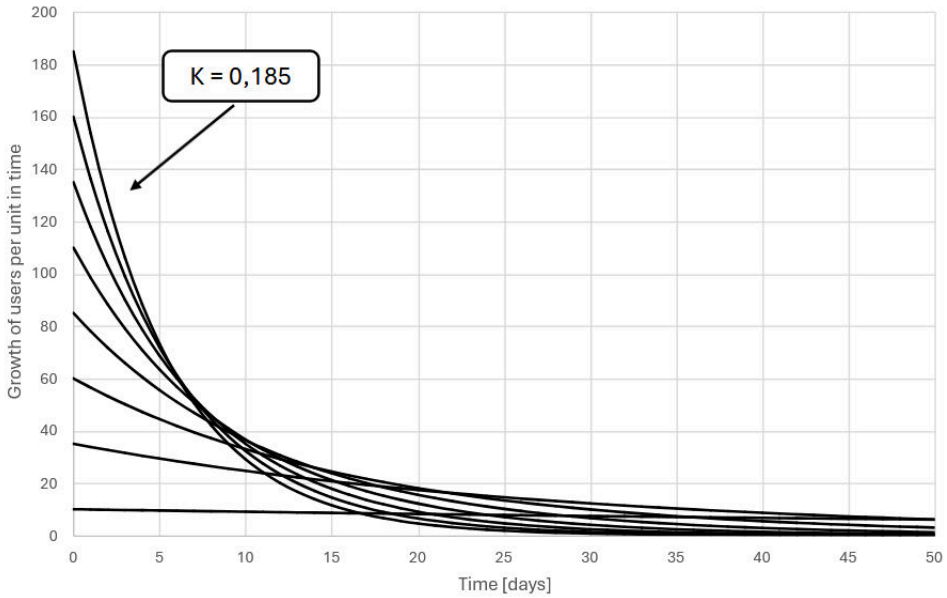

Figure 4b. Probability density curve of the source model under varying input parameters (N = 1000, Np = 1, k ∈ <0.01; 0.185> step 0.025).

Source: authors' elaboration using AnyLogic Cloud.

The source model of innovation diffusion (Figure 4a and Figure 4b) also shows that the higher the proportionality coefficient, the faster the diffusion occurs. However, a different nature of the curve can be observed, both in terms of user growth over time and maximum growth, which in this model always occurs at the very beginning of diffusion.

The figures below (Figure 5a and Figure 5b) show changes in the contact model depending on changes in the initial population size, with f and l remaining constant.

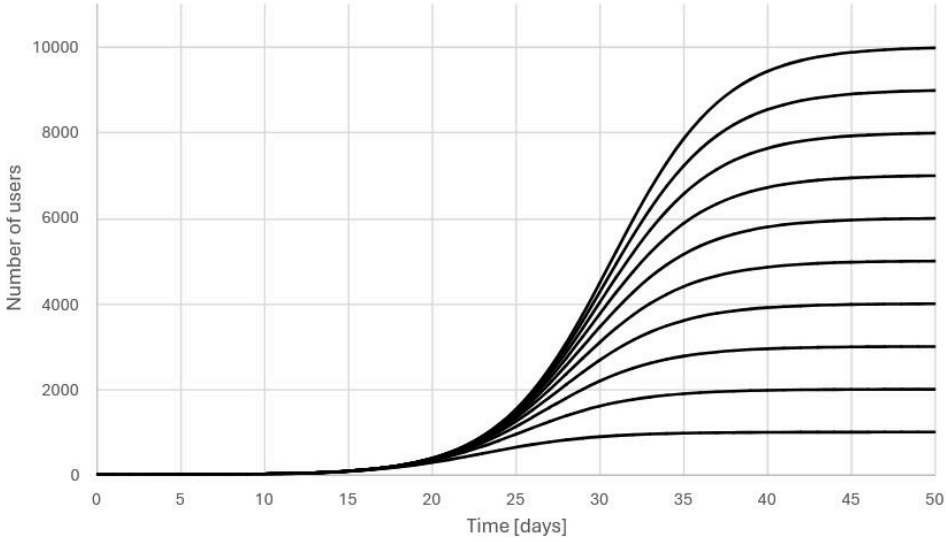

Figure 5a. Cumulative distribution curve of the contact model under varying input parameter s (N ∈ <1000; 10000> step 1000, Np = 1, f = 0.15, l = 2).

Source: authors' elaboration using AnyLogic Cloud.

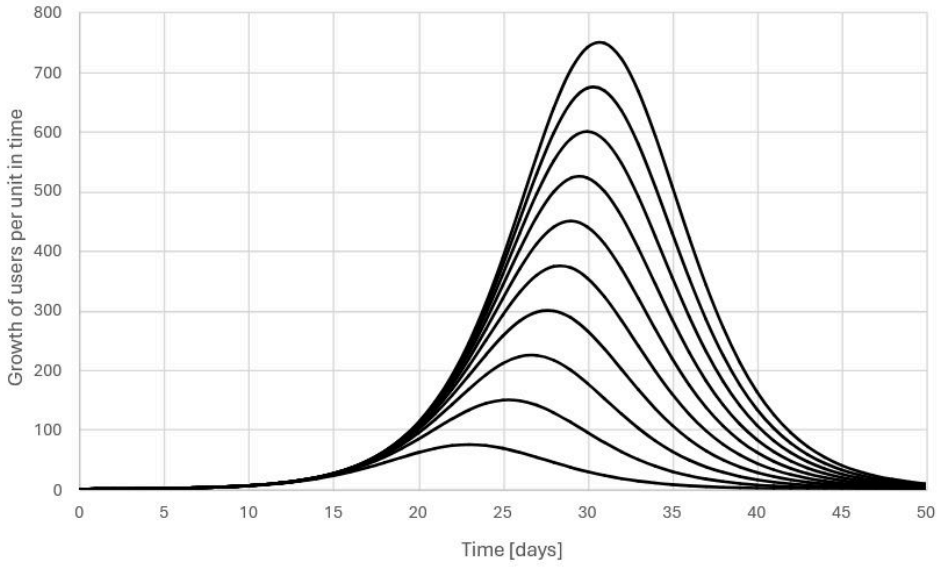

Figure 5b. Probability density curve of the contact model under varying input parameters (N ∈ <1000; 10000> step 1000, Np = 1, f = 0.15, l = 2).

Source: authors' elaboration using AnyLogic Cloud.

The figures above (Figure 5a and Figure 5b) show a different relationship. In the contact model of innovation diffusion, the size of the population in which diffusion occurs was changed. The other parameters related to the initial number of users and the coefficients responsible for the rate of diffusion remained constant. It can be observed that, despite the same coefficients, diffusion occurs more slowly as the population grows. Also, the moment when the maximum flow occurs is later in time, although its maximum is greater than in smaller populations.

The figures (Figure 6a and 6b) below show the results of simulations on a contact-source model, in which the proportionality coefficient, effectiveness of persuasion and number of contacts were changed.

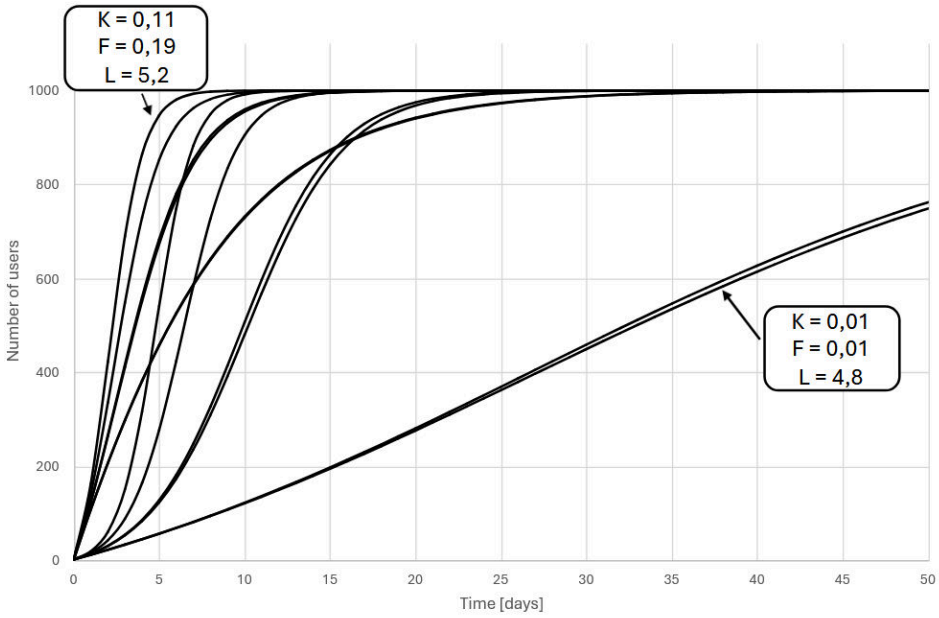

Figure 6a. Cumulative distribution curve of the contact–source model under varying input parameters (N = 1000, Np = 1, k ∈ <0.01; 0.15> step 0.1, f ∈ <0.01; 0.2> step 0.06, l ∈ <4.8; 5.2> step 0.2).

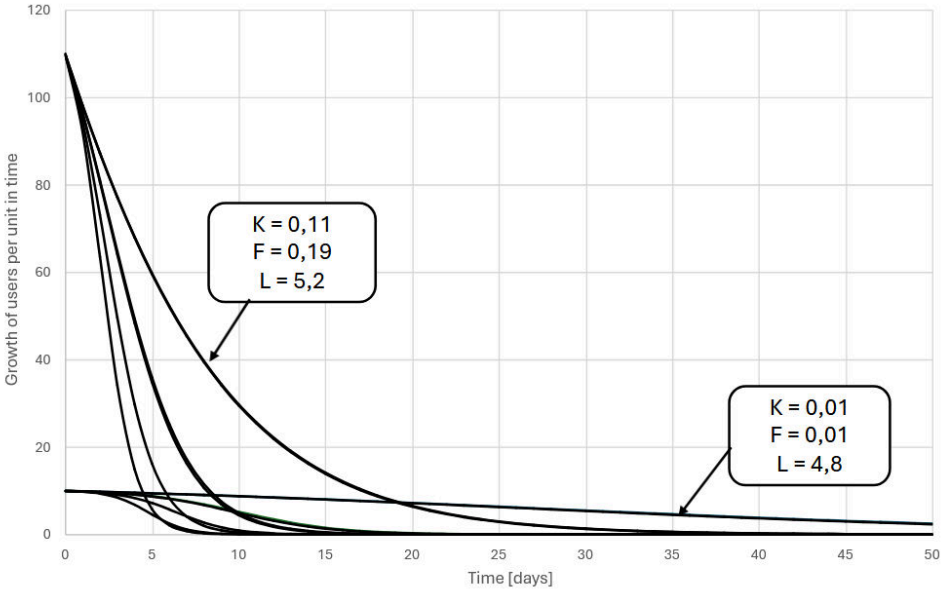

Figure 6b. Probability density curve of the contact–source model under varying input parameters (N = 1000, Np = 1, k ∈ <0.01; 0.15> step 0.1, f ∈ <0.01; 0.2> step 0.06, l ∈ <4.8; 5.2> step 0.2).

Source: authors' elaboration using AnyLogic Cloud.

Based on the results of simulations using the contact-source model, it can be seen that it is highly sensitive to changes in the parameters describing the diffusion of innovation. Depending on the initial values, this model may behave more like a contact model, a source model, or somewhere between these two characteristic curves. The curve representing the flow rate in a given unit of time behaves similarly.

Conducting a series of experiments in AnyLogic Cloud for all five developed innovation diffusion models made it possible to proceed with more detailed simulations of individual models in the context of the previously posed research questions. For this purpose, the desktop

version of AnyLogic was used due to its higher computational accuracy. Selected results of the identified dependencies in the analyzed models are presented below. Some of them relate to consumer groups derived from Rogers' model of adopters, which assumes the following percentage distribution of the population: innovators 2.5%, early adopters 13.5%, early majority 34%, late majority 34%, and laggards 16% (Rogers, 1983).

Based on the simulation series, it was also possible to determine parameter values under which diffusion occurs within the same time frame as in the Bass model with specific initial conditions. These values were then used for further model comparisons in terms of flow characteristics over different time intervals. The data are summarized in Table 2.

Table 2.
Parameter values for standardized models

Model name	Population (N)	Initial users (Np)	Parameter values	Diffusion time of 98% population
The Bass model	1000	1	p = 0,01 q = 0,3	23,39
The logistic curve	1000	1	r = 0,4625	23,29
The source model	1000	1	k = 0,1675	23,29
The contact model	1000	1	f*l = 0,463	23,29
The contact-source model	1000	1	f*l $k = 0{,}97(f \cdot l)^2 - 0{,}84(f \cdot l) + 0{,}17$ (7)	23,29

Source: authors' elaboration.

Additionally, during the simulations it was possible to establish the relationship between the innovation coefficient (p) and the imitation coefficient (q) in the Bass diffusion model in such a way that the total diffusion time remained constant and equal to that obtained for p = 0.01 and q = 0.3. This dependency can be expressed as follows:

$$q = 0{,}3383e^{-12{,}71p} \quad (8)$$

The results obtained in this way, together with further iterations of the simulations, provide a basis for drawing conclusions about the identifying features of the individual models. The next section discusses the similarities and differences revealed during the analysis.

4. Discussion

Impact of Changes in Initial Model Parameters on Total Diffusion Time

Understanding the relationship between initial parameters and the course of diffusion for each of the discussed models is a key issue, as it may provide answers to questions regarding, for example, the profitability of financial investments in marketing, advertising, or other

activities. These parameters represent factors influencing aspects of the model associated with the propagation of the innovation sponsor.

In the simulation scenarios, only the values of initial parameters were modified, while all other quantities describing the model and population remained unchanged.

For the logistic curve model, it was observed that changes in the growth rate coefficient (r) did not affect the shape of the curve; consequently, the percentage distribution of total diffusion time across Rogers' adopter categories remained constant. However, the relationship between the growth rate coefficient and the total diffusion time did change. Specifically, the higher the coefficient, the shorter the diffusion time. This relationship exhibited an exponentially decreasing character. Similar properties were observed in the contact model, where the values of the product of the persuasion effectiveness coefficient (f) and the number of contacts per person per unit of time (l) were varied.

In the source model of innovation diffusion, a mutual relationship was also noted between changes in the proportionality coefficient (k) and the diffusion time. This dependence likewise showed an exponentially decreasing character, though with different coefficients. Importantly, the impact of k on the curve's shape and on the percentage distribution of diffusion time across Rogers' adopter groups remained unchanged. Compared to the two earlier models, however, the source model demonstrated significantly faster diffusion among innovators and early adopters, and slower diffusion among laggards.

For the Bass model, simulations had to be divided into two stages due to the presence of two coefficients: the innovation coefficient (p) and the imitation coefficient (q). The simulation series revealed that the model behaved differently depending on which parameter was varied. With an increase in p, the total diffusion time decreased across all Rogers' adopter groups. When examining the percentage share of these times within total diffusion, a relationship became evident: as q increased, the percentage of diffusion time among innovators and early adopters grew, while that among the early and late majority and laggards decreased. This finding supports the theoretical interpretation of the q parameter, which describes the degree of information transfer within the population. Stronger influence leads to greater effectiveness in the early groups, while later groups are less affected. Conversely, when modeling changes in q, greater information exchange within the population resulted in faster adoption by later groups of customers, but adoption in the initial groups (without marketing interventions) was very slow.

For both dependencies, the changes in diffusion time exhibited a power-law character; however, for q, the magnitude of this effect was much smaller than for p (with regression values ranging from –0.149 to –0.819). Similar analogies in terms of variability were also observed in the contact–source diffusion model. The only difference was that the relationship between k and total diffusion time followed a logarithmically decreasing pattern.

Impact of Population Size on Total Diffusion Time

Scenarios involving changes in the size of the population within which diffusion occurs are of limited significance for companies aiming to sell innovative goods or services on the market, since they typically assume the largest possible target group of consumers. The situation is different for firms introducing process or organizational innovations, where a key question arises: should these innovations be implemented simultaneously across the entire workforce, or initially focused on a specific department, division, or process?

In the analyzed scenarios, only the population size (N) was varied, while all other model parameters remained constant throughout the simulation process.

As in the first scenario, similar relationships were observed between the logistic curve model and the contact model. In both cases, the relationship between population size and total diffusion time can be described as logarithmically increasing. This means that the larger the population, the slower the diffusion process. However, as population size grows further, the differences become progressively smaller. Observing the behavior of these models within Rogers' adopter categories revealed that the percentage share of innovators increased as the population expanded. This indicates that the larger the group in which diffusion takes place, the more time is required to reach the initial 2.5% of adopters in the logistic and contact models. Once this threshold is achieved, however, diffusion begins to progress more dynamically, making it easier to reach subsequent consumer groups.

In the source model, an interesting relationship was identified. Simulation results showed that population size had no effect on whether diffusion time lengthened or shortened. This means that regardless of how large the population is, if each individual has the same probability of adopting the technology, the total diffusion time remains unchanged. However, it should be noted that this condition assumes a constant value of the coefficient k. In practice, this implies that marketing expenditures remain fixed over time in order to achieve the same level of effectiveness.

When examining the results from the Bass model and the contact–source model, no clear mathematical relationship could be established between population size and diffusion time. For smaller population sizes, increases in diffusion time were observed, whereas for larger populations the diffusion time tended to stabilize at a constant level—though at different values for each of the two models. This effect stems from the fact that these models combine two approaches to innovation diffusion: in one, diffusion time is independent of population size, while in the other it is described as logarithmically increasing.

Impact of the Initial Number of Users on Total Diffusion Time

An important relationship to consider when designing processes associated with innovation diffusion is the initial number of users already adopting a given technology. Their presence can trigger the so-called "penguin effect", through which additional potential users are encouraged

to adopt the technology by following their example (Klincewicz, 2011). This factor is particularly relevant when launching product distribution in consumer markets, but also within enterprises, where early adopters among employees may encourage others to embrace change.

In the simulation scenarios, only the initial number of users at the start of diffusion was varied, while all other model parameters were kept constant.

Both the logistic curve and contact models are characterized by the necessity of having at least one initial user of the technology; otherwise, diffusion will never occur. The relationship between changes in the number of initial users and total diffusion time can be described as logarithmically decreasing. The percentage share of total diffusion time attributed to innovators and early adopters decreases substantially, while the shares for the early majority, late majority, and laggards increase correspondingly. However, the actual diffusion time within each group decreases—only the relative proportions of time change.

For the source model, a linearly decreasing relationship was identified, though with a very low slope (–0.01). Thus, the relationship can be considered practically constant, with only a minimal reduction in total diffusion time, attributable to the smaller number of individuals who must undergo diffusion during the simulation. Differences across Rogers' adopter groups are negligible.

Both the Bass model and the contact–source model proved challenging to describe in terms of a precise relationship between the initial number of users and diffusion time. It can, however, be definitively stated that such a relationship exists and has a positive effect on reducing total diffusion time. Nevertheless, the exact nature of this dependence is difficult to determine. Both parabolic and exponential forms of the relationship yielded similar regression coefficients of approximately 0.98. In the simulations, reductions were observed in the percentage share of diffusion time among innovators and early adopters, followed by an increase among the early and late majority, and then another decrease among laggards.

Comparison of Diffusion Times across Rogers' Adopter Categories in Averaged Models

The simulation results for the logistic curve and the contact model are very similar. This arises from the comparable structure of their parameters and their influence on flow magnitude. In the contact model it was additionally demonstrated that the combined product of parameters f and l does not affect the shape of the cumulative distribution curve. Compared with the reference Bass model (with $p = 0.01$ and $q = 0.3$), both models exhibit a slow initial increase within the innovator group. Subsequently, this difference diminishes to the point that, within the laggard group, innovation spreads more rapidly.

The source model is characterized by a highly dynamic initial increase in the number of users. The innovator group requires only 0.68% of the total diffusion time. Subsequent groups are persuaded at an increasingly slower pace, to the extent that laggards account for over 53% of total diffusion time (compared to approximately 30% in the baseline Bass model). Relative

to the Bass model, the source model demonstrates much faster diffusion among innovators, early adopters, and the early majority, a similar pace in the late majority, and significantly slower diffusion among laggards.

From the analysis of results for the Bass and contact–source models, it follows that even though the total diffusion time across the entire population is identical, the behavior of each model in the tested scenarios differs and depends on the parameter combinations. When the parameters associated with the contact-based approach (i.e., the product $f \times l$ and parameter q) dominate, the results resemble those of the logistic curve and the contact model. Conversely, when the parameters associated with the sponsor's influence (k and p) prevail, the outcomes resemble those of the source model.

This indicates that these models are flexible in terms of parameter configurations depending on real-world conditions. This flexibility is a major advantage, as it allows for a more accurate representation of the diffusion process—not only in terms of total diffusion time, but also in relation to the conditions and the manner in which the process unfolds.

Comparison of the Moments of Maximum Flows in Averaged Models

To determine the magnitude of flows at specific points in time, flow plots were developed for each model. These represent the first derivatives of the cumulative curves previously discussed for each diffusion model. In this analysis, the parameters specified in Table 1 were used, while the remaining model characteristics were held constant.

For the logistic curve, source, and contact models, only a single simulation was conducted, since earlier analyses had already identified parameter conditions under which these models could be made comparable to the Bass model with $p = 0.01$ and $q = 0.3$. In both the logistic and contact models, the curves are distributed symmetrically. The maximum flow values occur at the boundary between the early majority and late majority. The other adopter groups display similar distributions due to the symmetry of these curves.

In the source model, the maximum flow occurs right at the beginning of the diffusion process, within the innovator group. The rate then gradually decreases as the population becomes saturated. Compared with the logistic curve and the contact model, the maximum flow in the source model is considerably higher (by approximately 30%).

The Bass and contact–source models, due to their universal character and adaptability to different diffusion conditions, can exhibit maximum flows at varying points. For $p = 0.01$ and $q = 0.3$, the peak occurs symmetrically at the midpoint of diffusion—at the boundary between the early and late majority. However, with different parameter combinations, the peak may shift to earlier adopter categories, such as early adopters or even innovators.

Based on the earlier simulation results, the following quantitative conclusions can be drawn regarding the analyzed diffusion models:

- Increasing initial parameter values leads to a decrease in total diffusion time for a fixed population size. This relationship is power-law for the logistic, Bass, source, and contact models, and logarithmic for the contact–source model.
- In the logistic, source, and contact models, changes in initial parameters do not alter the percentage distribution of diffusion time across Rogers' adopter categories—the curves retain their shape, and diffusion proceeds proportionally over time.
- In the Bass and contact–source models, the proportions of diffusion time across Rogers' adopter categories vary depending on the relative strength of parameters, which causes the shape of the curve to change with parameter adjustments.
- Changes in population size do not affect diffusion in the source model. With a constant k, the total diffusion time remains unchanged, as does the time distribution across Rogers' categories.
- In the other models, population size influences total diffusion time. For the logistic and contact models, the dependence is logarithmically increasing; for the Bass and contact–source models, the relationship is harder to characterize, though in general, larger populations are associated with longer diffusion times.
- In these latter models, increasing population size also shifts the percentage distribution of diffusion time: the shares for innovators and early adopters grow, while those for the early and late majority, as well as laggards, shrink.
- When the initial number of users increases, total diffusion time decreases across all models. The logistic and contact models exhibit logarithmic decline, the source model shows linear decline, while the Bass and contact–source models demonstrate mixed effects from overlapping dependencies.
- With more initial users, the share of diffusion time for innovators and early adopters declines, while it increases for the other groups—except in the Bass model, where laggards once again show a decrease.
- In scenarios where parameter adjustments allowed the models to produce identical total diffusion times, it was demonstrated that the models can be synchronized for further comparison and simulation.
- It is possible to establish interdependencies between parameters in the Bass and contact–source models such that the total diffusion time remains constant under specific conditions.
- Simulations under equal total diffusion times enable interpretation of individual model properties. For the logistic and contact models, diffusion times in Rogers' groups are similar—initially low, accelerating in later groups, and slowing again among laggards.
- The source model is marked by rapid initial growth that slows sharply over time, with laggards requiring over 50% of total diffusion time.

- In the Bass and contact–source models, even when parameters are adjusted to yield identical total diffusion times, diffusion durations across adopter categories differ. Depending on parameter dominance, the models may resemble either the source model or the logistic/contact models.
- Simulations of flow dynamics reveal where models are most effective. The logistic and contact models show symmetric curves, with the peak at the midpoint (between early and late majority).
- The source model peaks at the very beginning (innovators), with diffusion rates declining steadily thereafter, leading to substantially different timing.
- In the Bass and contact–source models, peak flow positions vary with parameter combinations. Greater influence of source-related parameters shifts the peak to innovators or early adopters, while stronger influence of interaction-related parameters shifts the peak toward the early majority, resembling the symmetric logistic/contact pattern.

In addition to these quantitative findings, the analysis of causal loop diagrams (CLDs) and stock–flow diagrams (SFDs) also provide the following qualitative conclusions:

- There are structural similarities between the logistic and contact models, though they differ in how flows are described and in the number of defining parameters.
- The Bass and contact–source models also share similarities but differ in how flow magnitudes are formulated.
- In the logistic and contact models, emphasis is placed on internal interactions within the population, i.e., between individuals and the current number of users.
- In the source model, emphasis is placed on the strength of the sponsor's influence in converting potential users into adopters.
- The Bass and contact–source models appear to represent a hybrid of the other models, combining aspects of both the source-driven and contact-driven approaches.

Acknowledgements

This article was prepared as part of the E2TOP research program at Lodz University of Technology.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

NATURE CONSERVATION AND ITS ECONOMIC ROLE IN SUPPLYING TERRITORIAL COMMUNITIES WITH HEALTHY FOOD

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Purpose: Sustainable development of territorial communities depend on nature conservation. Conservation initiatives seek to protect biodiversity and ensure proper food production, thus improving the local economy and public health. This article studies the economics of environmental conservation concerning the relationship between sustainable agriculture and the availability of nutritious foods. To examine, using case studies and an analysis of the literature, the effects of environmental conservation initiatives on local economics and the availability of nutritious food in communities.
Design/methodology/approach: The study is based on a systematic review of peer-reviewed literature, policy documents, and case studies related to nature conservation, sustainable agriculture, and economic development. Comparative and thematic analyses are applied to identify key trends, challenges, and best practices in integrating conservation strategies into local economic policies.
Findings: The results show that conservation efforts help boost the production of organic food, encourage ecotourism, and enhance green investment, all of which have a favorable impact on public health and regional economic growth.
Research limitations/implications: The study's conclusions are formed within the confines of the previous studies' availability and scope because it only employs secondary sources. There is a need for additional empirical research in order to assess the direct impacts of conservation strategies on specific territorial communities.
Originality/value: By combining knowledge from various sources, this study gives stakeholders and policymakers an extensive understanding of how to include nature conservation into plans for economic and social development.
Keywords: nature conservation, territorial communities, sustainable agriculture, healthy food, economic development.
Category of the paper: research paper.
JEL: Q54, Q590, Q520, Q15, O44.

1. Introduction

The contemporary world faces numerous environmental challenges that affect all aspects of society. In particular, the changing climate, soil and water pollution, soil erosion, and overexploitation of resources endanger the balance of ecosystems and the economic health of regional communities. In order to meet growing global food demand by 2050, global crop and livestock production must increase by approximately 60% compared to 2006 levels (Robinson, 2024). These challenges call for integrated approaches in which nature conservation becomes a key factor not only in maintaining ecological balance but also in stimulating economic growth.

Maintaining sustainability within the ecosystem is highly relevant to today's society. For example, maintaining cropped land, reducing pollution, and helping with the pollination of crops are just some of the roles that help the society (Story et al., 2008). These services form a foundation for sustainable agriculture where the focus is on providing safe food products and protecting the environment. Given current challenges, nature conservation assumes particular importance for territorial communities, where the rational use and protection of natural resources can serve as a powerful tool for enhancing the competitiveness of local economies and improving residents' quality of life. An example would be managing agricultural expansion alongside forest preservation to capture an optimum amount of carbon and slow the pace of climate change (Aronson et al., 2006).

Economic stability and the development of local communities increasingly depend on the effective management of natural resources (Aronson et al., 2006; Velten et al., 2021). Nature conservation contributes not only to sustaining ecological balance but also stimulates the development of ecotourism, reduces costs associated with artificial environmental remediation, and supports the sustainable growth of the agricultural sector. A clean environment ensures agricultural productivity and the quality of its produce meets international safety and nutrition standards – which is now more crucial than ever (Aronson et al., 2006).

The purpose of this paper is to describe the nature-ecological and economic interface of the region, analyzing the balance between the food security of the population and its healthy nutrition. The paper examines how ecosystem services contribute to the sustainability of agricultural production and how their effective utilization can underpin the implementation of innovative approaches to local economic development. Sustainable agricultural practices are necessary to maintain biodiversity and long-term economic stability in rural areas (Robinson, 2024). At the same time, growing environmental challenges, including those relating to land erosion and high resource consumption that need to be addressed quickly and more thoroughly. One of the most critical challenges is climate change and it's negative impacts on food productivity requiring adaptive responses (Robinson, 2024). Given this, nature protective measures should be integrated with policies aimed at agricultural development to maintain food supply, economic stability, and sustainability.

Later on, the article presents a summary of the existing literature that focuses on current research on the economics of nature conservation, ecosystem services, and healthy food production. Furthermore, it details the employed overarching research approach, outlines the key findings, and offers final thoughts and suggestions on how to advance the sustainable development policies in territorial communities. This comprehensive approach not only systematizes existing knowledge but also provides new perspectives for integrating nature conservation initiatives into the mechanisms of economic growth and social welfare.

2. Theoretical framework and methodology

This research applies a multi-method qualitative approach grounded in the theoretical frameworks of ecosystem services valuation and sustainable rural development economics. The methodological design is structured to integrate comparative case analysis, thematic synthesis, and policy document review to explore the complex interplay between nature conservation, sustainable agriculture, and the economic vitality of territorial communities.

The study is based on a systematic review of peer-reviewed literature, official policy documents, and documented case studies from both EU member states and Ukraine. The selection process followed the PRISMA 2020 guidelines to ensure transparency and replicability.

Three complementary methods were applied: analysis and synthesis, comparative case analysis, policy and document analysis. The analysis stage involved breaking down literature into thematic categories such as *ecosystem services*, *agricultural sustainability*, *economic benefits*, and *policy mechanisms*. The synthesis stage reassembled these components into an integrated understanding of how conservation strategies influence both environmental quality and socio-economic outcomes. Case studies from multiple territorial communities in the EU and Ukraine were compared to identify best practices and context-specific challenges. The comparison considered governance models, stakeholder engagement processes, resource management strategies, and economic results. Key variables included biodiversity indices, agricultural output levels, food security indicators, and local GDP contribution from eco-based industries (e.g., organic farming, ecotourism). Policy and document analysis – regulatory frameworks and strategic plans were evaluated for their capacity to support conservation-based development. Sources included the EU Common Agricultural Policy, the European Green Deal, Ukraine's State Strategy for Regional Development, and local government resolutions on land use and biodiversity protection. Emphasis was placed on identifying gaps between policy intention and practical implementation, as well as opportunities for cross-border policy learning.

Thematic coding of literature was conducted using *NVivo 14* to identify recurring concepts and cross-cutting issues. Triangulation was employed to enhance validity by cross-verifying findings from academic studies, policy documents, and statistical databases (e.g., FAOSTAT, Eurostat). Statistical figures were normalized to allow meaningful cross-country comparisons.

The study is limited by its reliance on secondary data, which may not fully capture local variations or recent post-conflict developments in Ukraine's agricultural sector. Furthermore, while the comparative approach provides rich contextual insight, the absence of direct fieldwork restricts the depth of socio-cultural analysis. Future research should incorporate longitudinal field surveys and participatory rural appraisal methods to directly capture stakeholder perspectives.

3. An overview of the literature

The literature addressing the intersection of nature conservation, sustainable agriculture, and the economic well-being of territorial communities is rich and multidisciplinary. The four primary documents that have been provided form an important set which, taken together, captures the need to think about environmental issues and local development in a comprehensive, context sensitive manner. Based on case studies from all over the European Union, S. Velten et al. conducted a meta-analysis on cooperative efforts for sustainable agriculture. The study shows several local and global factors capable in influencing the effectiveness of cooperative conservation projects and initiatives. An important remark is that certain internal aspects like stakeholder participation and engagement, and adaptive management and decision-making processes, are more critical in achieving successful outcomes than external, predetermined factors. The research about the European Union region reveals that farmers and other stakeholders must work together if agricultural sustainability is to be achieved in the long term (Velten et al., 2021). This demonstrates how locally driven approaches as international best practice to environmental sustainability can help communities strive to improve their socioeconomic positioning.

M. Story et al. examine the creation of healthy food environments through policy and environmental approaches to food systems. Their study highlights food environment as a crucial factor in public health and adoption of good lifestyles. This paper argues that by addressing the issues of food deserts and inequalities in food aid as well as the effect of the built environment on eating behavior, policy measures are needed to create surroundings that are helpful for the availability of nutritious foods. For territorial communities, this combined strategy is especially important since providing wholesome food choices improves public health, increases sustainable agricultural output, and strengthens community resilience. If these communities

serve as the basis for sustainable agricultural output, then they can be more robust going forward (Story et al., 2008).

In his study on global systems of sustainable land use and agriculture, G. Robinson defines ecocentric and technocentric methods. His examination of modern methods indicates that precision farming, organic farming, and agroforestry are being employed in tandem with modern strategies. He argues that centeric methods wherein elements like Agriculture 4.0 and genetic engineering are employed, greatly increase productivity but do not embed the same emphasis on biodiversity and soil health as the extreme centric systems do. Robinson combines the extremes of ecocentric and technocentric systems in order to maximize the benefits of conservation without losing economic profits or value. It is evident, however, that these systems outcomes are tied to the economic health of the community regions (Robinson, 2024). This is because sustainable agricultural practices guarantee productivity and environmental quality which are important for food security and economic development.

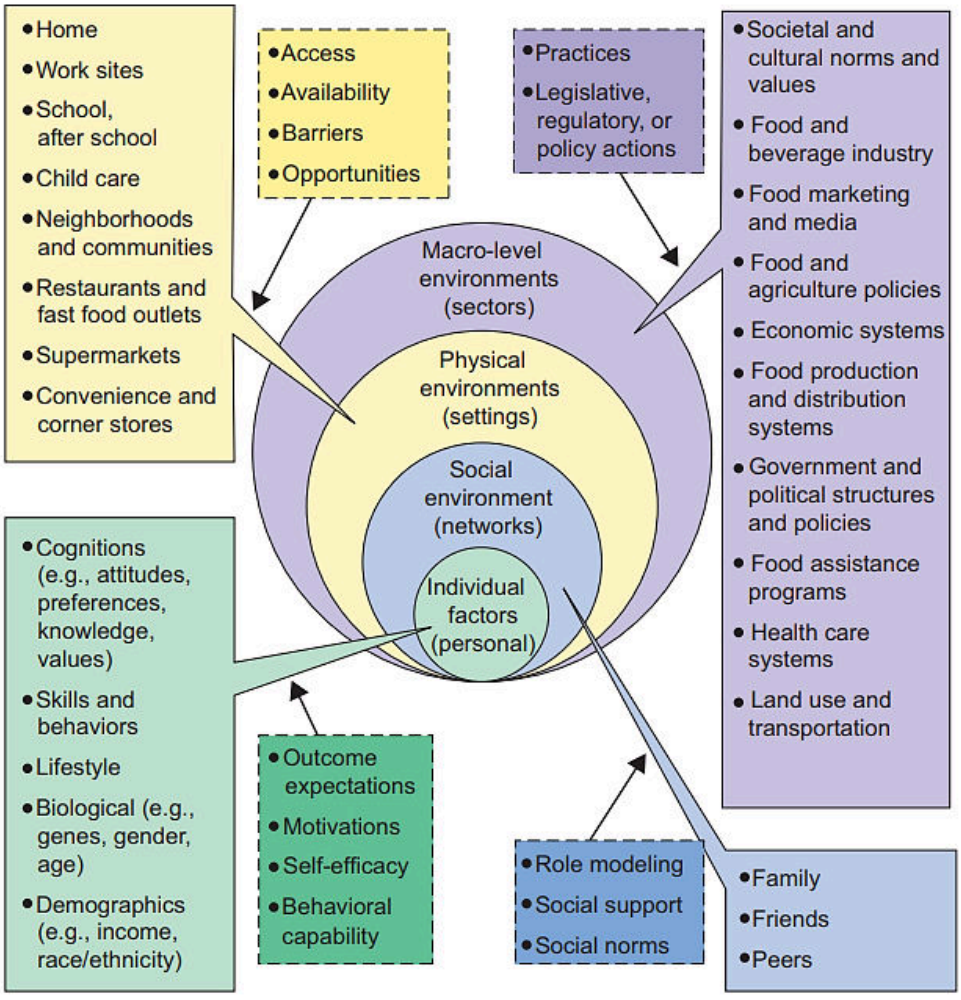

Figure 1. An ecological framework depicting the multiple influences on what people eat.

Source: Story et al., 2008, 29.08.2025.

J. Igoe examines the trade-offs of conservation initiatives by estimating the costs and benefits of conservation to the local communities. In J. Igoe's framework, which is based on DFID sustainable development model, he measures the consequences on different forms of capital such as natural, financial, physical, social, and human. His analysis astounding finds indicate that there are significant constraints to naturally-available resources at the community level, but the conservation measures proffer important benefits by way of ecosystem services that can help improve soil, water, and agricultural productivity (Igoe, 2006). This perspective amplifies the importance of appropriate policies that focus on local economic development while protecting the environment in an appreciable manner.

The literature addressing the intersection of nature conservation, sustainable agriculture, and the economic well-being of territorial communities is not only rich and multidisciplinary but also rapidly evolving in response to climate change, geopolitical instability, and global market pressures. Recent research (2023-2025) has increasingly emphasized the economic valuation of ecosystem services as a strategic instrument for policy-making at both local and national levels.

For instance, M. Smith et al. quantified the contribution of biodiversity conservation to regional GDP in Eastern Europe, finding that conservation-oriented land management yields a 15-20% higher net economic return over a ten-year horizon compared to conventional exploitation (Smith et al., 2024). This aligns with the EU Green Deal and the Global Biodiversity Framework**,** highlighting the integration of environmental assets into fiscal planning. Similarly, FAO reported that communities adopting ecosystem-based agricultural models in Eastern Europe demonstrated a 30% increase in soil productivity and a 25% reduction in irrigation costs within five years (FAO, 2019; 2023). Overall, these sources collect a significant quantity of data about the protection of nature in relation to the environment and the economics of local communities. They are predicated on the idea that conservation efforts must simultaneously preserve the natural balance and ensure both food security and financial success. This will lead to the creation of programs that support sustainable agriculture, boost community resilience, and guarantee the availability of safe food products.

4. Results of the investigation

The analysis confirms that nature conservation plays a crucial role in ensuring the economic sustainability of territorial communities by safeguarding agricultural productivity, fostering food security, and promoting public health. Long-term agricultural viability and economic growth depend on ecosystem services, which are maintained through conservation efforts and sustainable land management techniques (Robinson, 2024; Velten et al., 2021).

One of the key conclusions is that when conservation policies are effectively integrated with agricultural strategies, they help lessen the effects of climate change, soil degradation, and water scarcity. By protecting natural resources and biodiversity, communities can sustain resilient food production systems, ensuring consistent access to safe and nutritious food while mitigating the economic consequences of environmental decline (Story et al., 2008; Velten et al., 2021). Sustainable agricultural investment increases soil fertility, crop production, and enhances local economies, which creates jobs in environmentally friendly sectors. Robinson also advocates for an integration of ecocentric and technocentric management systems as these approaches provide maximum conservation gains and economic benefits (Robinson, 2024).

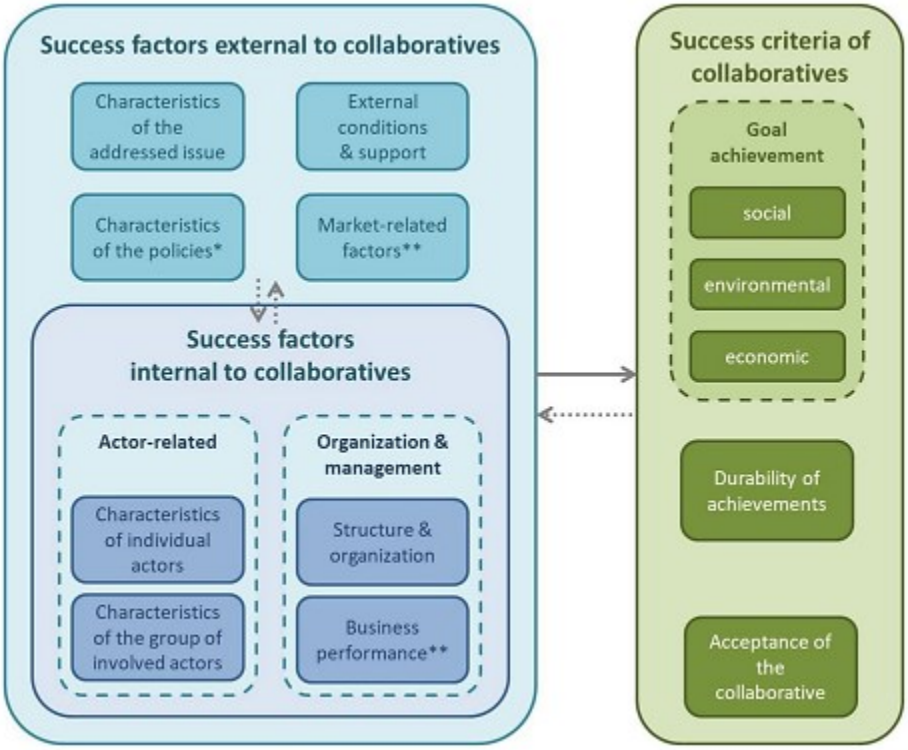

Figure 2. Conceptual framework illustrating potential success factors (left) and success criteria (right) in collaborative approaches.

Source: Velten et al., 2021, 29.08.2025.

Another important aspect is the broader economic benefits of conservation, such as the development of ecotourism and reduced expenditures on artificial environmental remediation (Igoe, 2006). While some conservation measures may impose short-term constraints on resource use, their long-term advantages, such as improved soil fertility, water management, and resilience against climate variability, outweigh the costs. J. Igoe emphasizes that in order to guarantee fair results, local government structures must address the uneven distribution of the financial benefits of conservation. The study shows the relationship between nature conservation, sustainable agricultural practices, and economic stability of the territorial communities. The research findings do posit that when conservation is well managed, it will help conserve ecosystems and also help local economies by ensuring agricultural productivity, thereby boosting public health programs (Robinson, 2024; Velten et al., 2021).

The maintenance of food security is an important part of the sustainability in territorial communities, as it involves ecosystem services. Studies show that nature conservation, promotes soil fertility, biodiversity, and water management, all of which are vital for agricultural sustainability (Robinson, 2024). The expansion of agricultural land might cause deforestation, environmental degradation, and a reduction in food production capacity in the long run if it is not managed in adequate way. By introducing conservation strategies, communities can mitigate these risks while guaranteeing the continued economic growth (Velten et al., 2021; Yakymchuk, 2024).

Besides agricultural sustainability, ecological principles and policy actions are important to healthy food environments. Story et al. (2008) further argue the importance of environmental and political strategies in affecting dietary patterns and the availability of healthy food. Therefore, with territorial communities integrating conservation into their food production systems can not only guarantee food quality, but also reduce expenses associated with artificial remediation of degraded lands. Thus, reinforcing the connection between conservation and public health policies enhances the overall resilience of local populations and economies.

Beyond agriculture, the conservation efforts may create financial value. Sustainable land management has been found to improve ecotourism, lower the financial burden of environmental restoration, and generate long-term job possibilities inside the green businesses (Igoe, 2006). Even though they have big financial advantages, there is a chance that conservation initiatives might temporarily restrict resource availability for local communities. J. Igoe's cost-benefit study shows that although efforts at conservation may restrict certain extractive activities, the long-term benefits – such as better soil and water quality would absolutely outweigh the initial economic losses.

According to Statista, unsustainable food production represents one of the main drivers of global biodiversity decline, responsible for around 70% of terrestrial biodiversity loss through agricultural habitat conversion, farmland-driven deforestation, and irrigation-related water use. Although the full details of Statista's paid reports are not publicly accessible, their open resources emphasize the critical interconnection between food systems and biodiversity loss, highlighting issues such as the economic risks associated with biodiversity decline and consumer attitudes toward sustainable food choices (Statista, 2025).

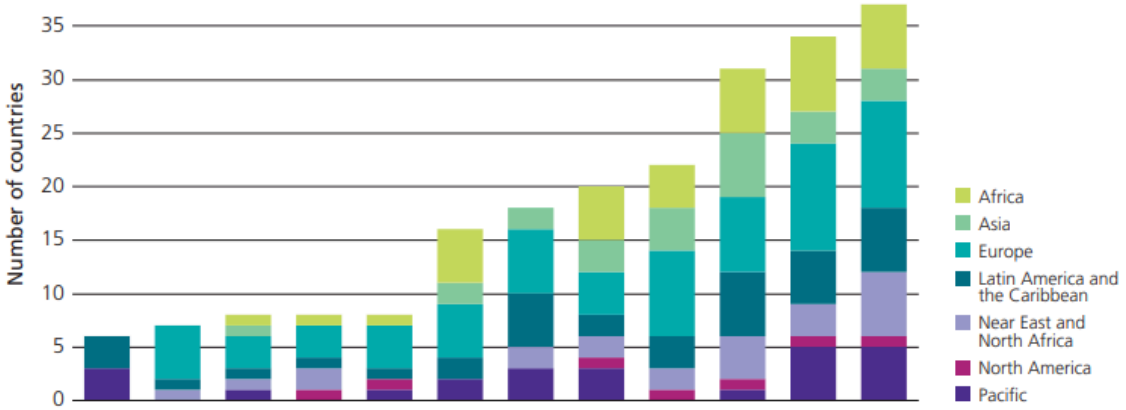

Figure 3. Reported threats of climate change to associated biodiversity.

Source: FAO, 2019, 29.08.2025.

The results of this study reinforce the central thesis that nature conservation is intrinsically linked to the economic sustainability and food security of territorial communities. Conservation-oriented policies and practices not only safeguard ecological integrity but also act as catalysts for diversifying rural economies, improving agricultural productivity, and fostering resilience to environmental and geopolitical shocks.According to Statista, Ukraine's gross agricultural output is valued at USD 40.64 billion with a projected 2.07% annual growth rate (CAGR 2025-2029). Agricultural exports are expected to reach USD 17.6 billion by 2029, growing at approximately 3.02% annually. This underscores the sector's pivotal role, contributing 7.41% of national GDP and occupying 41.5 million hectares of land (Statista, 2025).

Nature conservation measures – such as crop rotation, agroforestry, and organic farming – can directly enhance this productivity while mitigating soil degradation and water scarcity risks. FAO (2023) reports that communities adopting ecosystem-based agriculture experience a 30% increase in soil productivity and 25% lower irrigation costs within five years.

Ukraine is the world's largest producer of sunflower seeds (24.7% of global output) and the leading exporter of sunflower meal (39.8% of global trade). These commodities are highly dependent on healthy soils, pollinator populations, and water resources – all of which are supported by conservation measures. Without adequate biodiversity protection, these export advantages could be undermined by declining yields and quality. Moreover, as the European Commission notes, EU Green Deal directives and Farm to Fork Strategy increasingly demand traceable, low-carbon, and eco-certified agricultural products. This shift in consumer preference opens premium markets for Ukrainian communities that integrate biodiversity protection with sustainable production methods (European Commission, 2021).

The global food packaging market is projected to grow by ~25% between 2022 and 2028, reaching USD 512 billion (Statista, 2025). This expansion is driven in part by the transition toward biodegradable and compostable materials. Integrating local agricultural production with packaging material supply chains – e.g., producing bioplastics from maize or sugarcane – could

provide dual benefits: new income streams for farmers and reduced environmental impact. For example, European bioplastic production capacity reached 2.42 million tonnes in 2023, with forecasts of >3 million tonnes by 2027 (European Bioplastics, 2024). Ukrainian territorial communities could position themselves as suppliers of feedstock for this sector, aligning with conservation principles while expanding economic opportunities.

Ecotourism represents another synergistic avenue for linking conservation with economic growth. The Ukrainian travel and tourism market is forecast to grow from €640.1 million in 2024 to €930.7 million by 2029, at a 7.77% CAGR (Statista, 2025). Nature reserves, protected landscapes, and agritourism initiatives – when effectively managed – can draw domestic and international visitors, creating employment opportunities while incentivizing habitat preservation. Examples from Poland's Białowieża Forest and Romania's Danube Delta illustrate how well-designed conservation areas can generate significant tourism revenue while safeguarding biodiversity. Ukrainian communities situated near national parks or Ramsar wetlands could replicate such models, especially when supported by local governance and infrastructure investment.

The comparative analysis of EU and Ukrainian frameworks indicates that decentralized governance and community-led initiatives tend to yield more sustainable outcomes than centralized, one-size-fits-all approaches. Municipalities that integrate biodiversity valuation into budget planning and direct a portion of eco-tourism or green business revenues into conservation funds can achieve long-term stability.

5. Conclusions

This study demonstrates that nature conservation is not a simple ecological objective but a multifaceted socio-economic transformation influenced by environmental policies, sustainable agricultural practices, market dynamics, and community engagement. The systematic review and comparative analysis of literature and case studies allow drawing several overarching conclusions:

1. To fully benefit from conservation, both community engagement and legislative action are necessary. Activating economic interests through the modification of local governance as well as strengthening the regulations employing the use of sustainable land use practices have positive environmental consequences. Policies implemented in agriculture that aid in modification of the conservation practices cherish healthy food environments with reasonable access to quality food. Such governance structures are important for enabling shifts towards sustainable agriculture and for ensuring that conservation policies do not inadvertently result in negative socio-economic impacts.

2. The analysis indicates that meeting the requirements of nature conservation in the socio-economic development strategies of the territorial communities is not only an obligatory condition for the ecological balance of nature, but it is also a stimulant for smooth economic adjustment and maintenance of level of food security. If local communities wish to survive in the future and protect the environment, long-term planning and short-term investments should be balanced. With an economic policy integrated with conservation, these communities can prosper without disturbing their natural ecosystem. This study demonstrates that nature conservation is not an isolated environmental agenda but a strategic driver of economic growth, food security, and public health in territorial communities.

Based on the systematic review, comparative analysis, and integration of quantitative data, the following conclusions can be drawn:

1. Conservation enhances agricultural productivity and economic resilience. Implementation of ecosystem-based agricultural practices (e.g., crop diversification, agroforestry, organic farming) improves soil health, optimizes water use, and maintains biodiversity, resulting in higher yields and reduced production costs.
2. Biodiversity protection strengthens market competitiveness. Ukraine's dominant position in global sunflower production and export is highly dependent on healthy ecosystems. Conservation safeguards these advantages while opening access to premium eco-certified markets, especially within the EU's Green Deal framework.
3. Integration with circular economy models creates new income streams. Aligning agricultural production with sustainable packaging supply chains (e.g., bioplastics feedstock) can generate additional revenue while reducing environmental impact and promoting low-carbon trade. Ecotourism provides a complementary economic pathway. Properly managed protected areas and rural landscapes can attract tourism investment, diversify local economies, and create jobs without depleting natural resources.
4. Local governance is pivotal for success. Decentralized decision-making and community-led conservation funds improve accountability and tailor strategies to local ecological and socio-economic contexts. Conservation policies require social balancing mechanisms. Short-term restrictions on resource use must be offset by targeted subsidies, skill development programs, and market integration to ensure community buy-in and equitable benefits.
5. Future Research Directions. To build upon the findings of this study, future research should: conduct longitudinal field studies. Track the economic and ecological impacts of conservation measures in specific Ukrainian communities over a 5-10 year horizon; integrate natural capital accounting into local governance analysis. Quantify how biodiversity valuation in municipal budgets affects decision-making, investment allocation, and resilience planning; examine socio-cultural dimensions of conservation adoption. Use participatory rural appraisal methods to understand community

perceptions, traditional knowledge integration, and barriers to behavioural change; assess post-war reconstruction scenarios. Evaluate how nature-based solutions can be embedded into agricultural and infrastructure restoration plans in conflict-affected regions of Ukraine; link conservation to food system innovation. Explore synergies between biodiversity protection, climate-smart agriculture, and advanced technologies (e.g., precision irrigation, AI-driven soil monitoring); analyse cross-border cooperation models. Study EU–Ukraine joint initiatives to identify effective mechanisms for knowledge transfer, funding, and scaling up conservation-led rural development.

Acknowledgements

This article has been prepared within the framework of the Ivan Vyhovskyi Award research fellowship (internship under the Award, Centre for East European Studies, University of Warsaw, Poland) and as part of the Visegrad Fund project (Slovakia, grant №. 52510523) in 2025/2026.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

IMPLEMENTATION OF DATA-DRIVEN ORGANISATION PRACTISES IN SME ENTERPRISES

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Purpose: In the modern economy, the concept of data-driven organization is gaining importance. This applies to both large, global enterprises and SMEs. The aim of this article is to examine whether implementing solutions typical of data-driven organization translates into improved financial performance in SMEs.
Design/methodology/approach: The author conducted his own survey (online survey) on a sample of 146 SMEs (respondents included managers and entrepreneurs). Respondents received a questionnaire containing closed-ended questions and questions requiring assessment based on a Likert scale, focusing on issues such as the degree of implementation of analytical tools and the approach to data in management. The theoretical section presents definitions, key characteristics of data-driven organizations, and the specific nature of the SME sector in the context of digital transformation.
Findings: Analysis of the research results indicates a clear correlation between the level of implementation of data-driven practices and a positive assessment of financial performance. Significant differences in approach were also identified depending on the industry and the level of the organizations' digitalization.
Research limitations/implications: In the future, it is also worth considering the customer perspective and the level of employee analytical competence as factors that may influence the effectiveness of data-driven organization solutions.
Originality/value: This article demonstrates the relationship between the implementation of data-driven solutions and the financial performance of SMEs. It can be a source of knowledge for entrepreneurs and managers planning investments in analytical technologies.
Keywords: data-driven organization, SME sector, small and medium enterprises.
Category of the paper: Research paper, viewpoint.

1. Introduction

In the 21st century, amidst the turbulent free market economy, data has become a key resource for companies, often exceeding the value of traditional physical assets. Their importance stems from the growing role of information in strategic decision-making, process optimization, and innovation. Access to precise data enables rapid adaptation to the changing market environment, translating into a competitive advantage and increased enterprise value.

Data from OpenAlex indicate that the topic of "data-driven organization" is enjoying growing interest in the scientific community. A total of 5377 publications related to this topic were identified. Articles constitute the largest part of the research material (3466), but there are also a significant number of dissertations (476), book chapters (346), and preprints (300). The dominant areas of research are big data and business intelligence (256 results), digital transformation in industry (64), quality and supply chain management (54), as well as HR and AI technologies. Geographically, the most research activity is demonstrated by institutions in the United Kingdom (1074), Australia (473) and the United States (468). The most frequently used keywords include "thematic analysis", "empirical research" and "business intelligence", confirming that the dominant trend is empirical research and qualitative analyses, focused on the use of data in a managerial and organizational context[1].

A search for the phrase "data-driven organization in SMEs" on OpenAlex reveals a significantly smaller number of publications – just 140. This shows that while the general topic of data-driven organizations is gaining interest, its application in the context of the SME sector remains niche. Among the publication types, academic articles predominate (69), and the topics focus primarily on entrepreneurship, big data, knowledge management, and digital transformation in companies. It is worth noting that the largest number of studies comes from universities in the UK, Australia, Germany, and Nigeria, indicating moderate but geographically diverse interest in this topic[2].

Valuable information on data-driven organization considerations is provided by a report generated using the Elicit platform (Table 1).

[1] https://openalex.org/works?page=1&filter=title_and_abstract.search:data-driven+organisation&group_by=publication_year,open_access.is_oa,primary_topic.id,authorships.institutions.lineage,type,authorships.countries,keywords.id

[2] https://openalex.org/works?page=1&filter=title_and_abstract.search:data-driven+organisation+in+SME&group_by=publication_year,open_access.is_oa,primary_topic.id,authorships.institutions.lineage,type,authorships.countries,keywords.id

Table 1.
A review of the literature on data-driven organization

Study	Study focus	Industry sector	Digital solutions implemented	Financial metrics used
Okeke et al., 2024	Impact of data-driven financial management systems on SME performance	Manufacturing, Retail, Services	Enterprise Resource Planning (ERP) systems	Revenue change, profitability ratios, financial liquidity
Pfister, Lehmann, 2023	Digital transformation and ROI of data analytics in SMEs	Not specified (German SMEs)	Data analytics tools	Revenue, revenue per customer, ROI
Klimecka-Tatar, Ingald, 2022	Digitization and process analysis in manufacturing SMEs	Manufacturing (not specified)	Value stream mapping, Total Productive Maintenance (TPM) indicators	process improvement
Surma-Syta, Majek, 2021	Use of accounting information in SME financial management	General SMEs (Poland)	Accounting data usage	Return on Equit, debt collection
Boichuk, 2020	Industry 4.0 solutions in automotive SME	Automotive (Poland)	Automated machines, cyber-physical systems, cloud services	productivity improvement
Pech, Vrchota, 2020	Industry 4.0 implementation classification in SMEs	Manufacturing (Czech Republic)	IT infrastructure, digitalization, sensors, Big Data tools	implementation level, investment cost
Szopa, Cyplik, 2020	Digital transformation model for SME supply chains	Furniture manufacturing (Poland)	Digital platforms, cloud services, Internet of Things (IoT)	digitization index
Wasiński, 2018	Performance measurement systems and financial results in SMEs	General SMEs (Poland)	Optima (Comarch), Customer Relationship Management (CRM) tools, performance measurement systems	relationship between measurement systems and financial results
Zimon, 2018	Impact of group purchasing organizations on SME financials	Construction wholesalers (Poland)	Central warehouse, procurement strategies	Revenues, costs, profitability and liquidity
Drelichowski, 2012	ERP and Business Intelligence (BI) tool efficiency in micro/small enterprises	Printing (Poland)	Enterprise Resource Planning (ERP) and Business Intelligence (BI) tools	efficiency, success factors

Source: Elicit.

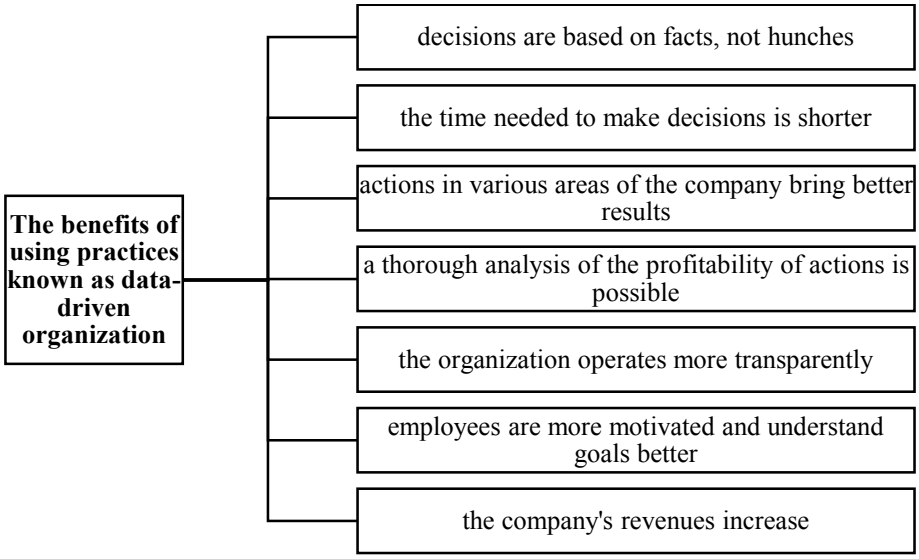
Analysis of the report reveals that research on the concept of data-driven organization in the SME sector covers a wide range of areas. Some focus on the impact of digital financial tools, such as ERP systems and data analytics, on corporate financial performance, while others analyze the broader context of digital transformation, including the implementation of Industry 4.0 solutions and process automation.

The diversity of industries – from manufacturing, through trade, to services – demonstrates that a data-driven approach is applicable across many sectors (Mandal, 2019). The range of financial metrics used is equally broad, indicating the lack of a single, universal model for assessing the effectiveness of data-driven activities in SMEs (Liu, Bell, 2019; Mehdi, 2018).

There is no single definition of the term "data-driven organization", although there are some characteristic elements. The most important is the conscious use of data by decision-makers – not just its collection. The essence of a data-driven approach is not to gather as much information as possible without putting it to practical use (Klimecka-Tatar, Ingaldi, 2022; Drelichowski, 2012). The key to success is its systematic analysis to achieve the strategic goals of the organization (enterprise) (Cao, Duan, 2017; Liu, Bell, 2019).

In the context of a data-driven organization, we refer to a model in which every decision is made based on analytical data (Surma-Syta, Majek, 2021). This approach means a shift away from basing actions on intuition, subjective opinions, or individual experiences. The implementation of this management model represents a significant organizational transformation, of paramount importance in a dynamic market environment (Klimecka-Tatar, Ingaldi, 2022; Zimon, 2018). It results in greater coordination of activities and a better understanding of shared goals by all teams (Pech, Virchota, 2020). The benefits of properly implemented techniques collectively referred to as data-driven organization are presented in Figure 1.

Figure 1.
The benefits of using practices known as data-driven organization



Source: Based on: Zimon, 2018; Surma-Syta, Majek, 2021; Drelichowski, 2012; Szopa, Cyplik, 2020; Rotella, 2012; McAfee, Brynjolfsson, 2012; Lindgardt et al., 2009; Gawin, Marcinkowski, 2017b.

A data-driven organization is one in which decisions are consistently based on reliable information. A key characteristic of such a company is the widespread belief – at every level, not just among management – that data is reliable, valuable, and forms the basis of action. In the process of transitioning to full analytical maturity, organizations progress through successive stages (Zimon, 2018; Surma-Syta, Majek, 2021; Cheah, Wang, 2017). The first is a complete lack of data – the organization neither possesses nor collects any information about its customers or processes. The second stage, "tracking", is the implementation of tools for basic traffic tracking (this can be data derived, for example, from web analytics tools). The third

stage, "data capture", involves not only collecting data but also ensuring its quality. The company ensures that the data is complete and that the collection systems are properly configured. At the fourth stage, "reporting", the data begins to be used across the organization, by employees from various departments and at various levels – from senior management, through middle managers, to assistants. Reports and dashboards are created for ongoing data visualization and interpretation. The fifth stage, "analysis and insights", is when data is actively analyzed and transformed into specific recommendations. Companies conduct campaign analyses, segment customers, test communication options, and personalize content (Surma-Syta, Majek, 2021; Drelichowski, 2012; Szopa, Cyplik, 2020; Cao, Duan, 2017). The final level is where data supports the functioning of the entire company – from operations, through HR, to management strategy (Szopa, Cyplik, 2020; Gawin, Marcinkowski, 2017a; Osterwalder, Pigneur, 2010).

Data is not only a byproduct of economic processes, but one of the most valuable strategic resources that can determine competitive advantage. Implementing the data-driven organization concept means that enterprise management is based primarily on reliable data analysis, not solely on intuition. Data becomes the foundation for rational decisions, enabling the prediction of market trends, more precise planning of activities, and optimization of operational and financial processes. Systematic data collection, processing, and interpretation enable the creation of advanced predictive models that support management in real-time decision-making. As a result, the organization gains greater flexibility, the ability to immediately respond to changing environments, and the ability to mitigate business risk. Importantly, data-driven management is not limited to large corporations; it also allows small and medium-sized enterprises to better tailor their offerings to customer needs, identify inefficiencies more quickly, and compete more effectively in dynamically developing markets. A data-driven approach therefore fosters an organizational culture in which decisions are objective, transparent, fact-based, and easy to verify, which significantly minimizes the risk of strategic errors and strengthens the long-term stability of the organization (Surma-Syta, Majek, 2021; Drelichowski, 2012; Cao, Duan, 2017).

Data-driven organization in small and medium-sized enterprises (SMEs) is currently the subject of intensive global research. Kasiri, Cirino, and Narimanian (2024) indicate that implementing business analytics and big data tools in American SMEs requires not only analyzing barriers resulting from the size and industry of the enterprise but also considering awareness of new trends and how companies adapt to dynamically changing technologies. Asgary, Ozdemir, and Özyürek (2020) demonstrate that Turkish SMEs perceive global economic, technological, and social threats differently from major global players, which influences their strategic decisions, resource allocation, and risk management plans. Chen, Li, and Zhang (2024) analyze Chinese SMEs operating within digital platforms, emphasizing that the use of data drives the development of dynamic organizational capabilities and supports the implementation of responsible innovation, while regulatory pressures and digital customer

expectations further enhance the effectiveness of these solutions. These studies indicate that regardless of the local context, SMEs face similar challenges related to access to modern technologies, adaptation to analytical trends and risk management, although regional differences shape different implementation strategies and risk perceptions.

This article puts forward the following research hypotheses, which will be verified later in the work:

- H1: Respondents' (entrepreneurs, managers) interest in using a data-driven approach increases with company size (measured by the number of employees).
- H2: Respondents' (entrepreneurs, managers) interest in using a data-driven approach increases with company time on the market.
- H3: Whether implementing data-driven solutions has a positive impact on the company's financial results correlates with company size, measured by the number of employees.
- H4: Employees have only limited knowledge of business data analysis software; there are significant gaps in this area, and this is independent of company size.
- H5: Whether operational employees are involved in data analysis processes or use analysis results does not correlate with company size.

The author verified the hypotheses based on a statistical analysis of the results of his own empirical research (for this purpose, selected methods of descriptive statistics, as well as correlation coefficients, etc., were used).

2. Methods

The survey questionnaire, which forms the basis of the empirical section of this study, was conducted from August 17 to September 4, 2025. Respondents were business owners and executives in SMEs. The questionnaire was prepared using MS Forms. The survey form contained closed-ended, single-choice, and multiple-choice questions, as well as Likert-scale questions. Table 2 summarizes questions included in the self-research questionnaire.

Table 2.
Questions included in the self-research questionnaire

Question number	Question	Answers / Instructions
1	How many people does your company currently employ?	In numbers
2	What industry does your company operate in?	Production/Trade/Services
3	How long has the company been operating on the market?	In years
4	How often is business decision-making in a company based more on data than on intuition?	Please rate on a scale of 1-5 (1 – very rarely, 5 – regularly)

Cont. table 2.

5	To what extent are the following activities undertaken in the enterprise: • Automation of decision-making processes. • Monitoring key, measurable performance and quality indicators. • Integration and analysis of data from various sources. • Sharing data with operational staff as well.	Please rate on a scale of 1-5 (1 – very rarely, 5 – regularly)
6	What areas of the company's operations are analyzed based on measurable data? • HR. • Price calculation. • Financial forecasts, sales forecasts, etc. • Cost analysis. • Staff work efficiency. • KPI performance indicators (e.g. revenue per employee, operating margin level). • Investment profitability analysis. • Creating a company budget.	Please rate on a scale of 1-5 (1 – very rarely, 5 – regularly)
7	Has the implementation of data-driven solutions had a positive impact on the company's financial results (e.g. increased revenue, reduced costs)?	Please rate on a scale of 1-5 (1 – definitely not, 3 – occasionally, 5 – definitely yes)
8	To what extent are the company's management staff able to use business data analysis software? • Microsoft Excel (with Power Query and Power Pivot). • Microsoft Power BI. • Tableau. • Programming languages, including R and Python. • SQL. • Zapier.	Please rate on a scale of 1-5 (1 – no knowledge of the software, 5 – proficient knowledge)
9	Are operational staff involved in data analysis processes or use the results of analyses?	Please rate on a scale of 1-5 (1 – very rarely, 3 – occasionally, 5 – regularly)
10	What are, in your opinion, the barriers to implementing data-driven organisation activities: • Lack of analytical skills among employees. • No time. • Low level of digitization in the company. • Employee resistance. • Lack of appropriate IT tools and systems. • Difficulty integrating data from different sources. • Concerns about data security and confidentiality.	Please rate on a scale of 1-5 (1 – a very strong barrier, 5 – the given factor is not a barrier)
11	Are you planning further investments in the development of analytical systems in the next 12 months?	Yes/No

Source: Own research.

The first set of questions (3 questions) concerned general information about the company, including: the scale of business operations measured by number of employees, company time on the market and the main sector of business activity. The next section, consisting of 9 questions, explored respondents' approaches to implementing solutions collectively referred to as data-driven organizations. A total of 146 completed forms were received.

3. Results

The study allowed us to obtain the following results (selected measures of descriptive statistics – Table 3). These results provide insight into key variables and their distributions within the sample. They serve as a foundation for further analysis and interpretation of the data-driven practices implemented by the SMEs. The detailed descriptive statistics presented in Table 3 help to contextualize the findings and highlight important trends in the dataset:

Table 3.
Survey results (selected measures of descriptive statistics)

	Question number							
	1	**2**	**3**	**4**	**5.1**	**5.2**	**5.3**	**5.4**
Average	30.16	Production: 19.9% Services: 60.3% Trade: 19.9%	8.31	3.29	2.14	3.23	3.36	3,33
Maximum	99		15	5	3	5	5	5
Minimum	3		2	1	1	1	1	1
1st quartile	16		6	3	2	2	3	2
2nd quartile (median)	23		7.5	3	2	3	3	3
3rd quartile	42		10	4	3	4	4	4
Variance	418.46		11.41	1.29	0.54	1.86	1.58	1,75
Mode	16		7	3	2	4	3	4
Question No	**6.1**	**6.2**	**6.3**	**6.4**	**6.5**	**6.6**	**6.7**	**6.8**
Average	2.6	4.48	3.65	4.38	2.77	3.68	3.42	3,14
Maximum	4	5	5	5	4	5	5	4
Minimum	1	1	2	2	2	3	3	3
1st quartile	2	4	3	4	2	3	3	3
2nd quartile (median)	3	5	4	5	3	4	3	3
3rd quartile	3	5	4	5	3	4	4	3
Variance	0.57	0.75	0.38	0.68	0.28	0.37	0.3	0,12
Mode	3	5	4	5	3	4	3	3
Question No	**7**	**8.1**	**8.2**	**8.3**	**8.4**	**8.5**	**8.6**	**9**
Average	3.07	3.66	2.72	1.38	1.01	1.04	2.03	2,49
Maximum	5	5	4	4	2	2	4	5
Minimum	1	1	1	1	1	1	1	1
1st quartile	2	3	2	1	1	1	2	2
2nd quartile (median)	3	4	3	1	1	1	2	2
3rd quartile	4	5	4	1.75	1	1	2	3
Variance	1.77	1.15	1.43	0.55	0.01	0.04	0.34	1,44
Mode	2	4	4	1	1	1	2	2
Question No	**10.1**	**10.2**	**10.3**	**10.4**	**10.5**	**10.6**	**10.7**	**11**
Average	2.58	2.76	3.11	2.72	2.77	3.23	2.97	Yes: 65,1% No: 34,9%
Maximum	5	5	5	4	4	4	3	
Minimum	1	1	1	2	2	1	2	
1st quartile	2	2	3	2	2	3	3	
2nd quartile (median)	3	3	3	3	3	3	3	
3rd quartile	3	4	3	3	3	4	3	
Variance	1.58	1.4	0.86	0.22	0.26	0.76	0.03	
Mode	3	3	3	3	3	4	3	

Source: Own research.

H1: The interest of respondents (entrepreneurs, managers) in using a data-driven approach increases with company size (measured by the number of employees)

Analysis of the relationship between company size (which the author measures by the number of employees) and the frequency of making business decisions based on data rather than intuition revealed a significant positive Kendall's tau-b correlation of 0.646. Therefore, as the number of employees increases, companies' propensity to use data in their decision-making processes increases.

H2: Respondents' (entrepreneurs and managers) interest in using a data-driven approach increases with the length of a company's market presence

Unlike the previous analysis, where the correlation was strong, this relationship is significantly weaker (Kendall's tau-b correlation of 0.16), meaning that the length of a company's market presence has only a small impact on the propensity to base decisions on data. Nevertheless, this result confirms the hypothesis posed in the introduction, indicating that greater market experience promotes, albeit to a very limited extent, a more frequent use of analyses and facts.

H3: The positive impact of implementing data-driven solutions on a company's financial performance correlates with company size, measured by employee count

Analysis of the relationship between the number of employees and the assessment of the impact of implementing data-driven solutions on financial performance revealed a positive Kendall's tau-b correlation of 0.229. This indicates a moderate, yet noticeable, trend, according to which the positive impact of such solutions is more often observed in larger companies. This indicates that as employment scale increases, the likelihood of effectively utilizing a data-driven approach increases. This result is consistent with the hypothesis posed in the introduction, according to which larger companies can better derive financial benefits from implementing analytical tools.

H4: Employees are only able to use business data analysis software to a limited extent, there are serious gaps in this area and this does not depend on the size of the company

The table below presents the distribution of ratings given in response to question no. 8 (Table 4):

Table 4.
Distribution of answers to question no. 8

Rate	Microsoft Excel (with Power Query and Power Pivot)	Microsoft Power BI	Tableau	Programming languages, including R and Python	SQL	Zapier
1	0.68%	21.92%	74.66%	98.63%	95.89%	15.07%
2	17.81%	23.29%	16.44%	1.37%	4.11%	67.81%
3	21.92%	15.75%	5.48%	0.00%	0.00%	16.44%
4	33.56%	39.04%	3.42%	0.00%	0.00%	0.68%
5	26.03%	0.00%	0.00%	0.00%	0.00%	0.00%
Total:	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Source: Own research.

The highest level of familiarity (score 5) was recorded for Microsoft Excel (26.03% of respondents), although this tool also received a relatively high percentage of average ratings (scores 3 and 4 – a total of 55.48%). Microsoft Power BI received a high percentage of 4 ratings (39.04%), suggesting it is relatively well-known, although there are few experts (0% in the 5 rating). Tableau was dominated by responses indicating lack of familiarity (74.66% – score 1), and a similar situation was observed for programming languages such as R and Python (98.63% – no familiarity) and SQL (95.89% – no familiarity). Zapier, on the other hand, is relatively more likely to receive a basic rating (67.81% – score 2), which may be due to its simpler nature and use in process automation. Overall, the results show that management competencies are mainly focused on Excel and, to some extent, Power BI, while more advanced tools such as Tableau, programming languages, and SQL remain largely unknown.

4. Summary

The implementation of data-driven organizational practices is crucial for small and medium enterprises (SMEs) as it enables them to make informed decisions based on evidence rather than intuition alone. This approach improves operational efficiency, enhances customer insights, and allows SMEs to respond quickly to changing market conditions. Embracing a data-driven culture helps these enterprises gain a competitive edge, optimize resources, and foster sustainable growth in an increasingly digital and complex business environment. Based on theoretical and empirical analysis, the author made the following conclusions:

- Using a data-driven organization allows companies to make more informed decisions, increasing management efficiency and minimizing business risk.
- Small and medium-sized enterprises, despite limited resources, can use data analysis to compete more effectively with larger entities, optimizing processes and better responding to market needs.
- Entrepreneurs and managers' interest in a data-driven approach increases with company size; larger companies are more likely to make data-driven business decisions (Kendall's tau-b = 0.646).
- The length of a company's presence in the market has only a small effect on the increased use of data in decision-making (Kendall's tau-b = 0.16), although the trend is consistent with the hypothesis.
- The impact of implementing data-driven solutions on financial performance is more noticeable in larger companies (Kendall's tau-b = 0.229), suggesting that employment scale favors more effective use of analytics in practice.

- Employee competencies in using data analysis tools are limited and do not depend on company size; Excel is the most familiar, followed by Power BI, while Tableau, SQL, and the R and Python programming languages remain largely unknown.

Based on theoretical and empirical analysis, it was found that a data-driven approach significantly increases management efficiency, minimizes business risk, and allows SMEs to compete more effectively with larger entities by optimizing processes and responding more quickly to market needs. In practice, larger companies achieve clearer financial benefits, although certain limitations must be considered, including the fact that employee competencies in data analysis tools are not always at an adequate level. For practitioners, this means the need for systematic investment in training in advanced analytical tools, developing competencies in data interpretation, and building an organizational culture that supports data-driven decisions. For policymakers and SME support programs, creating initiatives to finance the purchase of analytical tools, as well as organizing dedicated industry training and mentoring tailored to the specifics of the sector, company size, and available human resources, is becoming crucial.

The considerations presented in this paper constitute a starting point for further, in-depth analyses of the phenomenon of adopting a data-driven approach in enterprises. In particular, it seems justified to expand the research perspective to include the variable of business sector. Differences in the methods and scale of data utilization may result not only from the size of the company or its length of operation, but also from the nature of the market environment, regulatory requirements, and the intensity of competition in a given sector. An industry-specific approach would allow for the capture of different patterns of analytical tool implementation, thus providing conclusions with greater application value.

Another area that requires further research is the comparison of SMEs with large companies, both in terms of technological advancement and the organizational culture supporting data-driven decision-making. Such an analysis could reveal differences in resource availability, staff competencies, and the pace of adoption of new technologies. The results of such research would be of significant importance not only to the academic community but also to management practitioners, providing them with reliable guidance on the effective implementation of data-driven strategies in various types of organizations.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE
SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

PERSPECTIVES ON NETWORK COOPERATION OF SME BUSINESSES AS AN ENTREPRENEURIAL INITIATIVE

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Purpose: The purpose of this paper is to analyse network cooperation, its impact on the development of entrepreneurship and relevance for implementation in the small and medium-sized enterprise sector.
Methodology: A review of the literature on the subject, theoretical concepts and models describing the functioning of network relations in the context of entrepreneurship. The method of analysis draws on existing theories and concepts relating to business networks.
Findings: Small and medium-sized enterprises increasingly often look at network cooperation as a key component of their development strategies, which allows them to boost innovation and operating efficiency. Participation in networks fosters the emergence of new business ideas, facilitates the transfer of knowledge and technology, and enables the implementation of joint research and development projects. Network cooperation affords SMEs access to financial, technological and human resources that would be difficult to reach on their own. Networks create opportunities for development in new markets and distribution channels. Companies participating in networks are capable of competing more effectively against larger entities by developing joint proposals, sharing costs and strengthening their market position. The effectiveness of network cooperation is largely reliant on mutual trust, good communication and strong relationships between partners. Those factors have a significant impact on the sustainability and effectiveness of the cooperation. The development of network cooperation requires active support from the authorities, including in respect of financial, advisory and educational instruments that may improve business readiness to engage in such initiatives.
Originality/value: This study offers a novel perspective by integrating the concept of network cooperation with entrepreneurial initiatives in the SME sector. While previous research often tackled those aspects separately, this paper emphasises the role of inter-business networking as a catalyst for innovation, startup creation, and business growth.
Keywords: entrepreneurship, organisational network, small and medium-sized enterprises sector.
Category of the paper: Research paper.

1. Introduction

The modern economy is characterised by growing complexity, disruptive technologies, and intense competition. Under such circumstances, of particular importance are flexibility, innovation and the capacity to respond quickly to market needs, which are all typical of entrepreneurship, especially in the small and medium-sized enterprise (SME) sector. This sector is the foundation of the European and national economies, playing a key role in the labour market, regional development and the implementation of innovation.

One of the tools supporting the development of entrepreneurship among SMEs is networking, understood as long-term partnerships between independent economic entities, business support and research institutions. Cooperation networks allow companies to share resources, reduce costs, improve access to knowledge and technology, and jointly undertake innovative projects.

The creation of networks of organisations is a tool to achieve better results in every area of a company's operations through cooperation with other entities, the harnessing of shared creative potential and the focus on mutual benefits. Those goals can be achieved through cooperation with specialised organisations, often with complementary functions, and lead to creative and innovative activities and new value.

SMEs are increasingly often recognising the benefits of cooperation, although the process still faces numerous barriers, such as the lack of trust, limited management competence and low awareness of the options for cooperation. For that reason, it is particularly important to examine the prospects for the development of network cooperation as a tool that supports entrepreneurial initiatives in the SME sector.

2. Network organisation and operating principles

The management of a network organisation should focus on managing dependencies between individual participants – network partners – as well as between the network as a whole and its individual members. Based on the assigned tasks and objectives of the organisational network, a team of interrelated entities is built, where the entities complement one other with key competences for the common goal of the partnership cooperation.

The crucial organisation in the network is the orchestrator, who organises the network, coordinates its activities, defines its objectives, scope of activities and the means of achieving those objectives. That entity shapes its structure, determines the participants, defines the role of each partner, and their relationships and links with other network participants, but also shapes trust-based cooperation between entities (Tubielewicz, 2013). The orchestrator introduces

a motivation system ensuring a specific distribution of benefits for all partners. Those tasks require the orchestrator to ensure an efficient system of communication with other partners, including access to information exchange. The orchestrator's actions should also demonstrate a dynamic approach to new opportunities created by the network and its participants. The orchestrator's tasks should therefore be focused on creating economic or social ties that unite network participants through common ideas, development prospects, or mutual trust.

A network organised and managed by the orchestrator as described above should perform its tasks and achieve its objectives more effectively and generate greater added value than companies outside the network.

Network management, ensuring effective and sustainable cooperation between entities in order to achieve mutual benefits, should be based on specific principles and assumptions for the functioning of the network, which include (Odlanicka-Poczobut, Knop, 2016):

- the principle of cooperation – striving to achieve goals and satisfying needs and desires,
- the principle of responsibility – cooperating entities must take responsibility for the consequences of their actions,
- the principle of complexity – the ability to act on the basis of multifaceted principles, jointly created and shared by them,
- the principle of continuous creation – the creation of new values through cooperation with partners,
- the principle of cooperation – relationships between partners based on trust, ensuring that each partner has access to the information necessary to make improvements that will benefit the entire network.

A properly functioning network requires the mobilisation of partners to achieve strategic objectives and to ensure that network partners have common tasks assigned to them and that they are ready to take on new challenges set at the stage of building the network organisation. If a company or another organisation decides to participate in the network, its project must be consistent with its business needs and the expected benefits that participation in the network can bring to the company (Tubielewicz, 2013).

Strategic objectives adopted by the network management and the ways of achieving them allow to formulate the definition of the primary principles of the network's operation (Tubielewicz, 2013):

- consistency of objectives – achieving one's own objectives as well as those set for the network,
- interdependence – which includes, among other things, benefits and risks; interdependence increases the cohesion of the network and contributes to improved cooperation,
- trust and commitment – resulting from the consistency of the partners' efforts to fulfil their tasks and obligations,

- communication and information – results from maintaining good communication between companies, assumes equal access to information and its flow or processing. It is therefore necessary to build an integrated information and communication infrastructure for the network.

Managing a network requires its participants to think strategically, using their knowledge, experience and skills to set the conditions under which the network organisation will operate and the prospects for developing its production, organisational and marketing potential. Those activities also include setting the direction, scope and spatial dimensions of the network in the context of cooperation and coordination of network activities, and building economic, organisational and social relations in order to maintain a sustainable competitive advantage for the network in an increasingly competitive market.

3. Entrepreneurship – theoretical aspects

One of the first definitions of entrepreneurship comes from A. Marshall, a neoclassical economist, who identified entrepreneurship as the fourth factor of production, alongside capital, labour and land. He also argued that entrepreneurs, as creators and leaders, should demonstrate a set of personality traits, a specific attitude, behaviour, and a tendency to initiate creative or innovative activities. Those abilities allow them to take advantage of entrepreneurial opportunities (Lichtarski, 2007).

On the other hand, J. Schumpeter (1962) believed that entrepreneurship is a type of activity that involves introducing new combinations of production factors, new products and methods, acquiring new markets and new sources of supply, and creating new, more effective organisational forms of economic activit (Bratnicki, Strużyna, 2001). He also distinguished five functions of entrepreneurship, the most important of which are (Schumpeter, 1962):

- the production and distribution of new products,
- introducing new production methods,
- creating new economic forms,
- discovering new markets,
- discovering new sources of supply of raw materials and inputs.

Entrepreneurship also refers to the activities of entrepreneurs in their environment, their actions for the benefit of the environment in which they operate, which comprises: employees, investors, shareholders, customers, competitors, the state, local communities, social organisations, the natural environment, etc. (Sudoł, 2006).

Similar concepts of entrepreneurship were also presented by P. Drucker, J. Timmons and H. Stevenson, who believed that the market is subject to permanent change, which is why a business must be an organ of growth and expansion. It is not enough to simply supply the

market with any goods or services. An entrepreneur must offer products of increasingly better quality and at increasingly lower prices.

J. Timmons (1999) defines entrepreneurship as "the pursuit of opportunities without regard to the constraints of currently controlled resources" and "a way of thinking, reasoning and acting that is directed towards the exploitation of opportunities". He was inspired by H. Stevenson et al. (1994), who defined entrepreneurship as "creating something valuable out of practically nothing". In both approaches, the idea is of seminal importance, and acquiring resources for its implementation carries much less weight. The following typology for understanding the concept of entrepreneurship can be provided (Glinka, 2008):

- running a small business - ways of managing a small organisation (Piasecki, 2001),
- a characteristic of individuals – a spirit of initiative (Chell, Haworth, Brearley, 1991),
- a socio-economic phenomenon – the creation of enterprises and innovation (Kwiatkowski, 2000),
- economic activity – initiative in business, i.e. corporate entrepreneurship (Pinchot, 1985),
- field of teaching – entrepreneurship as a way of coping in practice, in economic reality (Glinka, 2008).

Behaviour refers to a specific type of activity, the ability to use ideas and opportunities that are overlooked by others. It results from the attitudes of entrepreneurs and is determined by their needs and personality traits (Piecuch, 2010).

The process aspect manifests itself in the creation and development of new business ventures. In this sense, entrepreneurship is a process that involves innovative activities and takes into account the possibility of risk, with the purpose of achieving the intended benefits.

The functions of entrepreneurship of economic entities are also important, as they reflect their competitiveness and their efforts to introduce changes. These functions can be primary or auxiliary. Primary functions influence the achievement of set goals, while auxiliary functions include economic activities that are necessary for the achievement of the main goals. Entrepreneurship can also perform a regulatory function, concerning the shaping of the organisational structure (Moczydłowska, Pacewicz, 2007).

That was pointed out by A. Koźmiński (2004), who identified different functions of entrepreneurship, which relate to: more effective use of the available resources, flexibility in responding to market signals, creating innovation, and reducing disparities between the enterprise and its environment.

Creativity becomes the driving force for entrepreneurship, as it determines the search for and creation of opportunities. It also consists in the ability to think out of the box, which is reflected by new, innovative solutions (Karpacz, 2011). Having the right aptitude and utilising one's potential is instrumental in achieving success and full satisfaction from the achievement of one's goals.

A list of selected definitions describing the phenomenon of entrepreneurship is presented in Table 1.

Table 1.
Selected definitions of entrepreneurship according to various authors

Authors	Basic definitions
F.H. Knight (1921)	Profits in exchange for risk and uncertainty.
J.E. Schumpeter (1934)	The introduction of new combinations of company organisation, new products, new services, new sources of raw materials, new production methods, new markets, new forms of organisation.
B.F. Hoselitz (1952)	Bearing uncertainty, coordinating production resources, introducing innovation and providing capital.
A.H. Cole (1959)	Purposeful activity aimed at establishing and developing a profit-oriented company.
D.C. McClelland (1961)	Differentiation of risk-taking.
H. Leibenstein (1968)	Identifying and organising needs and resources for economic development.
M. Kirzner (1973)	The ability to see new opportunities, to seek out opportunities that others have not yet seen, in order to make a profit; knowing where to look for information.
C.A. Kent (1982)	A process of self-destruction and creative destruction that "sweeps away" old products and technologies, destroys old markets and the companies that supplied them, which is at the root of economic progress.
W. Garter (1985)	The creation of new organisations.
H.I. Grousbeck, M.J. Roberts, H.H. Stevenson (1989)	The pursuit of opportunity without regard to the constraints imposed by currently controlled resources.
R.D. Hisrich, MP. Peters (1992)	The process of creating something different in terms of value, devoting the necessary time and effort, assuming the accompanying financial, psychological and social risks, and thereby obtaining financial reward and personal satisfaction.
M. Duczkowska-Piasecka (1993)	A way of behaving based on knowledge rather than intuition.
R.W. Wright, D.A. Ricks (1994)	Leverage and flexibility of organisational resources.
J. Machaczka (1998)	The entirety of activities related to the launch of a new venture.
R.W. Griffin (1998)	Entrepreneurship is the process of organising and conducting business activities and taking the associated risks.
B. Wawrzyniak (1999)	The process of actively responding to any global changes.
T. Gruszecki (2002)	Entrepreneurship is a complex set of activities and predispositions of a specific person.
J.D. Antoszkiewicz (2003)	Activity leading to development and value creation.
S. Shane, S. Venkataraman (2003)	All activities that consist of identifying, evaluating and exploiting opportunities for introducing new products and services, or new ways of organising, new markets, raw materials.
J. Siekierski (2003)	The ability to actively work individually or in a team in a specific field.
J.A. Timmons, S. Spinelli (2004)	Creating new ventures, the classical expression of which is an innovative idea that transforms into a rapidly growing company.
Z. Dowgiałło, W. Nadworny (2005)	Entrepreneurship is a process of activities directed, under given conditions and with the presence of risk, towards establishing and developing a new venture or improving an existing one.
M. Stużycki (2006)	Entrepreneurship is not a sphere of ideological activity, but a well-understood interest for every entrepreneurial individual and enterprise.
F. Kapusta (2006)	Entrepreneurship is treated not only as an attitude, but also as a process. Entrepreneurship as a process consists precisely in the creation and development of enterprises – units of entrepreneurial economic activity.
T. Piecuch (2010)	A specific philosophy of action and functioning of enterprises. It is a tremendous driving force, a factor in the economic development of individual enterprises, regions and entire economies. It is one of the most important attributes of the market economy model.

Source: author's own research based on: Knight, 1921; Schumpeter, 1934; Hoselitz, 1952; Cole, 1959; McClelland, 1961; Casson, 1982; Gartner, 1985; Stevenson, Roberts, Grousbeck, 1989; Kapusta, 2006; Piecuch, 2010; Strużycki, 2006; Duczkowska-Małysz, Duczkowska-Piasecka, 1993; Machaczka, 1998; Siekierski, 2003; Griffin, 1998; Timmons, Spinelli, 2004; Leibenstein, 1968; Hisrich, Peters, 1992; Wright, Ricks, 1994; Kirzner, 1973; Kent, Sexton, Vesper, 1982; Shane, 2003; Gruszecki, 2002; Dowgiałło, Nadworny, 2005; Antoszkiewicz, 2003; Wawrzyniak, 1999.

Entrepreneurship is therefore a process whose emergence and development depends on multiple stimuli. It is the result of a combination of various conditions, depending both on the internal predispositions of specific individuals undertaking such activities, and on the external conditions in which the entrepreneur operates. Based on the above arguments, it can be concluded that there are interdependencies between the factors that create entrepreneurship, which may complement each other, but may also inhibit or limit each other.

Entrepreneurship can be described as a socially conditioned process of creating opportunities for wealth creation, and their creative use through the application of financial, property, human and social capital in an innovative way (Klasik, 2006). Cultural factors such as the systems of values and beliefs, traditions, trust as a cultural resource, family ties and the social climate also underpin the development of entrepreneurship (Kraśnicka, 2002). Recent years have seen many studies that treat entrepreneurship as a process occurring in organisations of all types and sizes. Entrepreneurship is understood in those studies not so much as a phenomenon, but as a process of creating new value through the use of a unique combination of resources and production factors combined to achieve new outcomes (Barczyk, 2004).

In analysing the phenomenon, the role of the entrepreneur becomes extremely important, as they operate in conditions of uncertainty, risking capital, and claiming the right to allocate profits as compensation for the risk they take (Knight, 1921). The entrepreneur's ability to take risks and engage in economic activity based on entrepreneurial actions may lead to (Kuszlin, Fołomyjow, 2000):

- high level of activity and striving for success,
- the ability to obtain internal company information and market information,
- the responsibility for making and implementing high-risk decisions,
- the ability to take all kinds of risks, to seek out market opportunities and initiate them.

The concept of entrepreneurship can only be formulated by taking into account the relationship between understanding that category as a feature and as a function. Thus, entrepreneurship is a set of activities aimed at creating and implementing ventures that allow for the achievement of specific values in conditions of uncertainty and risk (Bojewska, 2002).

The development of entrepreneurship among economic entities also depends to a large extent on the local environment. This was pointed out by M.E. Porter (2001), who argued that "companies are specifically dependent on the business environment in which they operate". The presence of local or regional entrepreneurial environments is the result of the interplay of several sectors of the economy and the development of reasonable behaviour by enterprises on the market (Ochojski, Szczupak, Zieliński, 2006).

4. The essence of regional entrepreneurial development towards the creation of networks

The competitiveness of the Polish economy in an increasingly global market is determined by the introduction of innovative process, technical and organisational solutions and their adaptation to market requirements, which include entrepreneurship, competitiveness and the creation of network relationships.

The development of entrepreneurship at the regional level is one of the key factors strengthening the economy and increasing the competitiveness of a given area. Contemporary approaches to regional development increasingly often argue that economic progress is not generated solely by the achievements of individual enterprises, but largely depends on the ability to establish and maintain lasting cooperative relationships between various entities operating in the region. The creation of networks among entities, especially from the small and medium-sized enterprise sector, and other participants in the regional business environment, is becoming an important element of economic development strategies. In this context, organisational networks play the role of the catalyst for innovation processes, enabling the effective exchange of knowledge, resources and experience that are difficult to access for individual entrepreneurs.

Network cooperation allows SMEs to overcome barriers resulting from limited capital, human resources or technology. Small and medium-sized enterprises often lack the capacity to finance research and development on their own and thus access specialist knowledge. Within networks, however, cooperation can take various forms, ranging from formal structures such as clusters or consortia, to informal groups based on personal relationships and mutual trust.

Entrepreneurial networks create a unique environment that fosters the creation and development of innovation. Joint research and development projects, the exchange of best practices and integration with scientific institutions and business support organisations, allow for a rapid implementation of modern technology and organisational solutions. This, in turn, translates into increased competitiveness of regional enterprises and entire sectors of the economy. Organisational networks also form the basis for building social capital based on trust, cooperation principles and mutual support. That capital is extremely important in the process of entrepreneurship development, as it promotes openness to knowledge sharing and the creation of lasting business relationships.

However, the development of entrepreneurial networks still faces challenges and barriers. Among those, the lack of trust between entrepreneurs comes first, which stems from the anxiety of losing competitive advantage, and reluctance to share information. In addition, many SMEs struggle with limited competence in managing network cooperation and the lack of knowledge about the benefits of participating in networks. Also, they often encounter insufficient support from business environment institutions and public administration, which should rather act as

facilitators and coordinators of network processes. In addition, cultural and communication barriers can hinder effective cooperation, especially in regions where there are disparities in economic and social potential.

In order to effectively support the development of entrepreneurship towards networking, it is necessary to take action at various levels. Regional policy should actively promote cooperation and create conditions conducive to the integration of economic operators, e.g. by financing network projects, organising training and workshops, and facilitating access to research and development infrastructure. EU-funded programmes that enable joint initiatives by entrepreneurs and business support institutions are particularly important. Such support also allows for the building of lasting links between the private, public and scientific sectors, which is the foundation of a modern knowledge-based economy.

The essence of entrepreneurship development in regions through the creation of cooperation networks lies in building synergies between various participants in the local economy. Cooperation offers SMEs access to resources, knowledge and markets that would be difficult to reach on their own. Cooperation networks are therefore becoming an important tool for strengthening innovation, competitiveness and the sustainability of regional development. At the same time, in order to fully exploit their potential, it is necessary to overcome existing barriers, develop competences and consistently support network initiatives through public policy and business environment institutions. That is how entrepreneurial networks become the foundation for building modern, dynamic and economically resilient regions.

5. Summary

Network cooperation among small and medium-sized enterprises is becoming an increasingly important factor in supporting the development of entrepreneurial initiatives. In the face of growing competition, globalisation and technology disruption, cooperation within networks enables companies to increase their efficiency, innovation and adaptability.

Cooperation in networks allows SMEs to conduct joint research and development, share resources, access new markets and technologies, and build stronger negotiating positions vis-à-vis larger entities, to name but a few advantages. Those activities foster an environment conducive to entrepreneurship, in which capacity is built respond more quickly to market needs and initiate new business projects.

Network cooperation can take various forms, ranging from industry clusters and strategic alliances to informal local partnerships. The key success factors in such initiatives are trust, open communication and a shared vision for development. Business support institutions, which facilitate the creation and development of networks and the transfer of knowledge and innovation, are also playing an increasingly important role in the process.

In summary, network cooperation among SMEs is an important element in building sustainable competitiveness and stimulating entrepreneurship. In an economy based on knowledge and innovation, such forms of cooperation will become increasingly important for the development of both individual companies and entire regions.

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