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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.

The papers presented in the number concentrate on many topics connected with organization and management. There are in the number papers about: finances; occupational safety; information management; e-services; the implementation of Artificial Intelligence in management; augmented reality; ecological awareness; tourism management; logistics; technology management; internationalization; innovation management; Industry 4.0; Industry 5.0; public management and sustainable development.

Radosław Wolniak

THE ROLE OF EDUCATIONAL POTENTIAL IN SHAPING THE LABOR MARKET: HOW UNIVERSITIES CAN SUPPORT GRADUATES' EMPLOYABILITY

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Purpose: The article on the educational potential of students in Poland could focus on the various factors influencing students' opportunities and development within the educational system. The educational potential of students refers to the capacity they possess to learn, grow, and develop skills and knowledge, given the right conditions. It's a multifaceted concept, shaped by various internal and external factors that influence a student's ability to succeed academically and personally. This article can serve as a tool for students of any year of study as well as for academic teachers.

Design/methodology/approach: This study adopts a mixed-methods approach, combining quantitative analysis of systemic data from a case study university (University X) and qualitative assessments based on student surveys. The main objective is to evaluate the educational potential of a university program (Program Y) and its alignment with labor market expectations. Quantitatively, the research utilizes a mathematical model based on vector functions and weighted coefficients to evaluate various resource streams (e.g., didactic, material, financial) and their contribution to educational, scientific/social products, and operational losses. These streams are analyzed using formula-based calculations and visualized through bar charts to illustrate the proportional impact on final outcomes. Qualitatively, the study involves structured student surveys covering three main categories: academic standards, economic efficiency, and educational usefulness. Each factor was rated by students on a scale from 0 to 10. The collected data are used to compute the overall educational potential score, which is then normalized using a derived mathematical function. The theoretical framework is grounded in human capital theory, systems theory in education, and educational potential modeling (Piwnik et al., 2020). The scope of the paper includes institutional educational efficiency, student learning outcomes, and labor market alignment, with an emphasis on supporting the development of management tools for higher education institutions.

Findings: The study found that the analyzed university program achieved approximately 68% of its maximum educational potential, with economic efficiency being the strongest component. While academic standards and educational usefulness showed moderate results, areas such as student participation in research and international exchange were identified as weak points. The mathematical model demonstrated that resource optimization can significantly enhance the value of educational outcomes.

Research limitations/implications: The main limitation of this study lies in its focus on a single university and one academic program, which may restrict the generalizability of the results to other institutions or educational systems. Additionally, the weights and variables used in the mathematical model were selected based on assumptions rather than empirical standardization, which may influence accuracy. Future research should aim to validate and refine the model across diverse academic institutions and incorporate longitudinal data to assess changes in educational potential over time.

Practical implications: The research provides a structured framework for universities to assess and enhance their educational potential by quantitatively analyzing resource streams and aligning them with labor market needs. Institutions can use the presented model to optimize resource allocation, improve academic standards, and better prepare graduates for employment. Implementing these changes can lead to increased graduate employability, stronger ties between academia and industry, and a more efficient use of public and institutional funding, contributing to the economic sustainability of higher education institutions.

Social implications: This research highlights the importance of aligning higher education with labor market demands, which can lead to greater social mobility, reduced graduate unemployment, and improved quality of life for students. By promoting the development of both technical and social competencies, universities can contribute to creating a more adaptable, ethically conscious, and socially responsible workforce. Additionally, the findings may inform public policy by encouraging investment in education systems that foster inclusive development, support lifelong learning, and respond to evolving societal and economic challenges.

Originality/value: This paper introduces a novel, quantifiable model for assessing a university's educational potential through the integration of resource stream analysis, student feedback, and labor market alignment. Its value lies in offering a systemic and data-driven approach that can support university administrators, educational policymakers, and employers in improving academic outcomes and graduate employability. The model serves as a practical tool for strategic decision-making in higher education, bridging the gap between education systems and the dynamic needs of the labor market.

Keywords: Educational potential, Educational indicators, Adaptation of education to the labor market, Educational ethics.

Category of the paper: Research paper, Case study.

1. Introduction

This article was developed on the basis of the concept of "Educational Potential" of a student and its metrication in higher education institutions. The authors emphasize the importance of standardization and the quantitative and qualitative monitoring of factors impacting the educational process, aiming to improve institutional efficiency (Piwnik et al., 2020).

This article addresses the issue of educational potential in the context of higher education institutions, analysing the systemic structure that plays a key role in the organisation and effectiveness of the educational process. A model is presented, describing resource streams and components that influence the quality of education and achieved outcomes. The discussed systemic approach takes into account various factors, such as academic standards, economic efficiency, and the market relevance of education, which are essential in the context of changing societal needs and demands (Piwnik et al., 2020). The systemic model includes financial, material, and technological aspects that significantly contribute to building both scientific and social products. The article also introduces a mathematical approach to educational potential using vectors and statistical algorithms, which allows for a more precise assessment of its individual components. The considerations in the article focus on developing norms and standards that can serve as tools to support university management, particularly in effectively utilizing resources and enhancing educational processes.

2. The Education System and Its Goals

The educational potential of the university is characterized by a set of resources, such as the educational potential of the socio-cultural, socio-educational, information-technical (human resources and materials) and integration-communication of the university. Updating the above-mentioned aspects ensures the optimal formation of the didactic potential of the university, which affects the student's experience in the field of scientific knowledge.

The educational system has several key goals, which are more detailed and focus on various aspects of individual and societal development. Existing educational systems around the world vary greatly, however they share some common goals and face similar challenges (Dhar, Chowdhury, 2013). Every educational system is more or less focused on teaching aspects in order to prepare students for the labor market. However, the goals of higher education may differ from the expectations of a potential employer. For instance, in the British job market, higher education is more important, while in Eastern Europe, skills are more important than having a university degree when it comes to employment (Xiong, 2024). However, there are professions where education plays a major role, such as the medical industry, academic

teachers, etc. Table 1 presents a comparison of the objectives of higher education, developed on the basis of the learning outcomes in higher education in Poland, and the expectations of the labor market towards graduates, developed on the basis of recruitment surveys (Zsigmond, Sarkozi, 2021).

In recent years, the global landscape of education and employment has been shaped by profound socio-economic transformations. Rapid technological advancements, such as digitalization, automation, and artificial intelligence, are redefining the skills and competencies expected from university graduates. At the same time, demographic shifts, climate change imperatives, and migration trends are exerting additional pressure on education systems to adapt.

As highlighted in the World Economic Forum's "Future of Jobs Report 2025", employers increasingly value adaptability, critical thinking, and digital fluency over traditional academic credentials. This necessitates a redefinition of educational goals and closer alignment between higher education and labor market realities (WEF, 2025).

Consequently, the higher education system must not only ensure academic excellence but also respond dynamically to these megatrends by embedding future-oriented competencies within curricula.

Table 1.

The effects of education in higher education institutions and the expectations of the labor market towards graduates

No	Goals of higher education systems for students	Potential employer's expectations from graduates
1.	General and Specialized Knowledge	Intellectual development: Possessing knowledge in various areas related to the position/specialization
2.	Practical Skills	Development of social and interpersonal skills
3.	Research and Analytical Skills	Emotional and psychological development: Ability to cope with stress and emotions
4.	Critical Thinking and Problem-Solving	Preparation of the workforce: Vocational and technical education
5.	Communication Skills	Moral and ethical development: Ability to learn value systems
6.	Ethical and Social Responsibility	Civic education: Ability to consciously participate in social and political life
7.	Lifelong Learning and Adaptability	Creativity and innovation
8.	Interdisciplinary knowledge	Adaptation to social and technological changes
9.	Global awareness and cultural competence	Supporting individual development

Source: Own elaboration on based Universities and the Labour Market Graduate Transitions from Education to Employment

The table 1 demonstrates a strong alignment between educational goals and labor market expectations. Higher education systems not only prepare students for specific jobs but also shape them as adaptable individuals capable of working in international environments and approaching personal and professional development responsibly. The integration of educational programs with labor market needs is essential for ensuring graduates' competitiveness and meeting employers' expectations in a global context (Frankowska et al., 2015).

This alignment can be observed through various theoretical lenses, including human capital theory, social learning theory, adaptability in a dynamic labor market, cultural awareness, critical thinking, and sustainability principles. By fostering a well-rounded set of competencies, educational institutions contribute to the creation of a workforce that is not only skilled but also ethically conscious and equipped to handle diverse and evolving challenges.

This article takes into account both the key factors of higher education and important factors for the employer when hiring a graduate (Piwnik et al., 2020).

3. The systemic structure of the university and its impact on the student's educational potential

The educational potential of a student depends on the existing educational system and the internal structure of the University (Piwnik et al., 2020). The article presents an analysis of data from University X and its study program Y. The University offers a wide range of study options, including Bachelor's (first cycle), Postgraduate (second cycle), Postgraduate, MBA and PhD programs. The teaching methodology standards at the University emphasize a practical and modern approach, aimed at equipping students with the skills they need in the job market. Building trust between universities and students, as well as between academia and the labor market, is a key mechanism for ensuring the effective transfer of skills and knowledge, supporting both employability and long-term economic development (Akberdiyeva, Antczak-Jarząbska, 2023). The analysed program of study Y has existed on the Polish market since the first decade of the 21st century, and has been actively offered by universities for the last 10 years. A qualitative method based on Table 2 below was used to assess the systemic structure of University X.

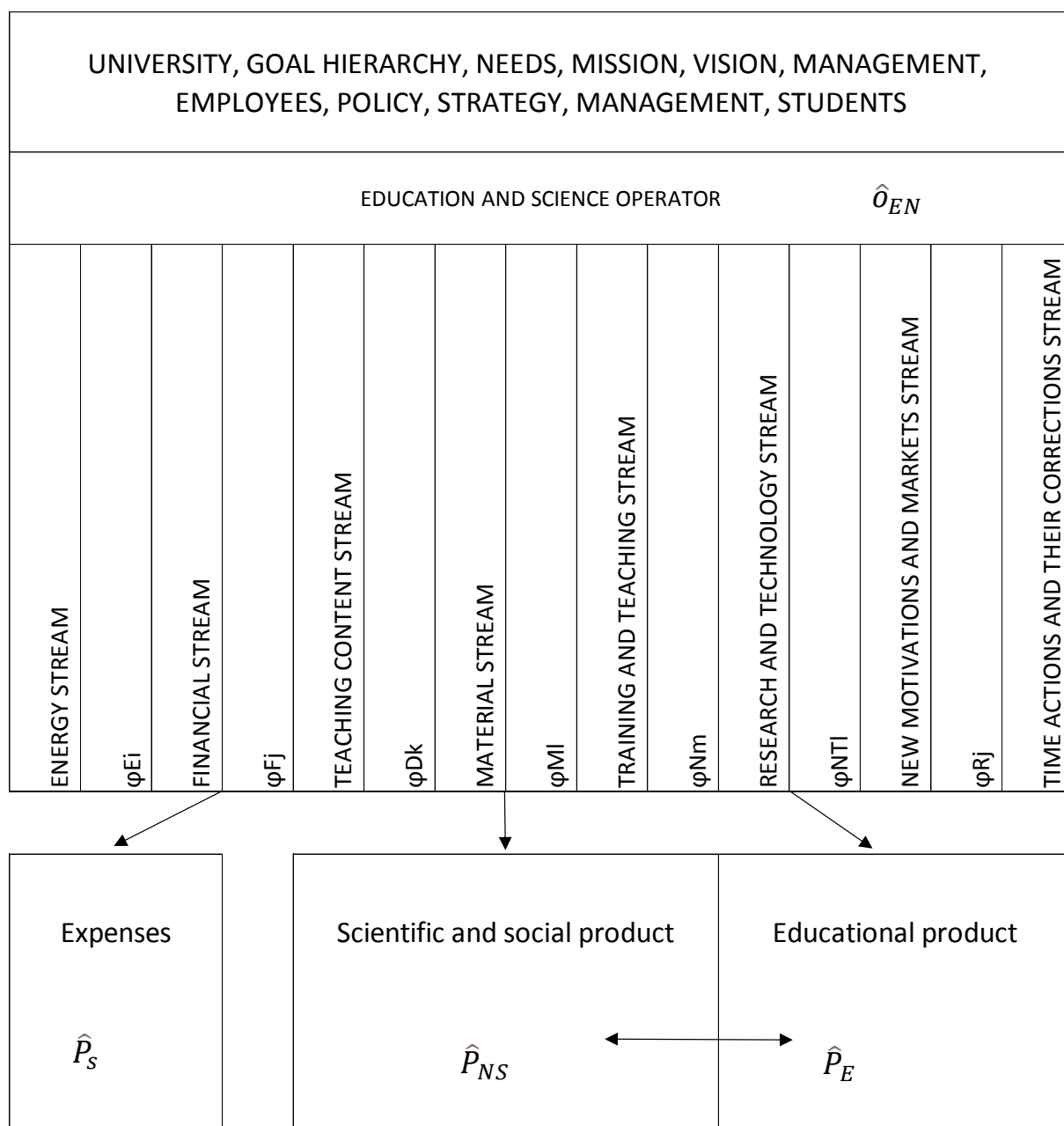


Figure 1. The systemic structure of the University.

Source: (Piwnik et al., 2020).

In the illustration, the analytical diagram presents a structure reflecting the systemic model of the university, in which different “streams” of resources and activities lead to specific outcomes in the form of scientific, social and educational products, as well as losses.

Table 2.
Interpretation of streams

No	Stream Symbols	Description	Indicator	Unit of measurement per year	Wieght	
1	φ_{Ei}	Energy Stream - includes the energy resources required for the university's operations.	7600	units of energy	38,66	Financial stream
2	φ_{Fj}	Financial Stream - financing that fuels other activities within the university.	3000	financial units (zł)	15,26	
3	φ_{DK}	Educational Content Stream - educational material that forms the foundation of the teaching process.	360	units of educational content (teaching materials)	1,83	Educational stream
4	φ_{ML}	Material Stream - material resources, such as educational aids, equipment, buildings.	80	material units (equipment)	0,41	
5	φ_{NM}	Training and Teaching Stream - pertains to the qualifications of the teaching staff and the teaching process.	8104	units for staff training (teaching hour per year)	41,22	
6	φ_{NTi}	Research and Technology Stream - research conducted by the university and applied technologies.	70	units for scientific research	0,36	Scientific and social stream
7	φ_{Rj}	New Market Motivation Stream - understanding market needs that influence educational directions.	350	market motivation units	1,78	
8	φ_{TKm}	Activities Over Time and Corrections Stream - continuous improvement and adaptation of university activities.	95	units for activities over time and corrections	0,48	

Source: Own elaboration based on the system structure of the University.

Assuming each stream affects the final products in a particular way, we can propose a mathematical model, for example:

$$\hat{P}_E = 1,83 * \varphi_{DK} + 0,41 * \varphi_{ML} + 41,22 * \varphi_{NM}; \quad (1)$$

$$\hat{P}_{NS} = 0,36 * \varphi_{NTi} + 1,78 * \varphi_{Rj} + 0,48 * \varphi_{TKm} \quad (2)$$

$$\hat{P}_s = 38,66 * \varphi_{Ei} + 15,26 * \varphi_{Fj} - (\hat{P}_{NS} + \hat{P}_E); \quad (3)$$

substituting the values into the equations:

$$\hat{P}_E = 1,83 * 360 + 0,41 * 80 + 41,22 * 8104 = 334\,176,77;$$

$$\hat{P}_{NS} = 0,36 * 70 + 1,78 * 350 + 0,48 * 95 = 693,96$$

$$\hat{P}_s = 38,66 * 7600 + 15,26 * 3000 - (334\,176,77 + 693,96) = 4134,28;$$

In the presented analysis, we assumed that each stream in the university's system has a specific impact on the final educational products, scientific/social products, and losses. Here's a detailed explanation of the starting assumptions:

1. Resource Streams - Each stream (energy, financial, didactic, material, etc.) is defined as a resource that supports various university processes:

φ_{Ei} - Energy stream, which may affect the efficiency of the university's infrastructure.

φ_{Fj} - Financial stream, representing the budget allocated for various university activities.

φ_{Dk} - Didactic content stream, indicating the number of hours dedicated to preparing and conducting classes.

φ_{Ml} - Material stream, covering physical resources like equipment and materials necessary for teaching.

φ_{Nm} , φ_{NTi} , φ_{Rj} , φ_{TKm} - The remaining streams (training, research, market initiatives, corrective actions) support education, research and development, and adaptation to market changes.

2. Stream Weights - Each stream is assigned a weight that reflects its importance for the output products: For instance, the energy stream (φ_{Ei}) constitutes 75% of the educational product value, meaning it significantly impacts educational activities. Similarly, the financial stream (φ_{Fj}) influences the educational product by 25% etc. These weights were chosen arbitrarily, meaning they could vary in reality, depending on the analysis of a particular university and its specifics.
3. Formulas for Final Products - We created formulas for the two main university products: Educational Product (PE) calculated as the sum of the weighted values of individual streams impacting education. Scientific and Social Product (PNS), which is generated through streams related to research and staff training. Expenses ($\hat{P}_S$) were calculated as the difference between the total resource (1000 units) and the sum of $\hat{P}_E$ and $\hat{P}_{NS}$, showing how much of the resources were lost or not utilized efficiently.
4. Assumption of Total Resource - We assumed that the system's total resource capacity is 1000 units, allowing for the calculation of losses ($\hat{P}_S$). This is a nominal value representing the overall system capacity, meaning the limit of resources that the university can process effectively. These assumptions aimed to simplify the analysis and demonstrate the impact of individual streams on the university's outcomes. In real-world conditions, the weights, stream values, and formulas would be more complex and tailored to the specific operational data of a university.

Based on these results, a bar chart was created to illustrate the values of the university's outcome products $\hat{P}_S$, $\hat{P}_{NS}$, $\hat{P}_E$:

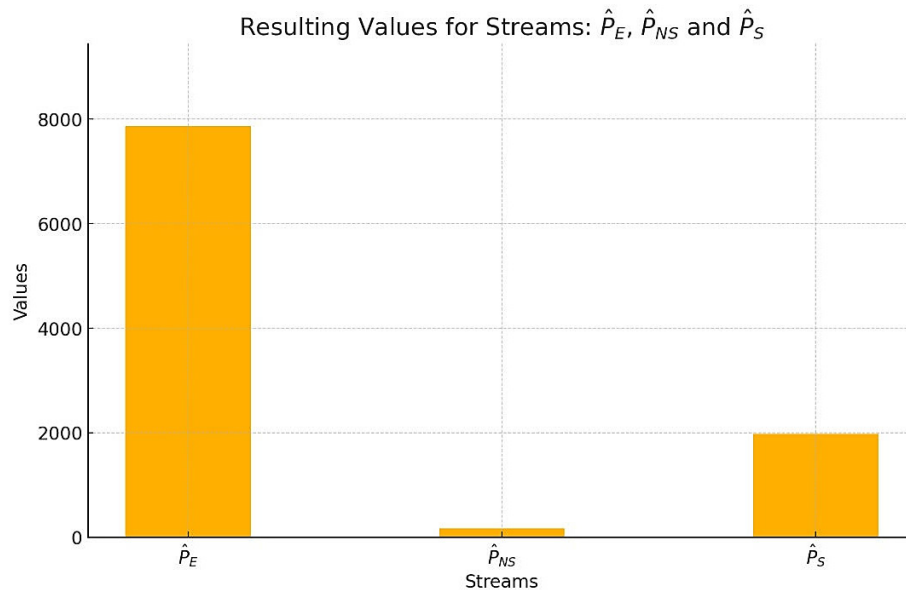


Figure 2. Contribution of resource streams to university products.

Source: Own elaboration based on calculations from Table 2

Educational Stream has the highest value of the three. In the context of a university, it represents resources or efforts that significantly contribute to educational outcomes, such as the quality of teaching, infrastructure, or access to educational materials. A high value for an educational stream suggests that the educational stream has a strong, positive impact on the university's ability to effectively deliver final educational products. In turn, Scientific/Social Products Stream has the lowest value, indicating that its contribution to the university's final output is relatively smaller. It may reflect resources or efforts focused on scientific or social products that are not as heavily emphasized or are less resource-intensive compared to the educational stream. This lower value could suggest a need for increased funding or attention if the university aims to enhance its scientific and social impact. The last stream shows that the intermediate value represents the support functions or potential losses incurred by the university. This may include facilities maintenance, administrative costs, or inefficiencies that subtract from the net result. Although its value is not as high as the value of educational potential, it is still significant, indicating that support and operational efficiency are essential for the institution to function well.

The distribution of values suggests that the university's structure places a strong emphasis on educational outputs, with moderate resources or impacts associated with support and losses, and relatively less focus or impact from scientific/social products. This could reflect the university's priorities, where educational quality and infrastructure are critical, while scientific and social initiatives may play a supporting but less central role. If the university wants to balance its impact across these areas, it may need to redirect resources or optimize certain operations to boost scientific and social output while maintaining its educational strengths. This model suggests that improving the university's efficiency could involve optimizing resources to minimize losses and enhance the value of the final products.

4. Student learning outcomes

A survey was conducted among Y program students based on factors related to academic standards (Piwnik et al., 2020). The survey was developed based on the factors presented in Figure 3. Full-time and part-time students participated in the study as respondents.

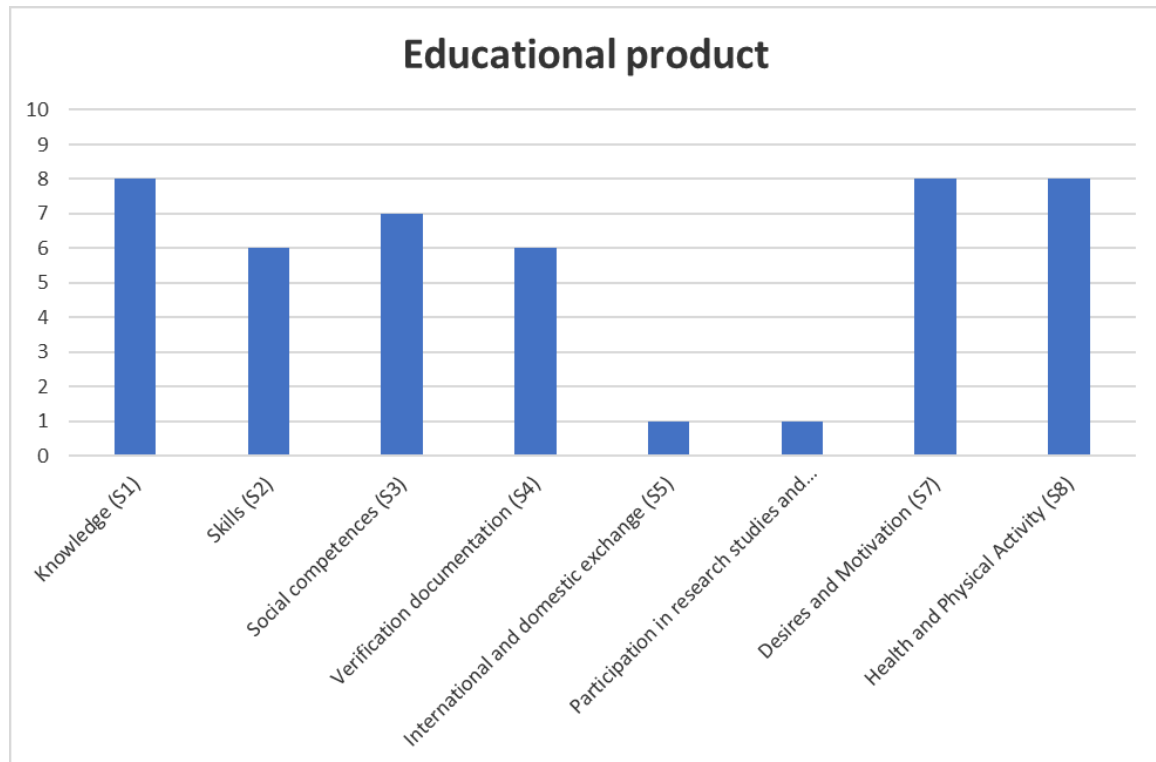


Figure 3. Student educational product (S)

Source: Own study based on respondents' answers

Based on the presented graph, it can be concluded that the survey results refer to the assessment of individual aspects of the Y programme, made by students, who assessed each aspect on a scale from 0 to 10, where 0 means a very low assessment and 10 means a very high assessment. Here's the interpretation of the results:

1. Knowledge (S1): This received a very high score (9 points), indicating that students view the knowledge gained from the program as a key and highly valued aspect.
2. Skills (S2): With a score of 7, it shows that the skills taught in the program are also highly appreciated but slightly less so than the knowledge.
3. Social Competences (S3): This category scored 6 points, suggesting that social competences are rated at an average level.
4. Verification Documentation (S4): Also scored 6 points, similar to social competences, indicating that this aspect is seen as positive but not outstanding.
5. International and Domestic Exchange (S5): Rated at 2 points, which reflects a low rating for the opportunities for international and domestic exchange within the program, indicating that this area may need improvement.

6. Participation in Research Studies (S6): Scored 1 point, meaning that students either rarely participate in research or this aspect of the program is underdeveloped.
7. Desires and Motivation (S7): With a score of 2 points, this suggests a low level of motivation or insufficient support for student aspirations within the program.
8. Health and Physical Activity (S8): Scoring 8 points, it indicates that students highly value the health and physical activity aspects of the program.

Overall, the results show that students most appreciate knowledge, health, and physical activity, while aspects related to international exchange and participation in research are rated the lowest. It would be beneficial to focus on improving these weaker areas.

Economic efficiency is denoted by the vector E, it contains 7 factors and is presented in the figure below.

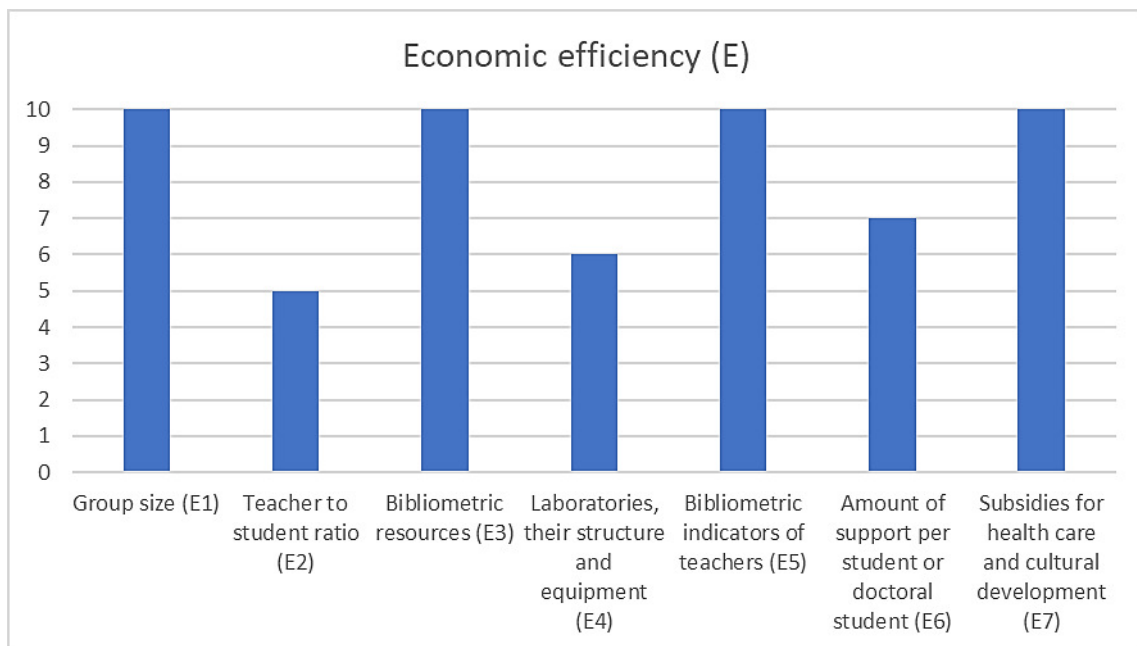


Figure 4. Economic efficiency of universities (E).

Source: Own developed based on the curriculum and university resources.

Based on the presented chart evaluating economic efficiency on a scale from 0 to 10, here's the interpretation of the results:

1. Group size (E1): Received the maximum score (10 points), indicating that the size of student groups is optimal and meets the expectations for providing comfortable conditions for both students and lecturers.
2. Teacher to student ratio (E2): Scored 5 points, suggesting that the ratio of teachers to students is average. There may be room for improvement here to enhance the quality of education.
3. Bibliometric resources (E3): Also received 10 points, meaning the bibliometric resources are of a very high standard and meet the needs of both students and faculty.

4. Laboratories, their structure and equipment (E4): Scored 6 points, indicating that the laboratories and their equipment are in relatively good condition but not ideal. This may suggest a need for improvement in infrastructure.
5. Bibliometric indicators of teachers (E5): With 10 points, this shows that the bibliometric indicators of teachers are very high, likely reflecting their research activity and competence.
6. Amount of support per student or doctoral student (E6): This category scored 7 points, indicating a decent level of financial or material support for students, though there is room for further improvement.
7. Subsidies for health care and cultural development (E7): With a maximum score of 10 points, this suggests that subsidies for health care and cultural development are well-developed and meet student expectations.

In summary, the strengths are the optimal group size, high-quality bibliometric resources, strong teacher bibliometric indicators, and sufficient subsidies for health care and cultural development. Areas for improvement include the teacher-student ratio and the infrastructure of laboratories.

The Usefulness of education is the third parameter of educational potential, which is represented by the graph below.

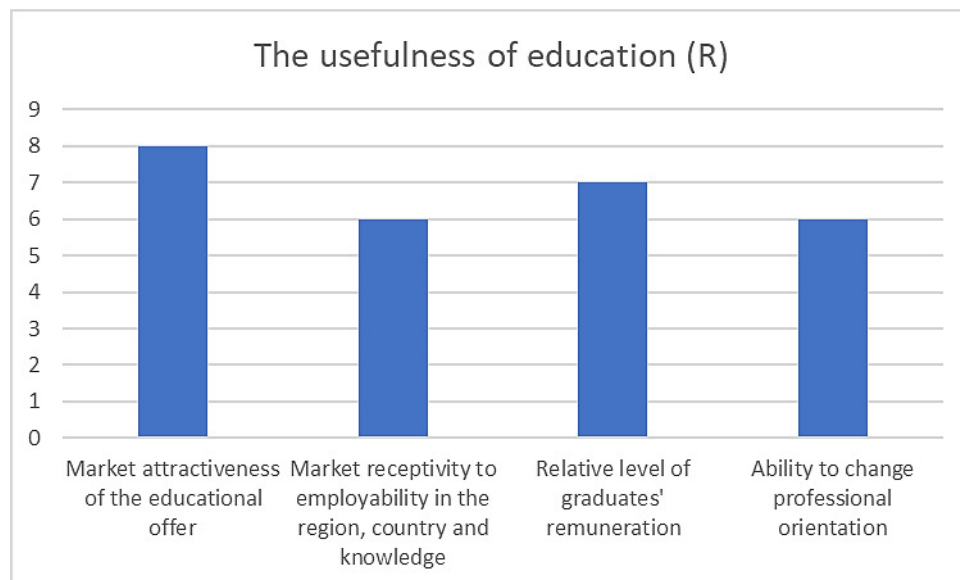


Figure 5. The usefulness of education for students.

Source: Own study based on respondents' answers.

Based on the presented chart evaluating the usefulness of education, here's the interpretation of the results as rated by students:

1. Market attractiveness of the educational offer: This received the highest score (8 points), indicating that students perceive the educational offer as highly attractive in the market. The program seems well-aligned with job market demands and student expectations.

2. Market receptivity to employability in the region, country, and knowledge: Scored 6 points, suggesting that the job market is moderately open to graduates of this program in the region, country, and in relation to the knowledge gained. There may be a need to better align the program with local job markets.
3. Relative level of graduates' remuneration: With a score of 7 points, this suggests that graduates' salaries are relatively good, though there is room for improvement.
4. Ability to change professional orientation: Scored 6 points, indicating that students view the program as moderately flexible when it comes to the ability to shift career paths.

Overall, the results suggest that the program is seen as market-attractive, providing graduates with relatively good career prospects and salaries. However, there are areas like flexibility in career changes and better alignment with local job markets that may require further improvements.

Thus, taking into account the above-mentioned factors, we can indicate the educational potential.

EDUCATIONAL POTENTIAL		
ACADEMIC STANDARDS (S)	ECONOMIC EFFICIENCY (E)	EDUCATIONAL USEFULNESS (R)
$\vec{S} = \sum_{i=1}^8 \vec{S}_i$	$\vec{E} = \sum_{i=1}^7 \vec{E}_i$	$\vec{R} = \sum_{i=1}^4 \vec{R}_i$
$\vec{S} = 8 + 6 + 7 + 6 + 1 + 1 + 8 + 8 = 45$	$\vec{E} = 10 + 5 + 10 + 6 + 10 + 7 + 10 = 58$	$\vec{R} = 8 + 6 + 7 + 6 = 27$
$\vec{P}_E = \vec{S} + \vec{E} + \vec{R} = 45 + 58 + 27 = 130$		

Figure 6. Educational potential.

Source: Own developed based on the curriculum and university resources.

Based on the presented table and calculations, the educational potential (PE) is 130 points out of a possible 190. The table evaluates three key indicators.

Academic Standards (S), Economic Efficiency (E), and Educational Usefulness (R).

Detailed Interpretation shows:

1. Academic Standards (S): The total points scored here is 45 out of a possible 80 (each of the eight factors was rated up to 10 points). This suggests that academic standards are at about 56% of their potential ($45/80 * 100$), indicating room for improvement, particularly in areas like participation in research (S6) and international exchange (S5), which received low scores previously.

2. Economic Efficiency (E): This category scored 58 out of a maximum of 70, or around 83% of its potential. High scores in group size (E1), bibliometric resources (E3), teacher bibliometric indicators (E5), and subsidies for healthcare and cultural development (E7) show that the program is efficiently managing its resources. However, the teacher-student ratio (E2) and laboratory conditions (E4) might need further optimization.
3. Educational Usefulness (R): In this category, 27 out of a maximum of 40 points were scored, representing 67.5% of its potential. The educational offer's market attractiveness (R1) was rated highest, but other indicators like the ability to change careers (R4) and regional employability (R2) indicate gaps that might limit the overall educational usefulness.

For further analysis when evaluating the values of the moduli of the component vectors, it is more convenient to write the expression in normalized form.

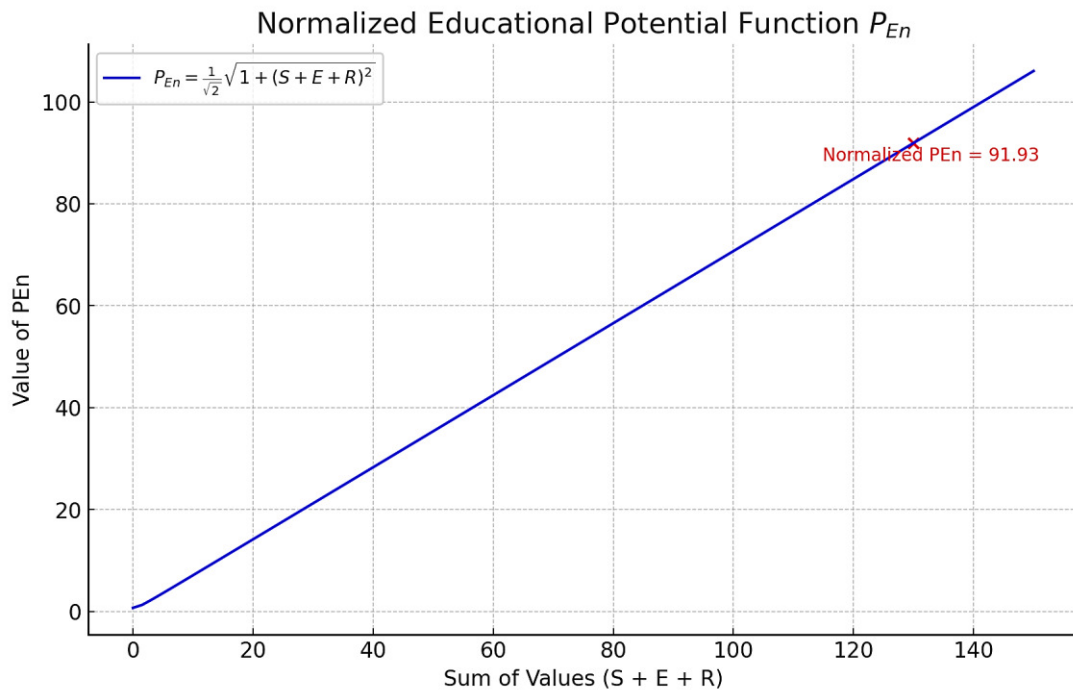


Figure 7. Function of Normalized Educational Potential.

Source: Own developed based on the curriculum and university resources.

The normalized educational potential PEn calculated based on the given values (Academic Standards $S = 45$; Economic Efficiency $E = 58$; Educational Usefulness $R = 27$) is approximately 91.93. This value is marked on the function graph above, which plots the function:

$$P_{En} = \frac{1}{\sqrt{2}} \sqrt{1 + (S + E + R)^2} \quad (4)$$

against the sum of $S + E + R$.

This chart helps visualize how the educational potential PEn increases with the combined values of the three components. The point marked in red highlights the specific normalized potential based on the input values.

5. Summary

The final score of 130 out of 190 means that the program achieved about 68% of its maximum educational potential, which is a good but not perfect score. Economic efficiency is the strongest area, nearing its maximum potential, suggesting that the program is well-managed in terms of material and staff resources. Academic standards and educational usefulness still have room for improvement, especially in providing better practical career opportunities and supporting students' adaptation to labor market demands. These conclusions suggest that the program is strong in infrastructure and resource management but should focus on better aligning academic content and career development opportunities with market needs and student expectations.

Additionally, increasing opportunities for international exchange and participation in research could significantly enhance the academic experience and broaden graduates' competencies. The integration of soft skills and digital literacy into curricula is also essential, given the evolving demands of modern work environments. Finally, continuous collaboration with employers and labor market analysts may help universities anticipate changes and proactively adjust their programs. Strengthening mentorship systems and individualized academic support could further improve student outcomes, particularly for those at risk of underperformance.

Implementing feedback mechanisms where students can regularly evaluate the relevance of course content may also guide timely curriculum updates. Enhancing interdisciplinary learning pathways can promote creativity and innovation, better preparing graduates for complex, real-world challenges. Ultimately, a more dynamic, student-centered approach to education is key to unlocking the full potential of academic programs and ensuring graduates are truly career-ready.

References

1. Akberdiyeva, A., Antczak-Jarząbska, R. (2023). Trust as an element of social capital and factor of economic growth. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 166, 9-18. <https://doi.org/10.29119/1641-3466.2022.166.1>
2. Aloï, S.L., Gardner, W.S., Lusher, A.L. (2003). A framework for assessing general education outcomes within the majors. *Journal of General Education*. <https://doi.org/10.1353/jge.2004.0009>

3. Cox, L. (2021). *Great expectations: The effect of unmet labor market expectations after higher education on political behavior*. Retrieved from: <https://thedocs.worldbank.org/en/doc/b70155b90f7c15aae42571579a5f2da9-0050022021/original/Great-Expectations.pdf>
4. Dhar, B.K., Chowdhury, R. (2013). Current education system of the world: The best practices. *A research Journal for Child Development*. ISSN: 1991-3699.
5. Frankowska, A., Glowacka-Toba, A., Rasinka, R., Prussak, E. (2015). Students entering the labour market, their hopes, expectations and opportunities in the context of sustainable economic development. *Journal of International Studies*, 7(3), 209-222. <https://doi.org/10.14254/2071-8330.2015/8-3/17>
6. Green, W. (2018). Engaging students in international education: Rethinking student engagement in a globalized world. *Journal of Studies in International Education*. <https://doi.org/10.1177/1028315318814197>
7. Jelonek, M. (2023). *Universities and the labour market: Graduate transitions from education to employment*. Routledge.
8. Pinevich, E., Safaryan, O. (2020). Methods for improving the educational potential of students. *E3S Web of Conferences*, 210, 1803. <https://doi.org/10.1051/e3sconf/20202101803>
9. Piwnik, J., Kurowska-Wilczyńska, K., Wilczński, K. (2020). System structure of the online learning process at higher education institutions. *Aparatura Badawcza i Dydaktyczna*, 25(2).
10. Piwnik, J., Kurowska-Wilczyńska, K., Wilczński, K. (2020). The concept of student's 'educational potential' and its metrisability at universities. *Aparatura Badawcza i Dydaktyczna*, 25(3).
11. Soumelis, C. (1979). *A quantitative analysis of the demand for higher education*. Retrieved from: <https://www.jstor.org/stable/3446265>
12. World Economic Forum (2025). *The Future of Jobs Report 2025*. Geneva: WEF.
13. Xiong, Z. (2024). Global comparison of education systems. *Education System Reform*. https://doi.org/10.1007/978-981-99-5861-0_8
14. Zsigmond, T., Sarkozi, B.S. (2021). *Graduates in the labor market: Expectations and opportunities*. Retrieved from: <https://www.researchgate.net/publication/356944661>

BUILDING TAX RATES REDUCTIONS AS A TOOL OF LOCAL FISCAL POLICY: EVIDENCE FROM THE SZCZECIN METROPOLITAN AREA ASSOCIATION

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Purpose: The purpose of this paper is to examine building tax rate reductions as an instrument of local fiscal policy, using the case of the Szczecin Metropolitan Area Association (SMA). The study aims to assess the extent to which reductions are applied by local government units (LGUs), and to determine whether these practices contribute to fiscal harmonization across the metropolitan area or foster tax competition among municipalities.

Design/methodology/approach: The research applies a comparative and spatial benchmarking approach, examining 13 municipalities belonging to the Szczecin Metropolitan Area Association over the period 2018-2020. Reduction coefficients were calculated to measure the extent to which local tax rates diverged from statutory maximums. This method allows for the assessment of fiscal practices across different types of municipalities and provides insights into the patterns of convergence or divergence in local tax policies.

Findings: The results reveal contrasting dynamics in local fiscal policies. Residential building tax reductions were moderate and uniform, reflecting fiscal harmonization, while business property rates varied widely, evidencing active tax competition. This confirms the coexistence of both dynamics within one metropolitan structure.

Research limitations/implications: The study is limited to one metropolitan area and a three-year observation period. Future research could expand the analysis to other Polish metropolitan associations and longer timeframes to capture broader patterns of fiscal coordination and rivalry.

Practical implications: The study highlights harmonized residential taxation as a safeguard of horizontal equity and tax stability, while competitive business taxation shapes regional development strategies and inter-municipal relations.

Social implications: The study shows that harmonized residential taxation ensures equitable treatment and limits tax migration, while competitive business taxation influences regional development and inter-municipal relations.

Originality/value: An in-depth empirical analysis of building tax rate reductions in a Polish metropolitan area, covering residential and business buildings. It shows harmonization for households alongside tax competition for enterprises, enriching tax competition/harmonization research and offering practical insights for local public finance and metropolitan governance.

Keywords: local taxes, property tax, tax rates, local fiscal policy.

Category of the paper: research paper.

1. Introduction

Local taxes constitute one of the fundamental sources of revenue for local government units (LGUs) in Poland and play a crucial role in ensuring their financial autonomy. Alongside revenue shares from national income taxes, as well as grants and subsidies, they represent the most important category of municipalities' own-source income. Their significance, however, extends beyond a purely fiscal dimension, encompassing social, economic, and developmental functions (Owsiak, 2005). Unlike state-level taxes, local taxes are closely linked to local policy and the expectations of the communities for which they are enacted (Ofiarski, 2010).

According to the Constitution of the Republic of Poland (Articles 167 and 168) and the European Charter of Local Self-Government, LGUs are entitled to determine the level of local taxes and charges within statutory limits, which reflects the principle of financial independence. In this regard, the most relevant regulations are those contained in the Local Taxes and Charges Act and the Local Government Revenues Act, which define both the structure of local taxes and the mechanisms for determining their rates (Constitution of the Republic of Poland, 1997; Local Taxes and Charges Act, 1991; Local Government Revenues Act, 2003).

Scholars emphasize that the efficiency of public expenditure increases when the authorities responsible for allocating resources are closer to the communities they serve (Owsiak, 2017). This assumption is embedded in the theory of public choice, which conceptualizes LGUs as actors operating within a quasi-market of public goods, competing with one another for residents and businesses (Buchanan, Tullock, 1965; Kociemska, 2017). Such competition leads to the phenomenon of tax competition, where decisions on local tax rates become both an instrument of local development policy and a tool of inter-municipal rivalry (Tiebout, 1956; Wyszowska, 2018).

Against this backdrop, the issue of property tax rate setting by LGUs organized within metropolitan associations becomes particularly relevant. These structures, established to enhance coordination of development activities and functional integration of urban areas, create a new context for local fiscal policy. The key question that arises is whether metropolitan areas foster fiscal harmonization, leading to the gradual convergence of tax rates, or conversely, whether they intensify tax competition, driven by efforts of individual LGUs to attract investors and residents. The originality of the presented material lies in conducting an in-depth empirical analysis of property tax rate setting in a Polish metropolitan area, covering both residential and commercial buildings. This approach adds new value to the literature on the relationship between tax competition and tax harmonization in the metropolitan context (specifically in relation to building taxation) and, moreover, provides practical insights for local public finance policy and the governance of metropolitan areas in Poland.

2. Literature review

2.1. Legal Framework for Determining Building Tax Rates

The property tax constitutes one of the most significant sources of municipalities' own revenues and serves as a fundamental instrument of local fiscal policy (Owsiak, 2005). Its importance derives not only from its substantial share in municipal budgets but also from the fact that it provides local governments with the legal capacity to shape tax burdens within prescribed boundaries (Filipiak, 2015). This dual role enables municipalities to perform public tasks while at the same time allowing for tax measures adapted to the socio-economic needs of local communities (Kosek-Wojnar, Surówka, 2013).

The foundations of the Polish tax system are set out in the Constitution of the Republic of Poland. Article 84 enshrines the principle of universal obligation to bear public charges, while Article 217 stipulates that the imposition of taxes, the determination of their structural elements including subjects, objects, rates, and exemptions may only occur by statute (Constitution of the Republic of Poland, 1997). These provisions restrict the discretion of local self-government bodies, confining them strictly to the scope of statutory authorization (Kosikowski, 2013). Particularly important is Article 168, which grants local government units (LGUs) the right to establish local taxes and charges within statutory limits, thereby guaranteeing the principle of financial autonomy (Kornberger-Sokołowska, 2018). The Constitutional Tribunal has consistently underscored that this autonomy is relative rather than absolute: in its judgment of 3 November 1998 (K 26/97), the Tribunal clarified that the right of LGUs to set local tax rates must be exercised in compliance with the principle of legality and within the competences conferred by law (Constitutional Tribunal, 1998).

The key legislative act governing property taxation is the Local Taxes and Charges Act of 12 January 1991. Article 5 of this Act empowers municipal councils to establish property tax rates by resolution, subject to the ceiling of maximum values annually published by the Minister of Finance (Local Taxes and Charges Act, 1991). These upper limits are indexed to inflation, ensuring the preservation of real revenue streams and protecting municipal budgets against erosion (Etel, Dowgier, 2013). Municipal councils may differentiate rates based on criteria such as location, purpose or use of the building, type of economic activity, or technical condition. While this catalogue is open-ended, granting municipalities considerable discretion, it is nonetheless constrained by the prohibition on using purely subjective criteria tied to the taxpayer as a person (Ofiarski, 2015; Pahl, 2017).

The Act further authorizes municipalities to introduce object-based exemptions beyond those prescribed by statute. However, subject-based exemptions are prohibited, as they would conflict with Article 217 of the Constitution (Kosikowski, 2013). This restriction is seen in the literature as a safeguard against arbitrariness in local fiscal policy and a mechanism for ensuring equality before the law (Etel, 2012; Ofiarski, 2016). Moreover, differentiation of property tax

rates that may confer selective advantages on specific business entities falls under the regime of European Union state aid law. In this respect, Articles 20b and 20c of the Act impose notification and compliance obligations on municipalities (Local Taxes and Charges Act, 1991).

The significance of property tax is reinforced by the Local Government Revenues Act of 13 November 2003. Article 3 classifies revenues from local taxes and charges, including the property tax, as municipalities' own-source revenues accruing entirely to local budgets (Local Government Revenues Act, 2003). This distinguishes the property tax from income taxes (PIT, CIT), where municipalities participate only through statutory shares without influence over their construction (Etel, 2007; Lubińska et al., 2007). Consequently, property tax remains one of the very few fiscal instruments through which municipalities exercise direct and tangible influence over both tax policy and revenue levels (Pahl, 2017).

A comprehensive assessment of the legal framework shows that municipal fiscal authority in the area of building tax rates is circumscribed by what the literature terms the principle of limited fiscal autonomy (Kotlińska, Nowak, 2010; Mańczyk, 2018). Local governments may not introduce new taxes or redesign structural elements of existing ones; their powers extend only to setting rates within statutory ceilings, applying object-based exemptions, and issuing individual tax decisions under the Tax Ordinance (Bajerska, 2018). This indicates that although LGUs possess instruments of tangible fiscal influence, their competences are firmly subordinated to statutory constraints and the broader fiscal policy of the state (Olek, 2014).

It should also be emphasized that the current regulations contain no special provisions for municipalities associated within metropolitan unions. Each municipality retains full competence to establish building tax rates, and participation in metropolitan areas does not formally affect the scope of their fiscal powers (Kornberger-Sokołowska, 2018). In practice, however, metropolitan cooperation may indirectly shape fiscal decision-making through benchmarking, coordination, and policy alignment processes that belong less to the domain of legal regulation than to the economic and political sphere, which will be examined in the subsequent section of this study.

2.2. Theoretical Background and Empirical Research

Although property tax formally operates within clearly defined legal frameworks, in practice it functions as an instrument of municipal fiscal policy. The statutory discretion to set rates within legal limits provides local government units (LGUs) with the capacity to shape tax burdens in diverse ways, using them both as instruments of inter-municipal competition and as tools of cooperation (Bajerska, Czerwiński, 2018).

The theoretical foundations of this debate are rooted in public sector economics and public choice theory. Within these frameworks, LGUs are conceptualized as actors in a quasi-market of public goods, competing for residents and businesses. Their fiscal decisions are driven not only by the need to secure adequate revenue but also by the pursuit of political legitimacy and

social approval (Owsiak, 2001; Kociemska, 2017). A central concept here is Tiebout's (1956) "voting with one's feet" hypothesis, which posits that households choose their place of residence based on the interplay between tax levels and the quality of public goods provided. In this perspective, variation in local property tax rates becomes a decisive factor influencing both household migration and business location choices (Wyszkowska, 2018).

This theoretical framework has been further refined in the literature on tax competition among territorial units. Ramajo et al. (2020) identifies three dominant strands: (1) the tax mimicking or yardstick competition model, in which political considerations are paramount and municipalities benchmark their rates against neighbors to preserve political capital (Shleifer, 1985; Besley, Case, 1992). Tax authority in this model is oriented toward the electoral system (term limits) of local government bodies (Bordignon, 2003); (2) the classical tax competition model, emphasizing economic rivalry for mobile capital, in which reductions in tax rates are deployed to stimulate local growth (Zodrow, Mieszkowski, 1986; Janeba, Osterloh, 2013); and (3) the fiscal policy interdependence model, which highlights hybrid dynamics in which fiscal choices are jointly shaped by political factors and mutual influences across interconnected jurisdictions (Swaniewicz, Łukomska, 2015).

Empirical research across Europe has confirmed the pervasiveness of tax competition, though with varying implications depending on institutional settings. Francois (2010) demonstrated that, in France, local tax differences exerted a stronger impact on business location than on household settlement patterns. Parchet (2019) observed that Swiss municipalities systematically lowered tax rates in response to neighboring jurisdictions, providing a classic case of yardstick competition. Comparable findings were reported by Moisio (2010) for Finland and by Janeba and Osterloh (2013) for Germany, while Sedmíhradská et al. (2015) confirmed the tax mimicking mechanism in the Czech Republic. In the Polish context, Łukomska and Swaniewicz (2015) and Łukomska and Neneman (2018) showed that municipalities frequently imitate their neighbors' fiscal policies, particularly with respect to business property taxation.

In addition to this, in recent years, the European Union has placed growing emphasis on deepening fiscal decentralization and strengthening the financial autonomy of local and regional governments. These policy debates focus on achieving an appropriate balance between local flexibility and macro-fiscal stability, as well as on recognizing metropolitan areas as key actors of regional and cohesion policy (European Committee of the Regions, 2022; OECD, 2023). In this context, the analysis of fiscal practices in Polish metropolitan areas provides valuable insights into the extent to which the national model of local governance aligns with broader European trends in multi-level governance and fiscal coordination.

Within this comparative framework, metropolitan areas emerge as especially instructive cases. Structures such as the Szczecin Metropolitan Area, the Upper Silesian-Zagłębie Metropolis, or the Poznań Metropolis Association serve not only as platforms for joint action in fields like transport and spatial planning but also as arenas for the exchange of fiscal policy

practices (Kornberger-Sokołowska, 2018). On the one hand, shared development strategies and strong functional interdependencies create pressures for fiscal harmonization (Poniatowicz, 2023), as excessive disparities in property tax rates could undermine the cohesion of the metropolitan space. On the other hand, the formal fiscal autonomy of individual municipalities remains intact, and this autonomy may fuel rivalry as local governments compete for residents and investors (Walasiak, 2023, p. 79) within the same metropolitan framework.

Viewed through an economic lens, the differentiation of property tax rates on buildings within the SMA demonstrates an inherently ambivalent character (Popławski, 2008, p. 167). On one side, it allows LGUs to calibrate fiscal burdens in line with local socio-economic conditions and the income structures of their populations. On the other, it risks triggering a “race to the bottom” or generating fiscal fragmentation within what is meant to function as a cohesive territorial unit (Felis, 2015, p. 78). This ambivalence makes the fiscal dynamics of the SMA an important case for examining how inter-municipal cooperation intersects with competitive pressures, and for exploring the broader tension between the principle of local autonomy and the growing need for coordination at the metropolitan scale (Lendzion et al., 2004).

Despite numerous studies on local fiscal policy and tax competition among local government units, the literature reveals several significant research gaps. First, there is a lack of detailed analyses of property tax rate reduction practices in the metropolitan context, particularly with regard to the distinction between residential and commercial buildings. Second, limited knowledge exists on the extent to which such reductions contribute to fiscal harmonization across entire metropolitan areas or, conversely, reinforce tax competition among municipalities. Third, comparative studies covering different types of municipalities within a single metropolitan structure, taking into account spatial and functional diversity, are scarce.

Addressing these gaps, through in-depth examination of property tax rate reduction practices in Polish metropolitan areas, can provide valuable insights for theories of tax competition and harmonization, as well as for the practical management of local public finance and metropolitan development policy.

3. Methodology

Economic and comparative analysis offers valuable insights into these mechanisms, particularly in assessing whether, in metropolitan areas such as the Szczecin Metropolitan Area (SMA), we observe tendencies toward fiscal harmonization or, conversely, intensified tax competition. The empirical core of this study is the assessment of fiscal practices applied by local government units (LGUs) belonging to the Szczecin Metropolitan Area Association (SMA). The analysis focuses specifically on property taxation in the segment relating to

buildings. The research encompassed thirteen LGUs: two cities with county rights, five urban-rural municipalities, five rural municipalities, and one urban municipality.

Within this framework, the property tax and in particular the component levied on buildings assumes special importance. Buildings not only constitute the largest source of municipal tax revenues, but also represent the most visible and tangible burden both for households and for business entities (Owsiak, 2001; Etel, 2012). Consequently, the level at which municipalities choose to set these rates provides a critical indicator of their fiscal strategy. Furthermore, the decisive criterion for determining the rates is the mere fact of owning such real estate. For example, in order to determine the rates for buildings used for business purposes, it is irrelevant whether business activity is currently being conducted in the building (Borszowski et al., 2019, p. 22).

The study examines the extent of reductions in building tax rates applied by SMA municipalities over the period 2018-2020. To capture these dynamics, the research employed a benchmarking approach combined with spatial comparisons. Such a methodology enables an assessment of the actual exercise of fiscal authority by LGUs. Instead of relying solely on nominal tax levels, the analysis concentrates on deviations from the statutory maximum rates, which are annually determined and announced by the Ministry of Finance. This procedure allows for comparability between municipalities of varying size and type, while also facilitating the identification of temporal patterns and tendencies.

The methodological framework rests on the construction of a reduction coefficient, defined as the ratio between the tax rate adopted by a municipality and the statutory maximum rate. A coefficient approaching 1 reflects the application of rates close to the legal ceiling, indicating an absence of reductions, while lower values denote the adoption of lighter burdens for taxpayers. This approach has strong foundations in the literature, which emphasizes that the fiscal autonomy of LGUs does not consist in creating new taxes but rather in their discretion to differentiate the level of burdens within existing statutory frameworks (Kosek-Wojnar, Surówka, 2013).

The benchmark, serving as a point of reference, was calculated as the average reduction level within a given year, tax section, and LGU type. In methodological terms, the research procedure unfolded in six sequential stages. First, datasets were acquired and merged from the Tax Portal. Second, these were supplemented with information on maximum rates as specified in official announcements of the Ministry of Finance. Third, detailed rate categories and incomplete data were eliminated to ensure consistency. Fourth, LGUs belonging to the SMA were identified and flagged. Fifth, reduction coefficients were computed for all applicable building tax rates. Finally, benchmarks were calculated for each year, section, and LGU type, providing a structured basis for comparative analysis across time and space.

4. Results of the Analysis

In this part, the analysis focuses on reductions in property tax rates in the section concerning buildings, based on the example of the Szczecin Metropolitan Area Association. The analysis is divided into two principal categories: residential buildings and buildings used for business purposes. This division reflects both statutory provisions and economic considerations. In the case of residential buildings, social and political motivations predominate, particularly the aim of protecting households from excessive fiscal burdens. By contrast, in the case of business properties, the emphasis shifts towards economic and competitive factors, and the differentiation of tax rates is frequently employed as an instrument for attracting capital (Janeba, Osterloh, 2013).

The property tax on residential buildings constitutes one of the most important categories of the real estate tax, and its level has a direct impact on household finances. For this reason, the literature highlights that local authorities are more strongly guided by social and political considerations in this category than in others (Kornberger-Sokołowska, 2018). Because households are the most immediate taxpayers affected, municipalities including those in metropolitan areas rarely impose maximum statutory rates (Owsiak, 2001; Etel, Dowgier, 2013).

The analysis of the data illustrated in Table 1, indicates that in all SOM municipalities tax rates were set below the maximum levels annually determined by the Ministry of Finance. The amplitude of differences between individual units remained relatively small, which points to a tendency towards fiscal harmonization in this category of taxation. Core municipalities, urban-rural municipalities, and rural municipalities maintained reduction coefficients at comparable levels, thereby minimizing the risk of significant disparities in tax burdens among residents across the entire metropolitan area.

Table 1.

Reduction Coefficient of the Property Tax Rate on Residential Buildings (Section 1.5) in LGUs Associated within the Szczecin Metropolitan Area Association (data in %)

Local Government Unit (SMA)	2018		2019		2020	
	LGUs benchmark		LGUs benchmark		LGUs benchmark	
Szczecin	9.09	15.01	11.39	15.90	0.00	14.18
Stargard*	3.90	17.30	5.06	18.16	6.17	16.86
Świnoujście	5.19	15.01	7.59	15.90	0.00	14.18
Dobra Szczecińska	2.60	26.50	5.06	27.25	4.94	24.53
Kobylanka	2.60	26.50	5.06	27.25	7.41	24.53
Stare Czarnowo	9.09	26.50	11.39	27.25	0.00	24.53
Police	10.39	20.34	12.66	20.92	9.88	18.74
Goleniów	22.08	20.34	24.05	20.92	19.75	18.74
Kołbaskowo	11.69	26.50	13.92	27.25	7.41	24.53
Gryfino	7.79	20.34	10.13	20.92	3.70	18.74
Stargard**	9.09	26.50	10.13	27.25	7.41	24.53
Nowe Warpno	0.00	20.34	2.53	20.92	0.00	18.74
Stepnica	20.78	20.34	21.52	20.92	18.52	18.74

Note. * Data for the urban municipality of Stargard, ** Data for the rural municipality of Stargard.

Source: own work.

The figure 1 indicates that during the examined period the reductions remained at a stable level, without clear convergence or divergence tendencies. The reduction coefficients in individual municipalities remained steady, and the differences between them did not deepen. This means that residents of the metropolitan area bore similar tax burdens regardless of their place of residence, which strengthens the sense of horizontal equity and eliminates the risk of tax migration within the area (Besley, Case, 1992; Wyszowska, 2018). This stability is consistent with the findings of comparative studies, which demonstrate that LGUs in European countries treat residential taxation as an element of social balance and do not employ it as a tool of aggressive fiscal competition (Moisio, 2010; Parchet, 2019).

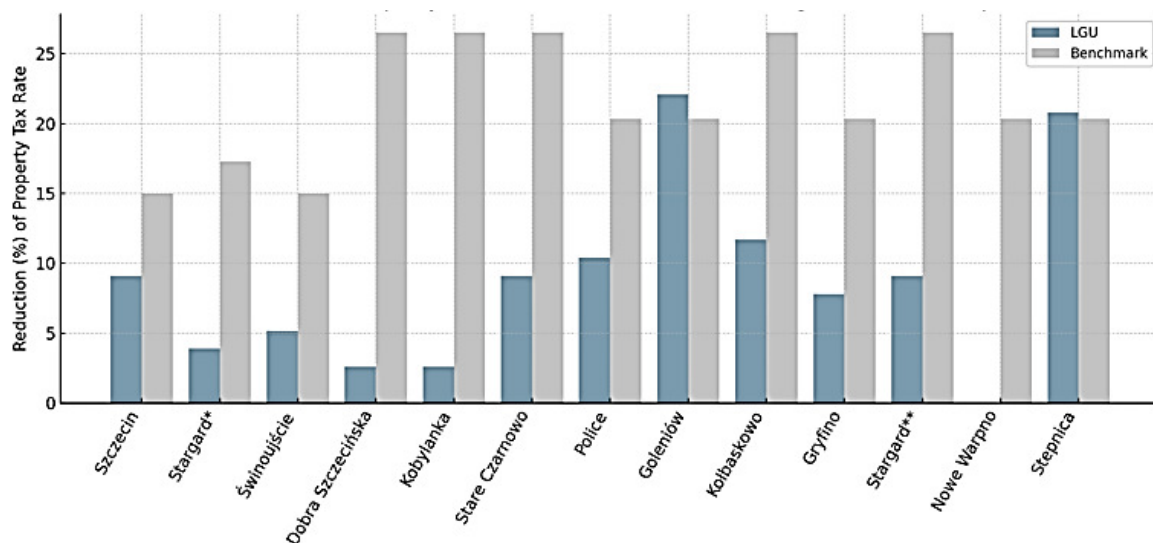


Figure 1. Property tax reduction rate for residential buildings in local government units affiliated with SMA in 2020.

Source: own work.

Interpreting these results in light of the literature, two mechanisms can be identified. First, socio-political pressure constrains municipalities from radical differentiation of residential tax rates, as such divergence could undermine electoral support (Łukomska, Neneman, 2018). Second, the strong functional interconnections within the SMA encourage the operation of yardstick competition, understood as benchmarking tax decisions against those of neighboring jurisdictions. Municipalities monitor one another and maintain similar rates to avoid unfavorable political comparisons (Ramajo, 2020). Overall, the SMA data confirm the international findings of Moisio (2010) for Finland, Janeba and Osterloh (2012) for Germany, and Parchet (2019) for Switzerland: in the residential category, LGUs pursue stabilization and harmonization, with reductions that are moderate and evenly distributed.

By contrast, the situation differs markedly in the case of buildings used for business purposes. This category of property tax is particularly significant for municipal revenues, and here economic motivations dominate. Local governments' decisions more often take on a strategic and competitive dimension (Zodrow, Mieszkowski, 1986; Janeba, Osterloh, 2013).

Table 2.

ax rate reduction coefficient for buildings used for business purposes and residential buildings or parts thereof used for business purposes (section 1.6), in local government units affiliated with Szczecin Metropolitan Area Association (data in %)

Local Government Unit (SMA)	2018		2019		2020	
	LGUs benchmark		LGUs benchmark		LGUs benchmark	
Szczecin	0.00	44.00	1.58	44.19	0.00	40.63
Stargard*	-	27.98	-	28.51	-	28.45
Świnoujście	1.90	44.00	3.45	44.19	0.00	40.63
Dobra Szczecińska	16.88	24.80	18.19	25.09	19.58	23.07
Kobylanka	4.16	24.80	5.67	25.09	3.77	23.07
Stare Czarnowo	1.90	24.80	3.45	25.09	0.00	23.07
Police	-	29.31	-	29.37	0.00	27.57
Goleniów	20.22	29.31	21.47	29.37	8.28	27.57
Kołbaskowo	-	24.80	7.63	25.09	7.91	23.07
Gryfino	-	29.31	2.00	29.37	0.00	27.57
Stargard**	6.93	24.80	6.95	25.09	4.44	23.07
Nowe Warpno	0.00	29.31	1.58	29.37	0.00	27.57
Stepnica	17.49	29.31	16.92	29.37	15.94	27.57

Note. * Data for the urban municipality of Stargard, ** Data for the rural municipality of Stargard.

Source: own work.

As shown in Table 2, the range of reductions for business property tax rates across municipalities is considerably wider than for residential buildings. Some units especially urban and urban-rural municipalities with a strong industrial and service profile introduced significant reductions relative to statutory maxima, using them as instruments for attracting investment and enhancing local competitiveness. By contrast, rural and peripheral municipalities generally retained rates closer to statutory ceilings, reflecting both limited capacity to attract capital and the need to safeguard stable budgetary revenues.

A particularly noteworthy case is the municipality of Dobra Szczecińska, which has consistently deepened reductions year by year, despite the benchmark remaining relatively stable. Equally significant is the policy of Szczecin itself, which in 2018 and 2020 applied the statutory maximum rate, while in 2019 it introduced only a marginal reduction of less than 1.6%. This likely reflects the city's dynamic development and its position as the leading municipality within the SMA, with an advantageous location near the border and easy access to external markets.

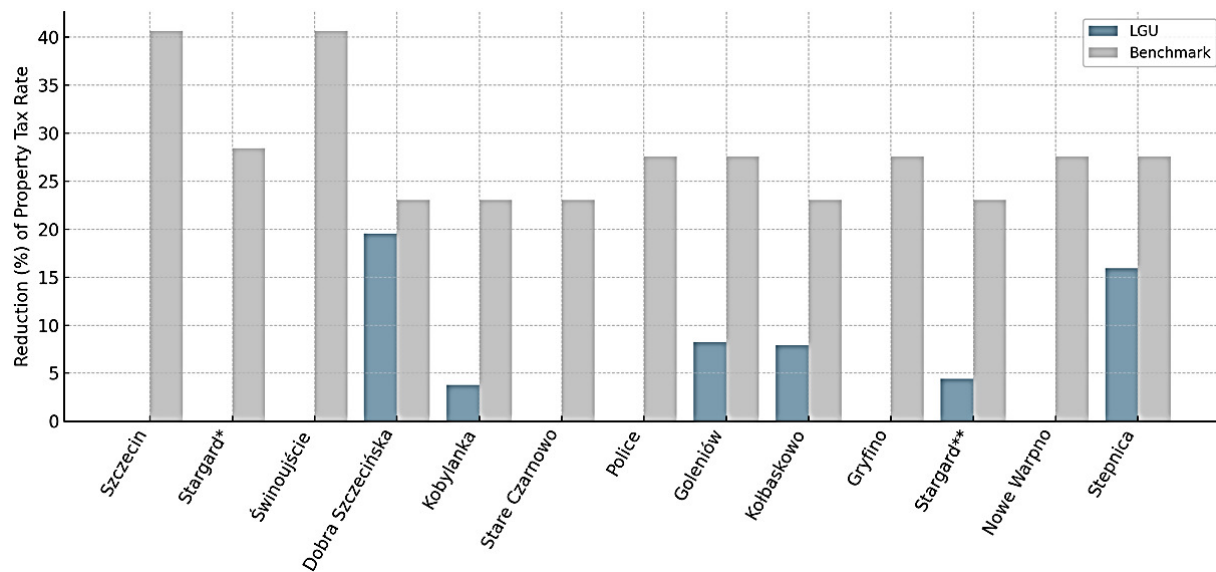


Figure 2. Tax rate reduction coefficient for buildings used for business purposes and residential buildings or parts thereof used for business purposes, in local government units affiliated with SSOM in 2020.

Source: own work.

Figure 2 further illustrates that the amplitude of differences among municipalities remains significant and shows no sign of narrowing over time. This demonstrates that, in the economic sphere, no strong harmonization trend is present. On the contrary, SMA municipalities actively use their tax authority to differentiate burdens, consistent with theoretical and empirical accounts of tax competition (Ramajo, 2020). Comparative studies by Parchet (2019) for Switzerland and Janeba and Osterloh (2013) for Germany demonstrate similar mechanisms, whereby municipalities lower tax rates in response to their neighbors' policies to preserve investment attractiveness. In the Polish context, Łukomska and Swaniewicz (2015) identified analogous dynamics, with business property taxes serving as one of the key instruments of inter-municipal fiscal rivalry. As Jasiniak (2025) emphasizes, the analysis of the American property tax system shows that transparency mechanisms, frequent updates of property values, and clearly defined appeal procedures may serve as an important reference point for research on fiscal policy in Poland.

Taken together, the empirical results for the SMA align with these broader observations: while the residential category reflects fiscal stabilization and harmonization, the business category reveals pronounced differentiation and competitive behavior. This duality illustrates how the metropolitan area simultaneously constitutes a space of stability for residents and a field of rivalry for entrepreneurs.

5. Discussion and conclusions

The findings of this study contribute to the broader discussion on the nature of local fiscal behavior within metropolitan structures, extending the theoretical and empirical work of scholars such as Swaniewicz and Łukomska (2015), Łukomska and Neneman (2018), and Poniatowicz (2023). Previous research has largely focused on the determinants of tax competition and harmonization in national or regional contexts, while the present analysis provides new evidence from a metropolitan perspective, where both mechanisms coexist within a single functional area.

The analysis of property tax reductions on buildings in local government units (LGUs) forming the Szczecin Metropolitan Area (SMA) allows for the formulation of several general conclusions. The empirical results confirm the findings of the literature, which highlight the differentiated logic of local tax policies with respect to various categories of taxpayers (Owsiak, 2001; Zodrow, Mieszkowski, 1986; Łukomska, Neneman, 2018).

First, in the case of residential buildings, tax reductions were moderate and relatively uniform across all municipalities within the SMA. This pattern reflects the predominance of fiscal harmonization, primarily driven by social and political considerations. Local governments deliberately avoided sharp differentiation in household tax burdens, as this could have fostered perceptions of unequal treatment among residents across the metropolitan area. The stability of tax policy during 2018-2020 further underscores the importance of predictability and fiscal security in this category. The relative uniformity of residential taxation supports earlier findings by Francois (2010) and Ramajo et al. (2020), confirming that municipalities tend to avoid socially sensitive differentiation in household taxation.

Second, with respect to business buildings, tax reductions were considerably more diverse, and the range across municipalities remained substantial. This indicates that SMA municipalities employ this tax category as an instrument of fiscal competition, shaping local business conditions. These findings correspond with tax competition theory as developed by Zodrow and Mieszkowski (1986) and expanded by Janeba and Osterloh (2013), which posits that local governments reduce the costs of business activity to attract investment and capital. Most empirical research on tax competition concerns the US tax system (Mast 2020), but similar conclusions were reached by Moisio (2010) and Parchet (2019), who found that municipalities in Finland and Switzerland lower tax rates in response to similar decisions in local governments in their immediate vicinity. Evidence from SMA suggests that such mechanisms are also present in Polish metropolitan areas.

Third, the case study confirms the coexistence of two contrasting mechanisms within a single metropolitan area: fiscal harmonization in relation to residents and tax competition in relation to businesses. The SMA illustrates how social and political factors are balanced against economic motivations, producing differentiated strategies depending on the taxpayer category.

This finding is significant not only for understanding local fiscal practices but also for broader debates on the balance between cooperation and competition in metropolitan governance in Poland.

Fourth, the analysis substantiates the presence of yardstick competition (Besley, Case, 1992), whereby local authorities adjust their tax decisions in response to those of neighboring municipalities to avoid unfavorable comparisons. In the SMA, this mechanism was most apparent in residential taxation, whereas in business taxation municipalities more often pursued competitive strategies, consistent with the observations of Ramajo (2020).

Compared with previous research, the results of this study partially confirm earlier findings on fiscal convergence in residential taxation (Moisio, 2010; Francois, 2010), while simultaneously diverging from them in the case of business property taxation, where fiscal differentiation remains more pronounced. This study therefore introduces a new analytical perspective: focusing on property tax reductions as an operational measure of fiscal behavior within a metropolitan association. This approach allows for a more nuanced assessment of how inter-municipal fiscal interactions manifest themselves in practice, going beyond theoretical assumptions about decentralization. This contrast suggests that the mechanisms of fiscal coordination in Polish metropolitan areas are less institutionalized than in Western European contexts, where inter-municipal cooperation has longer traditions and stronger formal structures.

The findings thus confirm the study's initial hypothesis that metropolitan areas in Poland exhibit a dual fiscal dynamic combining harmonization and competition, but they also reveal that the relative strength of these mechanisms depends on the nature of the tax base and the local economic structure. This nuanced outcome contributes to refining existing theoretical models of fiscal federalism and inter-jurisdictional competition by introducing the metropolitan scale as an intermediate level of analysis.

From a broader European perspective, the results also reflect the mixed nature of fiscal decentralization processes observed across the EU. While the harmonization of residential taxation within the SMA is consistent with European objectives of fiscal stability and social cohesion, the persistence of competitive behavior in business taxation illustrates the limits of coordination within decentralized systems. This finding suggests that, although the Polish model of metropolitan fiscal governance partially aligns with current EU trends promoting local financial autonomy, it still faces challenges in balancing competitiveness with fiscal discipline and inter-municipal solidarity (European Committee of the Regions, 2022; OECD, 2023).

From a methodological perspective, the study also has several limitations that should be acknowledged. It focuses on a single metropolitan area, which constrains the generalizability of the results. Furthermore, the analysis is based on statutory tax rates and does not account for non-tax instruments, such as subsidies or local incentives, that may also influence fiscal competition. Future research should therefore extend the temporal scope and include comparative analyses across multiple metropolitan areas to capture the diversity of fiscal behaviors in different institutional contexts.

The contribution of this study lies not only in its empirical findings but also in providing a metropolitan-level perspective that links fiscal behavior with governance arrangements. This perspective highlights that effective metropolitan fiscal management requires both institutional capacity and informal coordination based on trust and policy learning among local actors.

Despite these limitations, the study contributes new empirical and conceptual insights to the understanding of local fiscal dynamics in metropolitan settings. It identifies the simultaneous presence of fiscal harmonization and competition as a defining feature of metropolitan governance, thereby extending the theoretical framework of fiscal federalism and inter-jurisdictional competition. The findings also have practical implications for policymakers, demonstrating how institutionalized fiscal coordination through metropolitan forums, agreements, or benchmarking systems can balance local flexibility with financial stability and spatial cohesion. Future metropolitan policy should account for the need to coordinate fiscal actions to prevent excessive competition leading to a “race to the bottom”, while at the same time preserving flexibility and the capacity to adapt tax burdens to local socio-economic conditions.

In conclusion, the case of the Szczecin Metropolitan Area demonstrates the dual nature of local fiscal policy: on the one hand, harmonization of household tax burdens; on the other, significant differentiation and competition in business taxation. These dynamics coexist and collectively shape the fiscal landscape of metropolitan governance. More broadly, the results suggest that metropolitan areas in Poland, despite their limited fiscal autonomy as defined by law, are arenas of both cooperation and tax rivalry. The findings have important implications for metropolitan governance, highlighting the need to strengthen mechanisms of fiscal coordination among municipalities within metropolitan areas. The dual nature of the observed phenomena, harmonization in residential property taxation and competition in business property taxation, requires a balanced approach. On the one hand, harmonization supports social cohesion and reduces tensions between local governments; on the other, competition can serve as a stimulus for economic growth but also as a potential source of fiscal imbalance. Therefore, it is crucial to establish common consultative frameworks for local tax policy, such as a metropolitan fiscal forum or agreement, that would help mitigate excessive competition, make better use of economies of scale, and enhance both the coherence of fiscal actions and the overall metropolitan area’s position in its relations with central authorities. By integrating such coordination mechanisms into metropolitan governance, local governments can balance competitiveness with cohesion, ensuring that fiscal autonomy contributes to sustainable regional development rather than fragmentation. In this sense, the study advances understanding of how local fiscal autonomy operates under metropolitan conditions, offering both theoretical refinement and policy-relevant insights for designing more coherent and resilient models of fiscal governance in Poland and across the European Union.

References

1. Act of January 12, 1991, on local taxes and fees (Journal of Laws of 2025, item 707).
2. Act of November 13, 2003, on the revenues of local government units (Journal of Laws 2003, No. 203, item 1966, as amended).
3. Bajerska, A. (2018) Władztwo podatkowe gminy : wybrane zagadnienia. In: P. Mańczyk (Ed.), *Daniny publiczne w Polsce i innych państwach Europy* (pp. 6-15). Szczecin.
4. Bajerska, A., Czerwiński, M. (2018). Nowy obowiązek sprawozdawczy samorządów w zakresie podatków lokalnych (cz. 1). *Finanse, Rynki Finansowe, Ubezpieczenia*, No. 92, pp. 433-441.
5. Besley, T., Case, A. (1992). Incumbent behavior: Vote seeking, tax setting and yardstick competition. *National bureau of economic research*, No. w4041.
6. Bordignon, M., Cerniglia, F., Revelli, F. (2003). In search of yardstick competition: a spatial analysis of Italian unicity property tax setting. *Journal of Urban Economics*, No. 54(2), pp. 199-217.
7. Borszowski, P., Stelmaszczyk, K., Bieniaszewska, A. (2019). *Sprawozdania podatkowe w zakresie podatku od nieruchomości, podatku rolnego i podatku leśnego*. Wolters Kluwer.
8. Buchanan, J.M., Tullock, G. (1965). *The calculus of consent: Logical foundations of constitutional democracy*, Vol. 100. University of Michigan Press.
9. Etel, L. (2007). Podatki realizowane przez gminne organy podatkowe. In: M. Popławski (Ed.), *Stanowienie i stosowanie prawa podatkowego w gminach*. Białystok.
10. Etel, L. (2012). *Podatek od nieruchomości. Komentarz*. Warszawa.
11. Etel, L., Dowgier R. (2013). *Podatki i opłaty lokalne - czas na zmiany*. Białystok.
12. Etel, L. (2012). *Podatek od nieruchomości. Komentarz*. LEX.
13. Felis, P. (2015). *Podatki od nieruchomości a polityka podatkowa gmin w Polsce*. Warszawa.
14. Filipiak, B.Z. (2015). Polityka podatkowa gmin czy realizacja władztwa podatkowego? *Zeszyty Naukowe Uniwersytetu Szczecińskiego. Finanse, Rynki Finansowe, Ubezpieczenia*, Vol. 1, No. 76, pp. 221-230.
15. François I. (2010). *Sub-central tax competition: The French case*. Conference: OECD Tax Competition Between Sub-Central Governments. Bern.
16. Janeba, E., Osterloh, S. (2013). Tax and the city—A theory of local tax competition. *Journal of Public Economics*, No. 106, pp. 89-100.
17. Jasiniak, M. (2025), Property tax system on the case of residential properties in the Cook County (Illinois, the USA). *Scientific Papers of Silesian University of Technology. Organization and Management Series*, No. 229, pp. 147-160. <https://doi.org/10.29119/1641-3466.2025.229.11>
18. Kociemska, H. (2017). Teorie wyboru publicznego i wyboru społecznego a partnerstwo publiczno-prywatne w ujęciu heterodoksyjnym. *Annales Universitatis Mariae Curie-Skłodowska, Sectio H Oeconomia*, No. 51(6), pp. 129-139.

19. Kornberger-Sokołowska, E., Bitner, M. (2018). *Prawo finansów samorządowych*. Warszawa.
20. Kosek-Wojnar, M., Surówka, K. (2013). Kierunki zmian w zakresie repartycji wpływów z podatków dochodowych pomiędzy państwo i samorząd terytorialny. *Zeszyty Naukowe Uniwersytetu Szczecińskiego. Ekonomiczne Problemy Usług, Vol. IX, No. 108*, pp. 177-188.
21. Kosikowski, C. (2013). In: C. Kosikowski, L. Etel, J. Brolik, R. Dowgier, P. Pietrasz, M. Popławski, S. Presnarowicz, W. Stachurski (Eds.), *Ordynacja podatkowa. Komentarz*, wyd. 5. Warszawa.
22. Kotlińska, J., Nowak, M.J. (2010). Podatek od nieruchomości w zewnętrznych strefach obszarów metropolitalnych Polski Zachodniej. *Problemy Rozwoju Miast, No. 4*, pp. 103-110.
23. Lendzion, J., Sołtys, J., Toczyski, W. (2004). Znaczenie obszarów metropolitalnych i ich otoczenia oraz współczesnych procesów metropolizacyjnych w kształtowaniu polityki regionalnej państwa. *Ekspertyza przygotowana na zamówienie Departamentu Polityki Regionalnej Ministerstwa Gospodarki i Pracy*, p. 5.
24. Lubińska, T., Franek, S., Będzieszak, M. (2007). *Potencjał dochodowy samorządu na tle zmian ustawy o dochodach jednostek samorządu terytorialnego*. Difin.
25. Łukomska, J., Neneman, J. (2018). Local Taxes and Fees as a Source of Revenue for Polish Municipalities: Substitutes or Complements? *e-Finanse, No. 14(3)*, pp. 49-59.
26. Mańczyk P. (2018), *Status prawny organów gminy i jego wpływ na zakres, formy i instrumenty lokalnego władztwa daninowego*. Szczecin.
27. Mast, E. (2020). Race to the bottom? Local tax break competition and business location. *American Economic Journal: Applied Economics, No. 12(1)*, pp. 288-317.
28. Moisis, A. (2010). *Tax competition among municipalities: The case of Finland*. Conference OECD Tax Competition Between Sub-Central Governments. Bern.
29. OECD (2023). *Fiscal Decentralisation Database: Tax autonomy of state and local government*. OECD Publishing.
30. Ofiarski, Z. (2015). Standard z art. 9 ust. 3 Europejskiej Karty Samorządu Lokalnego jako wzorzec kontroli na przykładzie wybranych orzeczeń Trybunału Konstytucyjnego. In: M. Ofiarska (Ed.), *Europejska Karta Samorządu Lokalnego a prawo samorządu terytorialnego*. Szczecin.
31. Ofiarski, Z. (2010). Normatywny model źródeł dochodów jednostek samorządu terytorialnego a ograniczenia wynikające z sytuacji sektora publicznego w Polsce. *Zeszyty Naukowe, No. 141*. Uniwersytet Ekonomiczny w Poznaniu, pp. 211-223.
32. Ofiarski, Z. (2016). System (zbiór) podatków samorządowych- wstępne propozycje uporządkowania. *Annales Universitatis Mariae Curie-Skłodowska, sectio H – Oeconomia, Vol. 50, No. 1*, pp. 265-274.
33. Olek, I. (2014). Polityka podatkowa gminy wobec przedsiębiorców – podatek od nieruchomości. *Finanse, Rynki Finansowe, Ubezpieczenia, No. 68*, pp. 195-204.
34. Owsiak, S. (2001). *Finanse publiczne. Teoria i praktyka*. Warszawa: PWN.

35. Owsiak, S. (2005). *Finanse publiczne. Teoria i praktyka*. Warszawa: PWN.
36. Owsiak, S. (2017). *Finanse publiczne: współczesne ujęcie*. Warszawa: PWN.
37. Pahl, B. (2017). *Podatki i opłaty lokalne. Teoria i praktyka*. Warszawa.
38. Parchet, R. (2019). Are local tax rates strategic complements or strategic substitutes? *American Economic Journal: Economic Policy*, Vol. 11, No. 2, pp. 189-224.
39. Poniatowicz, M. (2023). Decentralizacja oraz autonomia finansowa i podatkowa samorządu terytorialnego jako fundamenty federalizmu fiskalnego. In: J. Szołno-Koguc (Ed.), *Finanse samorządowe* (pp. 27-52). Polska Akademia Nauk.
40. Popławski, M. (2008). Uprawnienia rad gmin do określania stawek podatkowych – wybrane zagadnienia. In: M. Popławski (Ed.), *Podatki i opłaty lokalne w praktyce*. Warszawa.
41. Ramajo, J., Ricci-Risquete, A., Jerez, L., Hewings, G.J. (2020). Impacts of Neighbors on Local Tax Rates: A Space–Time Dynamic Panel Data Analysis. *International Regional Science Review*, Vol. 43, No.1-2, pp. 105-127.
42. Resolution of the European Committee of the Regions — The outcome and follow up of the Conference on the Future of Europe (2022). *Official Journal of the European Union* (C 375/02).
43. Sedmíhradská, L., Bakoš, E., Jirsová, D. (2015). *Czech property tax: Usage of local tax autonomy*. Conference NISPACee. Tbilisi.
44. Shleifer, A. (1985). A theory of yardstick competition. *The RAND Journal of Economics*, pp. 319-327.
45. Swianiewicz, P., Łukomska, J. (2015). *Polityka podatkowa władz lokalnych w Polsce*. Warszawa: Municipium SA.
46. The Constitution of the Republic of Poland of April 2, 1997 (Journal of Laws 1997, No. 78, item 483, as amended).
47. Tiebout, C.M. (1956). A pure theory of local expenditures. *Journal of Political Economy*, Vol. 64, No. 5, pp. 416-424.
48. Walasik, A. (2023). Problematyka konkurencji podatkowej w sektorze samorządowym. In: J. Szołno-Koguc (Ed.), *Finanse samorządowe* (pp. 73-85). Polska Akademia Nauk.
49. Wyszowska, D. (2018). Samodzielność finansowa gmin w opinii skarbników gmin w Polsce. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, No. 518, pp. 159-172.
50. Zodrow, G.R., Mieszkowski, P. (1986). Pigou, Tiebout, property taxation, and the underprovision of local public goods. *Journal of Urban Economics*, Vol. 19, No. 3, pp. 356-370.

CLASSIFICATION OF OCCUPATIONAL HAZARDS IN COAL MINING BASED ON CHARACTERISTIC FEATURES

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Purpose: The aim of this article is to analyze the process of occupational hazard identification in underground coal mining operations. Given the inherently high level of risk associated with mining activities, particular emphasis is placed on the accurate identification and characterization of hazard sources as a foundation for effective occupational risk assessment. The paper also seeks to propose a systematic classification of hazards that takes into account both their sources and their potential health and accident-related consequences.

Design/methodology/approach: The article is based on a comprehensive review of scientific literature and applicable legal regulations related to occupational health and safety in underground mining. The study was conducted using secondary data analysis, incorporating a review of normative documents and academic publications addressing occupational hazard issues.

Findings: As a result of this analysis, a structured classification of hazards was developed, including the determination of their characteristic features. This provides a foundation for further application in the context of selecting appropriate risk assessment methodologies.

Research limitations: Despite the broad analytical approach, which encompasses a review of scientific literature, legal frameworks, and accident causation data in the coal mining industry, the study remains theoretical and statistical in nature. It does not include data obtained directly from workplace observations in mining operations. The accident analysis is based on publicly available statistical reports and documents issued by mining supervisory authorities, which may limit the ability to fully capture the organizational and technical context of each event.

Implications: The presented classification of occupational hazards in the mining industry may serve as a foundation for optimizing occupational risk assessment processes by enabling a better alignment of assessment methods with the specific characteristics of identified hazards. A more in-depth characterization of hazard sources and their consequences can also contribute to a more accurate definition of preventive measures and more effective planning of protective strategies. The article contributes to the development of the theoretical foundations of safety management in mining by systematizing the hazard identification process within the framework of occupational risk assessment.

Practical implications: The findings of the study may provide a foundation for developing a more comprehensive methodology for occupational risk assessment that incorporates the

characteristic features of hazards. Consequently, they can facilitate the definition and optimization of preventive measures targeted at the sources of hazards.

Keywords: occupational safety, underground coal mining, occupational hazards, occupational risk assessment.

Category of the paper: research paper.

1. Introduction

Occupational risk is a critical factor contributing to workplace accidents and occupational diseases, and in specific circumstances, it may also lead to major failures or disasters. Ensuring the safety of workers is one of the fundamental objectives of any enterprise. Achieving this goal is possible through the systematic identification of hazards and reliable assessment of the associated risks. A key element of the hazard identification process is the detailed analysis of the factors influencing the likelihood and consequences of their occurrence. The more precisely hazards present in the work environment are identified and characterized, the more accurate and credible the risk assessment will be.

Every organization undertakes efforts aimed at eliminating or at least reducing the consequences and frequency of hazardous events. This is particularly important in industrial sectors, where threats are constant and effective safety management requires the consistent implementation of risk management principles. The risk assessment process begins with identifying its sources, that is, the factors underlying the occurrence of hazards. The more thoroughly these factors and the hazards they generate are identified and described, the more accurate the estimation of health-related risks assessment will be. This, in turn, enables the implementation of precise and adequate preventive measures directly targeting the control or elimination of hazard sources, ultimately improving workplace safety.

Guidelines for hazard identification are primarily determined by applicable legal acts and industry standards. In the Polish legal system (Regulation of the Minister of Health, 2011; Regulation of the Minister of Labor and Social Policy, 2014), various hazard classification criteria have been adopted, which include, among others, the level of detail and measurability. Among hazards resulting from measurable physical factors, harmful environmental factors have been distinguished, for which permissible exposure values (NDS, NDN) are specified, such as:

- chemical substances,
- industrial dusts,
- noise (within the audible and ultrasonic range),
- mechanical vibrations (hand-arm and whole-body exposure),
- extreme microclimates (hot and cold),
- optical radiation (laser and non-laser),
- electromagnetic fields and radiation (in the range of 0-300 GHz).

An additional classification of hazards is included in the "Z-10 Workplace Conditions Assessment" form (Statistic Poland, 2023), which distinguishes:

1. Hazards arising from the work environment:
 - chemical substances – toxic, irritating, sensitizing, carcinogenic, and mutagenic,
 - dusts – fibrogenic, carcinogenic, and others,
 - noise and mechanical vibrations,
 - microclimate,
 - ionizing and non-ionizing radiation,
 - electromagnetic fields,
 - biological factors (e.g., bacteria, viruses, fungi).
2. Hazards related to work strain:
 - excessive physical workload,
 - inadequate lighting,
 - ergonomic factors such as forced body posture and monotonous work.

Workplace accident rates may result from a combination of technical, organizational, and human factors (Gul, 2018; Nyoni et al., 2018; PN-N-18002, 2011; PN-Z-08052, 1980; Tian et al., 2024).

The sources of hazards include, among others:

Technical (mechanical) factors:

- design and construction errors,
- improper use of machinery and equipment,
- material defects,
- inadequate maintenance and operation.

Organizational factors:

- poor work organization,
- suboptimal workplace layout,
- lack of or improper use of personal protective equipment (PPE),
- insufficient training and low employee competence.

Human factors – psychophysical condition of the worker:

- sudden health problems,
- fatigue and exhaustion,
- stress, distraction, lack of focus,
- mental disorders,
- use of alcohol or psychoactive substances.

An inseparable element of the hazard identification process is also the analysis of unsafe behaviors, such as:

- actions inconsistent with regulations or instructions,
- lack of hazard awareness and unfamiliarity with OHS procedures,
- disobeying official instructions,

- overly fast or careless task performance,
- lack of professional experience,
- failure to use PPE,
- violation of organizational and safety procedures.

Accident cause analysis is a valuable and indispensable source of information about existing hazards and their origins. According to the Polish Classification of Activities (PKD), the "Mining and quarrying" section is among the most hazardous sectors of the economy. It is characterized by the highest accident frequency rate (per 1000 employees) and a high average number of work incapacity days per injured person.

In statistical summaries, this section includes the following divisions:

- hard coal and lignite mining,
- extraction of crude petroleum and natural gas,
- metal ore mining,
- other types of mining and quarrying,
- support activities for mining.

An analysis of accident rates in the years 2018-2021 within the entire "Mining and Quarrying" section revealed an average of 2181 occupational accidents per year, including 15.5 fatal, 12 severe, and 2153 minor accidents (Statistic Poland, 2023). The accident figures for individual years are presented in Figure 1.

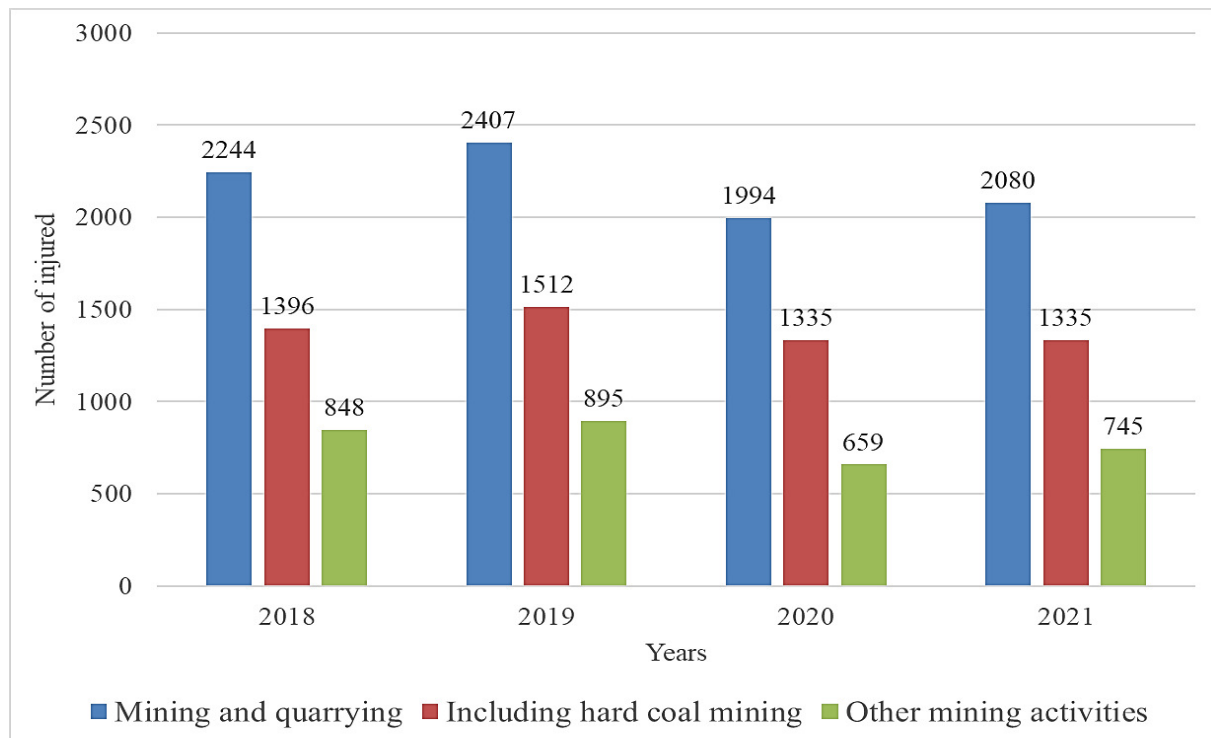


Figure 1. Total number of injured persons in occupational accidents in the mining and quarrying section in the years 2018-2021.

Source: Own study based on GUS data (Statistic Poland, 2023).

In the years 2018-2021, fatal accidents were also recorded in the Mining and Quarrying section, as illustrated in Figure 2.

Among the most common injury-causing events in the total number of occupational accidents in the "Mining and Quarrying" section during the years 2018-2021 were:

- being struck by a moving object,
- collision with or impact against a stationary object,
- physical or mental overload,
- contact with a sharp, rough, or abrasive object.



Figure 2. Fatal accident victims in the mining and quarrying section in the years 2018-2021.

Source: Own study based on GUS data (Statistic Poland, 2023).

Similar incidents also dominated within the "Hard Coal Mining" group. Considering the specific characteristics of the working environment in mining facilities, it can be observed that the most frequent injury-causing events correspond with typical hazards present at mining workplaces. These include, among others: movement in difficult terrain conditions, material transport, work with hand tools, operation of machinery and equipment, presence of transportation systems, exposure to static and dynamic loads, as well as natural hazards.

When comparing data on the most frequent injury-causing events in the "Mining and Quarrying" section with information on the causes of occupational accidents across the national economy in the years 2018-2021 (Statistic Poland, 2023), it is evident that the predominant cause of these accidents was improper employee behavior. This was accompanied by other, less significant contributing factors, which are detailed in Table 1 in relation to specific categories of injury-related events.

The most common events classified as deviations from the normal state in the same section (including the "Hard Coal Mining" group) in the years 2018-2021 were:

- other (unspecified) events,
- slipping, tripping, or falling on the same level,
- being struck by a falling object from above.

Table 1 presents a summary of the most frequent parameters describing the causes, circumstances, and consequences of occupational accidents in the "Mining and Quarrying" section in the years 2018-2021.

It should be emphasized that the data contained in this table reflect the most prevalent accident events, their causes, material agents, as well as the types and locations of injuries occurring within the analyzed economic sector.

In the following years as well, according to data from the Statistical Office (GUS) from 2023 (Statistic Poland, 2023), unsafe employee behaviors remain the leading cause of occupational accidents accounting for over 70% of all incidents. This makes them one of the key elements requiring detailed analysis within the occupational risk assessment process.

Employees in the "Mining and Quarrying" section and its subsections most frequently fall victim to so-called "other" accidents, most commonly involving slipping/tripping and falling on the same level, being struck from above, or slipping and falling from a height.

Table 1.

Causes, circumstances, and consequences of occupational accidents in the mining and quarrying section in the years 2018-2021.

Type of accident	Event causing injury	Cause of accident	Material agent causing injury	Activity at the time of accident	Cause of accident due to activity performed	Material agent related to activity performed	Deviation from normal state	Type of injury	Injured body part
- 1 -	- 2 -	- 3 -	- 4 -	- 5 -	- 6 -	- 7 -	- 8 -	- 9 -	- 10 -
Total – mining and quarrying (including hard coal mining)	impact by a moving object	– improper employee behavior, including: – improper condition of material agent, – lack of or improper use of material agent, – improper or unauthorized employee action	materials, objects, products, machine parts	movement	– improper employee behavior, including: – improper organization (of the workstation), – improper technical or ergonomic condition of material agent	buildings, structures and their components, surfaces (usually at ground level)	other	cuts and superficial injuries	upper limbs
	collision with / impact against a stationary object	improper employee behavior	buildings, structures and their components, surfaces (usually at ground level)	handling of objects	– improper employee behavior, including: – lack of or improper use of material agent, – poor organization of work and workplace – improper condition of material agent	materials, objects, products, machine parts	slip, trip, fall from height	bone fractures	lower limbs
	physical or mental overload	– improper employee behavior, including: – lack of or improper use of material agent, – improper condition of material agent	buildings, structures and components, surfaces (mainly ground level), materials, objects, products, machine parts	manual transport	– improper employee behavior, including: – poor work organization, – lack of or improper use of material agent	materials, objects, products, machine parts	struck by falling object	dislocations, sprains, strains	head
	contact with a sharp, rough, or abrasive object	improper employee behavior	hand tools without power, materials, objects, products, machine parts	working with hand tools	– improper employee behavior, including: – lack of or improper use of material agent, – improper condition of material agent, – poor work organization	equipment for generating, processing, storing, transmitting and distributing energy	—	—	—

Source: GUS (Statistic Poland, 2023).

In the “Mining and Quarrying” section, an average of 51.8% of occupational accidents in the years 2018-2021 were caused by events classified as "other". In 2018, 2020, and 2021, such events accounted for approximately 49% of all accidents, while in 2019 they represented nearly 58%. The second most frequent cause of accidents in this section was slipping, tripping, or falling on the same level, with an average share of 25.6%. The highest share for this cause was recorded in 2021, accounting for 29.7% of all reported events, whereas in 2019, the share was only 21%. The trend in the proportion of accidents involving this event has shown a year-on-year increase, with the exception of 2019 (Figure 3).

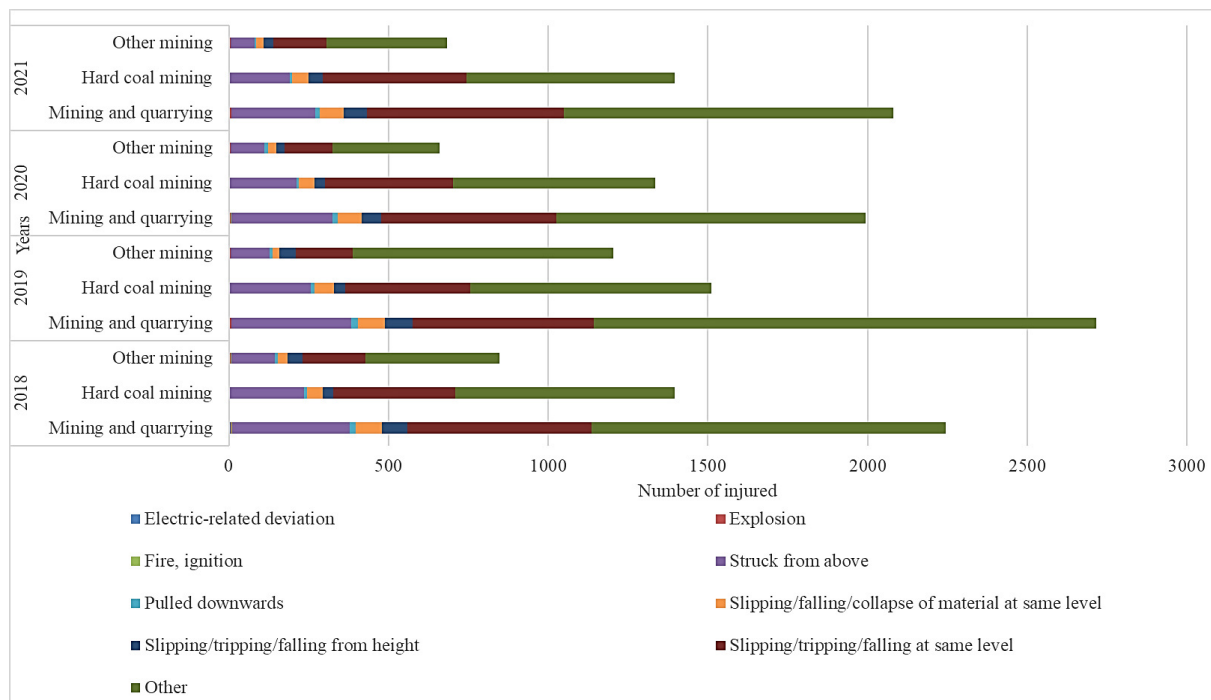


Figure 3. Victims of occupational accidents in the “Mining and Quarrying” section in the years 2018-2021, by events classified as deviations from the normal state.

Source: Own study based on data from Statistics Poland (GUS) (Statistic Poland, 2023).

Among the sources of accidents in hard coal mining, natural hazards must not be overlooked. Some of these particularly those of a catastrophic nature, such as methane explosions or rock bursts can lead to numerous and severe injuries, often with fatal outcomes. According to data from the Central Statistical Office (GUS) (Statistic Poland, 2023), accident rates resulting from natural hazards in the years 2020–2024 are presented in Table 2.

Table 2.

Accident rates resulting from natural hazards in the years 2020-2024

Hazard	Type of Accident			
	Total accidents	Fatal accidents	Serious accidents	Accidents causing temporary work incapacity
Methane	56	16	7	33
Rock Bursts	140	32	4	104
Endogenous Fires	0	0	0	0

Source: Own study based on GUS data (Statistic Poland, 2023).

Polish hard coal mining is characterized by the presence of all natural hazards typical of underground extraction. Among the most accident-prone natural hazards are rock burst hazard and methane hazard. Methane ignitions and explosions, as well as rock bursts and stress relief events that occurred in the years 2020-2024, accounted for the majority of fatal and serious accidents in the Polish mining sector.

The Polish Standard PN-Z-08052:1980 generally defines sources of hazards as follows:

- *hazardous factor* – one whose impact on a worker leads or may lead to injury,
- *harmful factor* – one whose impact may lead to the development of disease.

In addition, the PN-N-18001:2004 standard, now replaced by PN-EN ISO 45001:2024, introduced the concept of a *burdensome factor*, understood as a factor whose impact may cause discomfort or excessive fatigue, but does not result in permanent deterioration of health.

One of the key standardization documents relevant to hazard identification is ISO 12100-1:2012, which outlines the principles of risk assessment in the context of machinery safety. This standard introduces a comprehensive classification of hazards, encompassing mechanical, electrical, thermal, vibration-related, noise-related, and radiation hazards. It also addresses ergonomic hazards and those associated with materials and substances, including chemical, explosive, and biological agents. Additionally, it considers risks stemming from human error, slips, trips, and falls, as well as environmental hazards such as inadequate lighting, extreme temperatures, snow, and strong winds.

Due to the specific nature of mining hazards, the hazard identification process should also include *natural hazards*, defined in Mining Lexicon (Mining Lexicon, 1989), among others, as:

- gas hazard – resulting from the presence of gases, mainly methane and carbon dioxide, in the rock mass,
- fire hazard – related to the presence of fire, fire gases, and smoke in underground workings,
- dust hazard – related to the presence of fine dusts, including coal and silica dust,
- water hazard – sudden inflow of water into the workings from the rock mass or the surface,
- explosion hazard – methane or coal dust explosions.

In addition, the literature (Krause, 2012) lists the following:

- rock bursts,
- roof falls,
- endogenous fires,
- complex and technical hazards.

Other scientific publications (Burtan et al., 2018; Kabiesz, 2001; Krause, 2012; Nowak-Senderowska, 2014; Nyoni et al., 2018; Prusek et al., 2016; Tian et al., 2024; Tubis et al., 2020) also highlight natural hazards that are not explicitly included in legal regulations but nevertheless represent significant risks. These include:

- endogenous hazard – resulting from the spontaneous combustion tendency of coal,
- combined hazards – caused by the interaction of multiple simultaneous hazards,
- gasodynamic hazard – a combination of rock burst and methane hazards.

Occupational hazards in mining are also classified into five primary categories:

- physical,
- chemical,
- biological,
- ergonomic,
- psychosocial.

The most frequently encountered hazards in mining include:

- traumatic hazards (including natural ones),
- ergonomic hazards,
- noise exposure,
- psychosocial hazards.

A three-part classification of hazards is also present in the literature (Burtan et al., 2018):

- natural hazards, originating from the inherent properties of the rock mass:
 - *catastrophic*: methane, coal dust explosion, endogenous fires, rock bursts, gas and rock outbursts, water hazards and their characteristics,
 - *non-catastrophic*: health-threatening dusts, climatic and radiation hazards,
- technical hazards, related to machines, explosives, and exogenous fires,
- human-related hazards, caused by improper employee behavior or poor work organization.

Hazard identification is one of the key stages in the occupational risk assessment process. This stage involves the use of both formal and informal techniques, collectively referred to as hazard characterization (PN-N-18002:2011; Szczepański, 2024). Informal methods include:

- workplace observations,
- employee interviews,
- occupational health and safety committee meetings,
- expert experience,
- consultations with personnel,
- safety audit results.

According to the literature (Burtan, 2016), relying solely on employee knowledge and experience does not ensure complete hazard identification. Therefore, it is essential to use formal methods specifically designed for this purpose. One example is a catalog of 250 potential hazards developed for gold mines, as well as the application of the AHP (Analytic Hierarchy Process) method in occupational risk assessment (Badri et al., 2013).

In conclusion, effective identification and classification of occupational hazards should be based on the use of all available registers, lists, catalogs, and classifications – both those contained in legal regulations and in scientific literature.

2. Materials and methods - methodology

2.1. Groups of occupational hazard factors

Based on the previously indicated sources — including registers, lists, catalogues, and classifications compiled through a review of literature, standards, legal requirements, as well as expert knowledge and practical experience — a classification of factors contributing to the occurrence of occupational hazards in hard coal mining has been proposed. These factors have been divided into four main groups:

- **Natural hazardous factors** – these result from the natural properties of the rock mass and geological processes. In hard coal mining, they include: methane ignitions and explosions, coal dust explosions, seismic tremors, rock bursts, gas and rock outbursts, water inflow, and endogenous fires.
- **Technical hazardous factors** – these are related to the technical work environment. They include machinery and tools and their usage, installations, extraction and transportation systems, local workplace conditions, operational tasks, and the materials and substances used (including chemical agents).
- **Harmful and burdensome factors** – these lead to deterioration in health or cause temporary health issues. Common examples in mining include: noise, vibrations, radiation (IR, UV, electromagnetic, laser), microclimate, hazardous chemicals, biological agents, as well as static and dynamic loads.
- **Organizational and human factors** – these relate to work organization, compliance with procedures, stressors, and the psychophysical condition of workers. They include, among others: communication errors, fatigue, skill mismatch, lack of concentration, hazard disregard, and non-compliance with safety regulations.

The proposed classification facilitates a structured identification of occupational hazards in hard coal mining, ensuring a comprehensive view of risk factors.

2.2. Characteristics of occupational hazards

According to the definition provided in PN-N-18001:2004, hazard identification is not limited to recognizing hazards but primarily involves determining their characteristic features. As noted in Polish Language Dictionary (Polish Language Dictionary, 2021), "characterization" refers to the description of features defining a person, object, or phenomenon, while a "feature" is an element that distinguishes or defines living beings, objects, actions, states, or phenomena. In the context of hazard characterization, this means defining the features of each identified hazard.

In practical applications, this stage is often omitted in occupational risk assessments—resulting in a lack of documentation and analysis of key hazard attributes. Identifying a hazard merely by confirming its existence is insufficient for properly selecting an appropriate risk

assessment method (PN-EN ISO 45001:2024-02, PN-N-18001:2004; Szczepański, 2024; Tubis et al., 2020; Wróblewski et al., 2028). Skipping this step may result in using an unsuitable method that fails to identify the need for implementing control measures.

Determining the characteristic features of hazards is a critical stage in which a detailed hazard description is developed. Omitting this process may lead to underestimating occupational risks and, consequently, implementing ineffective protective measures. A comprehensive approach that incorporates hazard description enables more reliable and effective risk management.

Both literature and standards indicate that the following aspects should be considered when determining hazard features (Krause, 2012):

- physicochemical data of chemical substances and dusts,
- characteristics of energy types and their values (e.g., reactivity, concentration, voltage, current, kinetic, potential, and electric energy),
- information on work methods and organization (e.g., duration, load, working techniques, posture, task cycles, and repetition),
- hazard effects: injuries, illnesses, occupational ailments,
- statistical data needed to estimate probability (e.g., accident records, frequency, and severity),
- legal requirements and literature sources, including safety data sheets, biological agent profiles, and technical material sheets,
- threshold limit values (e.g., NDS – Maximum Permissible Concentrations, TLV – Threshold Limit Values).

Hazards may be classified according to various criteria, including: cause, nature of impact, effects, measurability, origin (internal/external), and applied preventive measures (Konopko et al., 2013; Krause, 2012). These criteria may simultaneously serve as characteristic features of hazards.

Publications concerning hazard identification focus primarily on two aspects:

- sources of hazards,
- consequences of their impact.

In the hazard characterization process, two types of features are distinguished (Act Geological and Mining Law, 2011):

- features of hazard sources,
- features of hazard consequences.

A feature is defined as a distinguishing or characterizing attribute of living organisms, objects, their actions, conditions, or phenomena (Polish Language Dictionary, 2021). A parameter is defined as a variable that takes on a constant value in a given context to emphasize its significance relative to other variables, or as a characteristic value of a material, process, or device (Polish Language Dictionary, 2021). In the context of hazards, parameters

may be expressed as measurable values (e.g., from physical measurements) or estimated values when precise measurement is not possible.

The explanatory notes of the "Z-10 Workplace Conditions Assessment" form (Statistic Poland, 2023) provide examples of features of mechanical factors that, when in contact with a person, may lead to injury. For instance, mechanical hazards associated with particularly dangerous machines can be described using features such as: kinetic and potential energy (including fluid pressure), shape, dimensions, surface properties, stability, and mechanical strength.

Taking the above into account, it is possible to propose a hazard identification algorithm based on characteristic features and their corresponding parameters (Szczepański, 2024) (Figure 4).

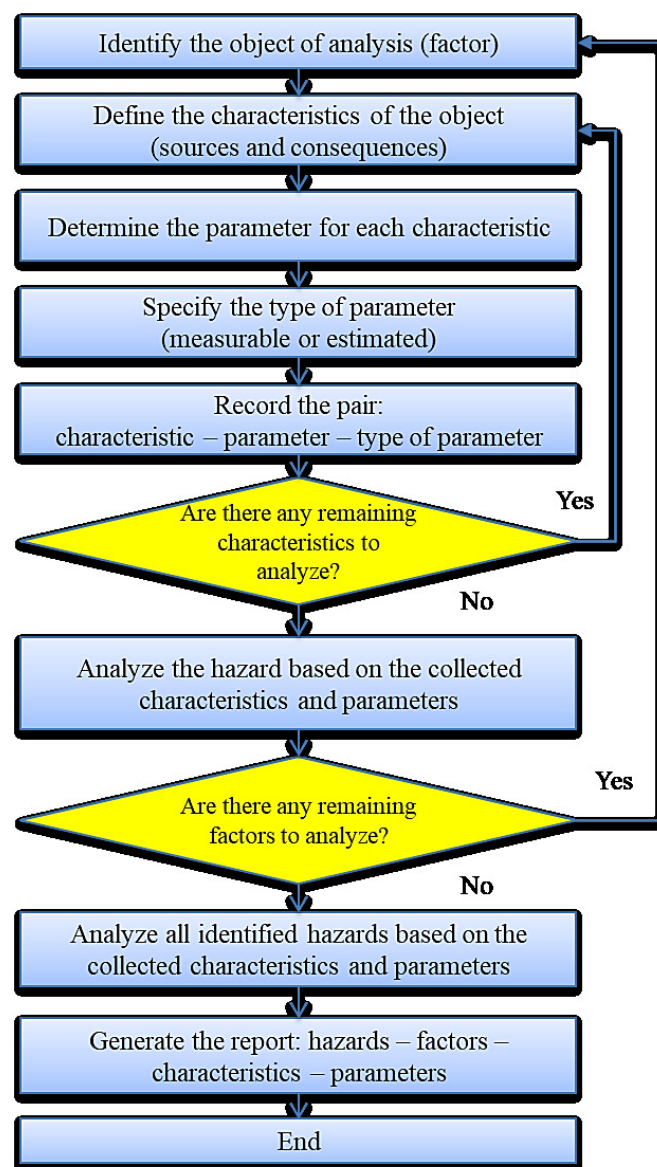


Figure 4. Algorithm for hazard identification considering characteristic features and their parameter.

Both the sources of hazards and their consequences can be described using specific features (Figure 4):

- **Features of hazard sources**, which describe their origin, are assessed based on:
 - physical measurements (e.g., kinetic energy, pressure, noise level),
 - qualitative estimations (e.g., hazard potential).
- **Features of hazard consequences**, which describe their impact on humans, the work environment, or technological processes, are assessed through:
 - probability estimations (e.g., likelihood of injury occurrence),
 - calculated parameters (e.g., risk indicators derived from mathematical models).

The subsequent steps of the algorithm are designed to provide comprehensive information on all identified occupational hazards by analyzing them in terms of underlying factors, characteristic features, and measurable parameters. This structured approach facilitates a systematic identification and classification of hazards, thereby enabling a more accurate assessment of occupational risk. Moreover, the use of characteristic features offers a robust foundation for the development of effective tools for occupational safety management. The implementation of such tools has the potential to significantly reduce the incidence of workplace accidents and enhance overall working conditions in the mining industry.

3. Results

The application of an approach based on characteristic features enables a structured identification and classification of hazards, which contributes to a more precise assessment of occupational risk. It is proposed that the hazard identification process be carried out by developing a detailed characterization of each hazard-inducing factor—taking into account both its sources and potential consequences. Accordingly, the first step in a comprehensive hazard characterization should be to determine its characteristic features, in line with the algorithm presented (Figure 3). These features should describe both the sources and the consequences of hazards in the most precise, exhaustive, and systematic manner possible.

Justification for the use of specific characteristic features of hazards was based on the following premises:

- Consistency with scientific and normative literature
The selection of features was based on an analysis of technical literature and normative documents, including ISO 12100, ISO 45001, and PN-N 18002. A shared aspect of these sources is the emphasis on physical and environmental parameters that directly influence the identifiability of hazards and the magnitude of the associated risk.

- **Measurability and objectivity**
The selected features—such as mass, exposure time, and energy—are characterized by a high degree of measurability and repeatability. This allows their use in both qualitative and quantitative analyses, supporting their practical application in occupational risk assessment.
- **Relevance to hazard impact mechanisms**
The features and their associated parameters directly relate to the mechanisms by which workplace environmental factors can affect the human body (e.g., greater mass results in higher impact force; longer exposure time increases the degree of biological damage). These relationships are reflected in fields such as injury biomechanics, toxicology, and ergonomics.
- **Application in occupational health and safety practice**
In occupational risk assessment methods commonly used in practice—such as the Risk Score method, KIM 1-6, and OWAS—similar characteristic features are used to assess and quantify risk levels. This confirms their practical relevance and applicability in real-world safety systems.
- **Utility in the hazard identification process**
The defined characteristic features included in the hazard classification form a standardized and structured data repository that supports consistent and systematic hazard identification across various work environments. Such a repository may serve as a foundation for both analytical applications and the development of decision support systems based on artificial intelligence.

In this context, the prioritization of features—such as data availability, clarity, and potential for quantitative processing—becomes particularly important. These aspects will be further elaborated in a forthcoming article dedicated to the practical application of the proposed hazard classification and characterization model in the occupational risk assessment process using analytical and digital tools.

Tables 3-6 present an original compilation of characteristic features of the most common hazards encountered in mining, divided into features of hazard sources and features of their consequences (Szczepański, 2024). The adopted classification corresponds to the categories of hazards identified in this study: technical hazardous factors, natural hazardous factors, organizational and human factors, and harmful and burdensome factors.

3.1. Characteristics of Natural Hazardous Factors

The first group of hazards comprises natural hazardous factors. Proposed descriptions of the sources and consequences of hazards within this group are presented in Table 3.

Table 3.
Characteristic features of natural hazardous factors

Type and description of factor	Hazard	Characteristic features of sources
methane	presence in areas with methane hazard	methane-bearing capacity, potential for methane concentration leading to ignition, explosion, or formation of oxygen-deficient mixtures, methane hazard classification (categories I-IV according to legal requirements)
coal dust	presence in areas with coal dust explosion hazard	occurrence of hazardous coal dust, potential for dust explosion, classification of seams or their parts, vertical and horizontal workings into two hazard classes (a and b), according to legal classification
rock bursts	presence in areas with rock burst hazard	susceptibility of rock mass to rock bursts, potential for seismic events (rock bursts) in mine workings, classification according to two hazard levels as defined by legal classification
gas and rock outbursts	presence in areas with gas and rock outburst hazard	methane-bearing capacity, cohesion, desorption index, friability, potential for sudden methane emission or methane and coal outburst, classification of gas and rock outburst hazard (categories I-III), according to legal classification
water	presence in areas with water hazard	hydrogeological conditions, potential for increased water inflow or water ingress with loose material, expressed in three hazard levels I-III), according to legal requirements
endogenous fire	presence in areas with endogenous fire hazard	coal self-ignition susceptibility, activation energy, fire incubation period, quantity and rate of carbon monoxide increase, classification of self-ignition potential in five groups

The characteristic features of consequences such as the number of incidents, types of injuries, number of affected individuals, and injury occurrence frequency which are largely common across all natural hazards, were not included in the table.

3.2. Characteristics of technical hazardous factors

The second group of hazards includes technical hazardous factors. Proposed descriptions of technical hazards and their sources are presented in Table 4.

Table 4.
Characteristic features of technical hazardous factors

Type and description of factor	Hazards	Characteristic features of sources
moving machinery and mechanisms and their components, manual and mechanized tools, transportation of excavated material, rock fragments, rock masses, mining supports	impact by moving objects, machine components, fragments	exposure time, mass, object size, speed of moving object, distance from object, technical condition of equipment, kinetic energy of the object
	entanglement by rotating components	exposure time, mass, object size, speed of rotating object, distance from object, technical condition of equipment, kinetic energy of the object
	crushing by moving object, rock mass, mine collapse	exposure time, mass, speed of moving object, object size, direction of object movement, technical condition of equipment, roof and sidewall condition, kinetic energy of the object
	overturning, falling, rolling, sliding of mining supports, machinery or other objects	exposure time, mass, speed and direction of object movement, object size, technical condition of equipment, kinetic energy of the object
	being covered by transported material	exposure time, mass, speed and direction of object movement, object size, technical condition of equipment, kinetic energy of the object
	impact by hand tools, processed items, assembled or disassembled structures	exposure time, mass, speed and direction of object movement, object size, technical condition of equipment

Cont. table 4.

protruding elements, narrow passages, local height reductions	impact against protruding elements in narrow passages	frequency of exposure, exposure time, size of elements, passage width, passage height, technical condition of workplace
height differences, movement, walking, transport of people, materials, equipment using technical means (e.g., suspended monorails, rail transport, floor-mounted railways, conveyor belts approved for personnel transport), drainage system inspections, sumps	fall from height	frequency of exposure, exposure time, height, technical condition of equipment
	tripping over an obstacle	surface condition, psychophysical state of employee, exposure time
	possibility of falling from transport means (locomotive, suspended tractor, personnel car, cabin), jumping out, collision, derailment, rolling of transport units	frequency of exposure, exposure time, height, speed of transport means, technical condition of equipment
machinery, installations, technological processes	exposure to high pressure (pressurized fluid jets, whipping hoses, fragments propelled by pressurized fluid due to hose rupture)	frequency of exposure, exposure time, pressure, technical condition of equipment and installations
	electric shock, electric arc burns	frequency of exposure, exposure time, electric current intensity, voltage, technical condition of equipment and installations
	high temperature, poisoning due to exogenous fire, underground exogenous fire	exposure time, fire size, fire sources, technical condition of installations
	explosion	frequency of work in explosive atmosphere, exposure time, type and size of explosive hazard zone, technical condition of installations
	hot liquids, hydraulic or pneumatic failure, explosion of pressure vessels, equipment and installations (e.g., tanks, hydraulic accumulators, compressors, pumps)	frequency of exposure, exposure time, quantity of liquid, temperature of liquid, technical condition of installations
	hot surfaces	exposure time, surface temperature, surface area
	low temperature	exposure time, temperature
energy from stress or jamming of supports or rock mass	sudden energy release due to stress or jamming (e.g., support relaxation, conveyor belt release, breaking of jammed pickaxe handle), cable or rope rupture	technical condition of supports and equipment
oxygen, non-breathable atmosphere	oxygen deficiency, mine gases released from rock mass due to mining activities (material decomposition), and operation of diesel-powered machinery	frequency of exposure, exposure time, size of components, passage width, passage height, technical condition of ventilation, ventilation system capacity
lighting	working in areas with inadequate lighting	lighting type (natural/artificial), lighting intensity, lighting color, lighting arrangement, exposure time

The characteristic features of consequences such as the number of incidents, types of injuries, number of affected individuals, and injury occurrence frequency which are largely common across all natural hazards, were not included in the table.

3.3. Characteristic features of harmful and burdensome factors

The third group of hazards comprises harmful/burdensome factors are provided in Table 5. The characteristic features of harmful and burdensome factors are considered together, due to the fact that the distinction between these factors is often unclear, as the features frequently overlap. For practical purposes, the characteristics of sources and effects for both harmful and burdensome factors are analyzed jointly.

Table 5.
Characteristic features of harmful and burdensome factors

Type and description of factor	Hazard	Characteristic features of sources
vibration	exposure to vibration	exposure duration, intensity, route/mode of exposure
noise	exposure to noise	exposure duration, noise level, frequency
radiation (infrared, uv, electromagnetic, visible, laser)	exposure to radiation	radiation type, exposure duration, wavelength, intensity, surface types
radioactive substances	presence in radioactive hazard zones, exposure to ionizing radiation	potential for inhalation or ingestion of short-lived radon decay products or radium isotopes, external gamma radiation emitted from mining sediments and rock formations (radiation hazard classes a and b according to legal classification)
lighting	exposure to inadequate lighting	type of lighting (natural/artificial), intensity, color, arrangement, exposure duration
microclimate	presence in areas with adverse microclimate	air temperature measured by dry bulb thermometer, cooling intensity, microclimatic hazard classification (levels I-III according to legal requirements)
chemical substances	exposure to chemical substances	concentration, exposure duration, hazard classification based on h-statements, physical state, route of exposure, boiling point, process temperature, amount, dust generation potential
biological factors	exposure to biological agents	concentration, exposure duration, classification, toxicity/allergenicity, route of exposure, effects, vaccine availability
static and dynamic loads related to posture	exposure related to body posture	exposure duration, working environment conditions, body posture
manual handling of loads	exposure related to manual transport tasks	load mass, object size, body posture, working conditions
operating transportation equipment	exposure related to operating transport equipment	exposure duration, travel distance, total weight of load and equipment, type and characteristics of equipment, access conditions, working conditions
manual operations	exposure related to manual activities	exposure duration, body posture, object handling method, grip force applied (hand/fingers), working conditions
exertion involving whole-body effort (lifting, pushing, pulling)	exposure to physical loads involving whole-body exertion	exposure duration, body posture, working conditions, symmetry of applied force, force type, force direction
loads associated with movements and relocation	exposure related to movement tasks	exposure duration, movement type (using muscle-powered means, walking, crawling, climbing stairs, ladder use, etc.), movement speed, load weight, carrying method, working conditions

The table does not include characteristics of the effects of each factor. These characteristics include: number of incidents, number and type of injuries, number of errors, number of affected persons and incidence of injuries and are basically consistent for all harmful and troublesome factors.

3.4. Characteristics of organizational and human factors

The final group of hazards, according to the proposed classification, includes organizational and human factors. Proposed descriptions of hazard sources and their consequences for this group are presented in Table 6.

Table 6.

Characteristic features of organizational and human factors

Type and description of factor	Hazard	Characteristic features of sources
stressors – quantitative overload, qualitative overload, quantitative underload, qualitative underload, role conflict, physical working conditions, disruptions, deprivation, tiredness, fatigue, illness, undertaking unacceptable risk	stress	frequency of exposure, duration of exposure, type of work performed, working time, frequency of occurrence
lack, insufficient or incomplete training, incomplete knowledge of methods/ tools/ procedures/ instructions, lack of instruction, or extended periods of inactivity	non-compliance with rules, human error	level of training and skills, competencies, working hours, task difficulty level, frequency of occurrence
misunderstandings, communication errors	aggression by third parties	frequency of exposure, duration of exposure, personal characteristics, type of work performed, frequency of occurrence
psychophysical condition	inappropriate psychophysical condition, fatigue, intoxication, illness	frequency of exposure, duration of exposure, personal characteristics, type of work performed, existing health conditions of employee, frequency of occurrence

The above table does not include columns containing repetitive phrases related to the characteristic features of hazard consequences, as these are common across all listed hazards. These features include: number of illnesses and injuries, type of illnesses and injuries.

For the four distinguished groups of factors, the consequences of their impact exhibit a similar nature—primarily focusing on the type and number of injuries or health issues they may cause. However, it should be noted that certain workplace environmental factors classified as harmful factors may, under specific conditions (e.g., high concentration or intensity), result in consequences typical of another group hazardous factors capable of causing direct injury.

In such cases, the concentration or intensity values of a given factor become critical, as well as the type and severity of the resulting health outcomes, which depend on the extent of the factor's impact on the worker's body. Examples include extremely high noise levels, which can cause immediate hearing damage, or toxic substances, which in large doses may lead to severe injuries or even death.

4. Discussion and conclusions

The proposed classification of characteristic features of factors and hazards occurring in underground coal mining provides a systematic framework for hazard identification and defines the scope of data required for effective hazard information gathering. Both the industrial sector and the specific nature of the process under analysis determine the types of characteristic features and the corresponding parameter values. Integrating characteristic features and their associated parameters into the hazard identification process requires a detailed analysis of each hazard. This approach ensures a comprehensive identification process that reflects the specific operational conditions in underground mining environments.

Adopting such a methodology with clearly defined characteristic features and assigned parameter values emphasizes the necessity of accurate and structured data collection concerning hazards. In subsequent stages of occupational risk assessment, identifying these features and determining the methods for measuring or estimating their parameters becomes crucial. This significantly enhances the effectiveness and credibility of the assessment process, enabling the implementation of targeted preventive and corrective measures tailored to the unique conditions of underground mining operations.

In the proposed classification of factors influencing the occurrence of occupational hazards, natural hazardous factors were identified as the most significant, with their relevance substantiated by statistical data on accident incidence in the mining sector. In current occupational risk assessment practice in mining, evaluations are typically based on estimations of parameters describing the characteristic consequences of hazards (such as the probability of occurrence, type, and severity of injury). However, basing the risk assessment process on the characteristic features of hazard sources enables a more precise estimation of occupational risk and a more effective determination of the necessary preventive measures.

Despite its significant theoretical and structuring value, this study has a validation-related limitation due to the lack of data obtained from direct workplace observations, which could contribute to expanding the repository with new characteristic features of identified hazards. In future research, it would be valuable to consider integrating the proposed hazard classification model with modern digital technologies, such as workplace environment monitoring systems, artificial intelligence (AI) algorithms, and Internet of Things (IoT) solutions. The application of these tools could support the automatic identification of hazards, the dynamic assignment of appropriate characteristic features in real time, and significantly enhance the precision of risk assessment as well as the effectiveness of safety management in the context of future mining operations.

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References

1. *Act of June 9, 2011 – Geological and Mining Law* (2011). Journal of Laws 2011, No. 163, item 981, as amended.
2. Badri, A., Nadeau, S., Gbodossou, A. (2013). A new practical approach to risk management for underground mining project in Quebec. *J. Loss Prev. Process. Ind.*, 26, 1145-1158.
3. Bahn, S. (2013). Workplace hazard identification and management: The case of an underground mining operation. *Safety Science*, 57, 129-137.
4. Burtan, Z. (2016). The significance of associated natural hazards in the mines of the Upper Silesian Coal Basin. *Przegląd Górniczy*, T 72 11, 21-29.
5. Burtan, Z., Chlebowski, D., Kapusta, M. (2018). Conditions and scale of occurrence of catastrophic natural hazards in Polish coal mining. *Work Safety and Environmental Protection in Mining. WUG*, 7(287), 3-11.
6. Donovan, S.-L., Salmon, P.M., Lenné, M.G., Horberry, T. (2017). Safety leadership and systems thinking: application and evaluation of a risk management framework in the mining industry. *Ergonomics*, 60, 1336-1350.
7. Gul, M.A. (2018). Review of occupational health and safety risk assessment approaches based on multi-criteria decision-making methods and their fuzzy versions. *Hum. Ecol. Risk Assess.*, 24, 1723-1760.
8. Higher Mining Authority (2025). *Assessment of Work Safety, Mine Rescue, and Public Safety in Relation to Mining and Geological Activities in 2024*. Katowice.
9. Hu, J., Huang, R., Xu, F. (2022). Data mining in coal-mine gas explosion accidents based on evidence-based safety: A case study in China. *Sustainability*, 14, 16346.
10. Kabiesz, J. (2001). Normative occupational risk assessment of rockburst hazards and associated (coexisting) threats. *Bezpieczeństwo Pracy i Ochrona Środowiska w Górnictwie*, 4, 27-33.
11. Kabiesz, P., Tutak, M. (2024). Developing a culture of safety for sustainable development and public health in manufacturing companies-a case study. *Sustainability*, 16, 7557.
12. Khanzode, V.V. et al. (2011). A methodology for evaluation and monitoring of recurring hazards in underground coal mining. *Safety Science*, 49, 8-9, 1172-1179.
13. Konopko, W. et al. (2013). *Work safety in coal mines. Volume 2: Natural hazards*. Katowice: GIG, 9-382.

14. Korzeniowski, W., Nowak-Senderowska, D. (2012). Efficiency of AHP method during determination of the impact of particular hazards on occupational risk level. *Przegląd Górniczy*, 12, 145-151.
15. Korzeniowski, W., Nowak-Senderowska, D. (2021). Multi-criteria analysis of ergonomic hazards with quantitative risk assessment for the operator of drilling and bolting truck. *Przegląd Górniczy*, 10-12, 54-59.
16. Krause, M. (2012). *Principles for selecting occupational risk assessment methods in the context of the diverse impact of hazardous and harmful workplace factors in coal mines*. Ages. Gliwice: Wydawnictwo Politechniki Śląskiej, 99-140.
17. *Mining Lexicon* (1989).
18. Nowak-Senderowska, D. (2014). *Methodology for Comprehensive Risk Assessment of Health Damage to Workers in Selected Mining Workplace*. Doctoral dissertation. AGH University of Science and Technology.
19. Nyoni, W., Pillay, M., Rubin, M., Jeeries, M. (2018). Organizational factors and risk management in the mining industry: An updated systematic literature review. *Int. J. Occup. Environ. Saf.*, 3, 53-69.
20. PN-EN 31010:2010-01 (2010). *Risk management – Risk assessment techniques*.
21. PN-EN ISO 12100 (2012). *Safety of machinery – General principles for design – Risk assessment and risk reduction*.
22. PN-EN ISO 45001:2024-02 (2024). *Occupational health and safety management systems – Requirements and guidance for use*.
23. PN-N-18001 (2004). *Occupational health and safety management systems – Requirements*. (Standard withdrawn and replaced by PN-ISO 45001:2018 and then PN-EN ISO 45001:2024-02).
24. PN-N-18002 (2011). *Occupational health and safety management systems – General guidelines for occupational risk assessment*.
25. PN-Z-08052 (1980). *Hazardous and harmful factors occurring in the work process*.
26. *Polish Language Dictionary* (2021). PWN.
27. Prusek, S., Rajwa, S., Wrana, A., Krzemień, A. (2016). Assessment of roof fall risk in longwall coal mines. *Int. J. Min. Reclam. Environ.*, 31, 558-574.
28. Regulation of the Minister of Health of February 2, 2011, on the examination and measurement of harmful factors in the work environment (2011). Journal of Laws 2011, No. 33, item 166.
29. Regulation of the Minister of Labor and Social Policy of June 6, 2014, on the maximum permissible concentrations and intensities of harmful factors in the work environment (2014). Journal of Laws 2014, item 817.
30. Regulation of the Minister of the Environment of January 29, 2013, on natural hazards in mining facilities (2013). Journal of Laws 2013, item 230, as amended.
31. *Statistic Poland* (2023). <https://stat.gov.pl>.

32. Szczepański, P. (2024). *Methodology for occupational risk assessment based on the Characteristic features of hazards in hard coal mines. Doctoral dissertation.* AGH University of Science and Technology.
33. Tian, S., Wang, Y., Hongxia, L.I. (2024). Analysis of the causes and safety countermeasures of coal mine accidents: A case study of coal mine accidents in China from 2018 to 2022. *Process Saf. Environ. Prot.*, 187, 864-875.
34. Tripathy, D.P., Parida, S., Khandu, L. (2021). Safety risk assessment and risk prediction in underground coal mines using machine learning techniques. *J. Inst. Eng. Ser. D.*, 102, 495-504.
35. Tubis, A., Werbińska-Wojciechowska, S., Wroblewski, A. (2020). Risk assessment methods in mining industry - A systematic review. *Appl. Sci.*, 10, 5172.
36. Wróblewski, D. et al. (2018). *Risk Management. Overview of Selected Methodologies.* CNBOP-PIB.

DETERMINANTS OF THE PROFESSION OF IT SPECIALIST. CASE OF SELECTED POLISH UNIVERSITIES

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Purpose: The objective of the article is to provide insights into students' awareness, preferences, and expectations regarding their future employment in the IT profession, with a focus on the challenges, hopes, and fears they face, as well as the barriers and determinants influencing their career choices, particularly within selected universities in Poland.

Design/methodology/approach: The research was conducted through a cross-sectional study involving students from selected faculties at four universities in Poland: the University of Warsaw (UW), the Maria Curie-Skłodowska University in Lublin (UMCS), the Czestochowa University of Technology (PCz), and the University of Economics in Katowice (UE Kat.). The study employed the Computer-Assisted Web Interviewing (CAWI) method to gather data from over 800 students. The survey focused on students' perceptions of the IT job market, including current conditions, development trends, and the challenges, hopes, and fears they associate with pursuing a career in this field. Additionally, the research explored the barriers and determinants influencing students' career choices, as well as the shortcomings in the curricula of the analysed universities.

Findings: The study found that while students are generally aware of the opportunities and challenges in the IT profession, they identified significant gaps in their university curricula that fail to adequately prepare them for the industry's demands. Despite these concerns, students remain optimistic about their future in IT but emphasize the need for more practical, hands-on experience in their education.

Research limitations/implications: If research is reported on in the paper, this section must be completed and should include suggestions for future research and any identified limitations in the research process.

Practical implications: The implications of the study suggest that universities need to revamp their IT curricula to better align with industry demands, focusing on providing more practical, hands-on training. This adjustment is crucial for enhancing students' readiness for the

IT profession, ultimately benefiting both the students and the employers who seek well-prepared IT professionals.

Originality/value: The novelty of this article lies in its regional focus, providing a cross-sectional analysis of students' perceptions across multiple universities in Poland, which highlights the specific gaps in IT education within this context. Additionally, the study offers unique insights into how these educational shortcomings affect students' readiness for a career in IT, contributing valuable recommendations for curriculum improvement.

Keywords: career in IT, determinants of the profession of IT specialist, advantages of a career in IT, factors affecting IT career, educational programs in IT.

Category of the paper: Research paper.

1. Introduction

The main aim of this article is to discuss students' perspectives, interests, and expectations concerning potential future employment in IT and their subsequent careers in this industry. The article provides a comprehensive view of the IT profession, which includes individuals who undertake tasks related to the analysis of needs, design, development, implementation, and maintenance of various management information systems. The study focuses on management information systems to avoid limiting the research discourse solely to programmers, who are often the only individuals associated with computer science and informatics. The research problem is not straightforward since the profession of an IT specialist is surrounded by many myths, which frequently get media coverage (Palombini, 2024; Sweeney, 2022; Willcoxson, Chatham, 2006). These myths are challenging to disprove except through scientific research. A new topic discussed is the role and position of women in the IT industry (Dumonceaux, 2023). Although these commonly held opinions are often repeated, they have some truth, as with all myths. The most prevalent myths (Chapman, 2020; Bradford, 2024) include:

- every IT specialist will always and quickly find a job,
- all IT specialists earn a high salary,
- work in IT is only computer-based,
- one needs to study and preferably graduate in computer science or informatics to work in IT,
- computer science and informatics graduates occupy managerial positions and earn the best salaries,
- work in IT is boring and repetitive, it does not involve business trips and training,
- a career in IT requires continuous learning,
- IT specialist knows computers and only serves the user,
- computer science and informatics are difficult to learn, and IT specialists are uncommunicative,

- work in IT requires special psychophysical competencies,
- computer science and informatics are the domain of males.

There are various myths surrounding the IT industry, some of which are backed by statistical data or limited studies, while others are propagated by HR professionals to increase the pool of job candidates. Some of these myths persist in society despite being untrue. Although the market for IT specialists in Poland is not yet saturated, it is crucial to consider the rapid and unpredictable changes in the industry when planning a career (Eurostat, 2024). The emergence of innovative tools like ChatGPT necessitates changes in the way professionals prepare for their roles in IT. Based on expert opinions and data analysis, high remuneration in IT is achieved through intensive work in a well-functioning team, after a minimum of two years. Factors that determine earnings include experience, region, specialization, knowledge of specific technologies, type of cooperation, and work environment (such as a startup or corporation) (Wilczek, 2021). It is worth noting that working in IT rarely involves just sitting in front of a computer (Parris, 2024; Kaatib, 2022).

This primarily applies to individuals in fields such as programming, database administration, and numerics, among others. Various functions related to organizational management, including customer service, marketing, pre-project analysis, data analysis, implementation, and training in new technologies, may also be required. Training for the use of implemented systems is often conducted on-site. IT studies are essential for programming, network configuration, and numerical problems. However, the application of knowledge acquired during these studies also depends on an individual's predisposition, enthusiasm, commitment, and experience. Graduates who specialize purely in IT often lack knowledge of management and soft skills such as teamwork and team management (Rudder, 2019). As a result, they usually do not occupy managerial positions unless they gain practical experience. Some people may find working in IT tedious, repetitive, and unsatisfying, especially if they do not wish to undergo constant training, which is a requirement in the rapidly developing industry. It is worth noting that there are different computer science and informatics specializations; for instance, not every IT specialist is expected to configure software on a PC. Informatics is not limited to just service work, such as helpdesk. The basic concepts of informatics can be learned, but success depends on individual predispositions and natural abilities. Some may find it challenging while others may find it easy and enjoyable. The use of these skills is influenced by the experiences gained through project implementation. While IT specialists may be perceived as uncommunicative due to their need for concentration, communication is crucial for analysts, designers, implementation specialists, and business analysts.

Many young individuals from Generation Z who are interested in pursuing a career in IT may be discouraged by common myths and misconceptions about the industry. Despite the potential opportunities offered by education and training in this field, they are often overlooked. This article aims to address these issues and raise awareness of the diverse career prospects

available in IT, not just in major cities like Warsaw, but also in smaller ones like Katowice, Lublin, and Czeszochowa.

To accomplish this goal, the article is divided into several sections. The second section provides a theoretical background on the subject, while the third section outlines the methodology of the survey research conducted, including the questionnaire structure, research procedure, and research sample obtained from various universities. The study results are then analysed and discussed, focusing on identifying differences between academic centres. Finally, the article concludes with recommendations, limitations, and potential areas for future research in this field.

2. Literature review

The constant, dynamic evolution of information and communication technologies with digital transformation (Vial, 2019) and their integration with the knowledge-based economy (Godin, 2006) are mutually dependent on each other. To achieve maximum success, both industries must coexist harmoniously, creating synergy.

Today, digitization and digital transformation trends affect almost all economic activity and personal life aspects. Many IT employees are responsible for creating, implementing, and improving these technologies. However, it is essential to remember that IT specialists are not a homogenous group but rather a diverse group of professionals, from hardware and software specialists to system implementation experts and business analysts. Therefore, the IT sector requires employees with various professional education backgrounds and specialist and social competencies.

The idea that IT professionals, along with other employees in the IT industry, are considered knowledge workers has been confirmed by trends in the knowledge-based economy and scientific research. Knowledge workers are highly motivated to continuously improve and develop their skills. They possess exceptional abilities in gathering, analysing, and utilizing information, allowing them to quickly adapt to changing circumstances and make informed decisions in their respective fields (Davenport, 2011; Kianto et al., 2019; Maruta, 2012). An increasing number of knowledge workers, including IT specialists, are now working remotely, which requires them to possess self-discipline, time management skills, and emotional intelligence, such as avoiding confrontations, striving for clear and respectful communication, establishing and maintaining relationships online (Charalampous et al., 2019; Grant et al., 2013).

Today, we see that many of these characteristics are no longer relevant as the focus has shifted toward soft skills. According to Boyatzis (2008) and Ngayo Fotso (2021) competencies can be divided into two categories: threshold competencies, which are necessary for a particular

job, and differentiating competencies, which are related to emotional and social intelligence. Willcoxson and Chatham (2006) emphasized that social competencies are essential for effective communication, teamwork, and building relationships with colleagues or clients, particularly for those looking to advance their managerial career in the IT industry (Deming, 2017).

The ICT increasing development is transforming the labour market, creating new job opportunities that require new professionals and high digital competencies. The broad scope of this undertaking is also emphasized by Berger and Frey (2016) who defined digital skills as an amorphous concept, encompassing a wide range of abilities from basic computer knowledge to advanced programming and block-chain development. Research has shown the growing importance of digital competencies as an asset in the labour market, particularly in the IT industry (Lloy, Payne, 2022; Berger, Frey, 2016).

The new generation of workers, known as Generation Z, are entering the workforce. They are individuals with high digital competencies who appreciate change, value innovation, and seek a balance between work and personal life (Barak, 2018; Dolot, 2018). As “digital natives” they regard technology as a natural part of their daily lives, influencing their work approach and expectations toward employers (Schroth, 2019; Chillakuri, 2020). Many of them may already be familiar with the possibilities of working as an IT specialist, therefore they will not be surprised by the topic of the presented research.

Diversity of IT specializations require different desirable characteristics of a good IT employee. Consequently, universities should strive to continuously improve education quality to meet the knowledge-based economy’s requirements. This includes providing timely and flexible education pro-grams and developing external partnerships with local industry, government, and community (Grebski, Grebski, 2018). This should be enhanced by selecting modern teaching methods (Jelonek, Chomiak-Orsa, 2018), such as e-learning (Tirziu, Vrabie, 2015), virtual technologies (Martín-Gutiérrez et al., 2017), and even artificial intelligence (Zhang, Aslan, 2021).

Academic researchers often delve into important questions regarding university education and employment. For example, do universities adequately prepare students for jobs that align with the labor market’s needs (Jelonek et al., 2020; Valberg, 2020)? Are PhD graduates prepared to develop careers beyond academia (Skakni et al., 2025)? Are students adequately prepared for careers in STEM (Liu, Kirk, Oseguera 2024)? Additionally, they examine whether graduates possess the necessary specialist skills and soft competencies (Gruzdev et al., 2018; Kulej-Dudek et al., 2018), sufficient competencies in digital fields (Falck et al., 2021), and if they can solve real-business problems (Lima et al., 2017), or are capable of abstract thinking (Jelonek, Stepniak, 2014).

However, there is a lack of research on whether students are adequately prepared for new and emerging professions in the IT industry, such as Real-time Data Analyst, Digital Transformation Engineer, Mobile UX Designer, Robotic Process Automation Engineer,

eSports Specialist, User Behaviour Analyst, Autonomous Systems Engineer, Extended Reality Architect, and many others.

Similarly, there is little data on whether graduates are willing to pursue jobs connected to their education, but they are largely new and did not exist a few years ago (e.g., listed above). The latter may be why universities did not prepare an education offer for such fields of study. There is also no research on students' attitudes, whether they are open to working in a different profession than indicated by the completed field of study, their self-assessment of their knowledge and competence resources, and whether they want to further their education. Are students aware that the potential of their knowledge may be sufficient as the first step on the path in the broadly understood IT profession, and that the willingness and ability to learn will allow them to take the next steps? Overall, it is essential to explore the attitudes and self-assessments of students to ensure that they are well-equipped for the ever-changing job market in the IT profession. The above formulations indicate a research gap resulting from the available literature, which this article hopes to fill. There is a lack of comprehensive opinions and assessments of students of economics and management studies on their knowledge of the IT profession and factors that would encourage them to do so, the necessary skills and sources of acquiring them, and the scope of work they could perform. In connection with this, the following research questions arise:

RQ1: What are the respondent's IT competencies and skills?

RQ2: What factors influence taking up work in IT?

RQ3: What scope of work in IT would an economics and management graduate prefer?

RQ4: What subjects are or will be needed as part of their current studies to be a specialist?

The structure of the survey was adapted to the answers to the above questions.

3. Research methodology

3.1. Research procedure

Based on the previously conducted research (Chmielarz, Zborowski, 2019) a research procedure was adopted, consisting of the following stages:

1. conducting a thorough analysis of the literature and seeking expert opinions on the IT sector's work-ing conditions and how society perceives them, particularly students,
2. taking into account the results of previous stage queries, our experience, and observations gained from years of working in IT teams,
3. testing the questionnaire's comprehensibility and relevance to the researched issue on a random group of respondents,

4. creating the final survey form and sampling student groups for the study, finalizing the survey form and selecting student groups to participate in the study,
5. providing a link to the survey form using the CAWI (Computer-Associated Web Interview) method to previously sampled student groups,
6. collecting research results, presenting them, measuring any cross-regional differences using the Euclidean distance, and finally analysing and discussing findings,
7. concluding the study and identifying potential avenues for future research.

The process used for this study is similar to that used in other comparative studies. The difference is that it involved standardizing and coordinating research. Compared to international research, the steps for agreeing on the questionnaire content and collecting data were quicker and more efficient without any unnecessary disruptions.

3.2. Questionnaire construction/design

The analysis of online and theoretical materials, supported by expert opinions, allowed us to specify requirements for the survey on students' expectations related to IT specialist work and their views on the educational needs accompanying this phenomenon.

First and most importantly – as stated – such a survey, in addition to its informative function (source of information), should also have an educational process dispelling doubts and some of the myths listed in the Introduction. Second, it combines the students' idea of the IT profession with their idea of the possibilities and necessity of education in this field. Third, it shows the factors that may attract or discourage them from starting an IT career. Four, the survey is addressed to students – not only IT studies (if anything, at universities of economics), but mainly students of economics studies, focused on management. Five, the survey was addressed to all students, regardless of gender and age.

Given the above requirements, the original questionnaire consisted of the subsequent parts, describing the following:

- respondent's IT competencies and skills,
- motivating and demotivating factors as well as limitations for taking up a job in IT,
- the graduate's preferred scope of work in IT in the future,
- students preferred necessary study courses to learn in a future IT specialist profession.

After consulting a pilot group of 30 randomly selected students whenever the questions are relevant, clarity presented, without any unambiguity of answering, five questions were abandoned, one was added, the answer options to four questions were extended, and several previously used terms were changed to achieve a complete understanding of their wording. Ultimately, the survey included twenty one extensive, detailed substantive questions and a data sheet on the sample demographics.

3.3. Sample characteristics

The research sample characteristics from four Polish universities are presented below: Czestochowa University of Technology (CUT), the Maria Curie-Skłodowska University in Lublin (MCSU Lub.), the University of Warsaw (UW), and the University of Economics in Katowice (UE Kat.). It was limited to organizational units related to the field of economics and management as well as business informatics. The study was conveniently conducted at the university level by restricting it to the faculties associated with management, economics, and business informatics. The survey was carried out at individual year-of-study levels at random by asking student groups available at the time to complete the questionnaire.

The data were collected and broken down by gender, age, education and major, place of residence, and financial status.

In general, based on the collected data, it can be stated that:

- women dominate the management faculties of the selected universities – on average they constitute over 60% of the population (men almost 40%), which is typical for this type of study; only UE Kat. differs from this pattern as this university conducts the IT majors (63% of men, 37% of women),
- the largest difference calculated by the Euclidean distance (nearly 30%) occurs between UW, and a slightly smaller one (29%) between (MS) and UE Kat.,
- most respondents (nearly 90%) are aged 19-24, which is also typical for this population, only over 10% are aged 25-34 and above, and the largest (3.68%) difference calculated by the Euclidean distance occurs between CUT and UW,
- according to declarations about studying in a given year of study, almost 56% of respondents have secondary or basic vocational education (most at UW - 78%), and a bachelor's degree - over 34% (most at CUT - almost 53% - the surveys were carried out at the second cycle). For this reason, the greatest variation (30%), calculated by the Euclidean distance, occurred between UW and UE Kat.,
- as expected, the dominant field of education was social sciences – almost 54%, and exact and technical sciences – almost 36% on average (most at UE Kat., nearly 74%, due to surveying students of econometrics and business informatics),
- on average, most individuals (34%) come from cities with more than 200,000 inhabitants (mainly UW - 60% - due to Warsaw) and the rural areas - on average over 34% (mainly due to CUT - 58%). In these two categories, the most significant difference measured by the Euclidean distance occurs between CUT and UW.

The conclusions indicate, the research sample was characterized by quite a large diversity as in mass studies.

The statistical analysis of the input data was limited to calculating the variance and standard deviation for the sub-criteria in each criterion at the selected universities. The variance indicates the difference in the results in a given set. The standard deviation determines the degree of concentration of the variable value around the arithmetic mean.

Significant differences in the data collected from individual universities were measured by the Euclidean distance. These cases were previously observed in the respondent's year of study (45% on average, with as much as 117% difference between UW and MCSU Lub.) and the intention to pursue a career in IT (17%, mainly due to the 36% difference between CUT and UE Kat.). These differences seem justified in the case of a randomly selected sample.

In the survey, participants chose from a list of possible options to answer questions. This means that the variables were nominal, and each observation could only belong to one category for each variable. To compare respondents from different universities, we used the Chi2 test, which is a commonly used statistical tool to determine if there is a significant dependence between variables. We put forward the null hypothesis (H_0) in the Chi2 test, which assumes that the variables are independent. However, in the alternative hypothesis (H_1), we assumed that the variables are dependent. If the significance level (p) is less than 0.05, we reject the null hypothesis and conclude that there is a statistically significant dependence between the variables. The Chi2 test helped us identify significant differences between respondents' universities and the answers they gave. Additionally, we used adjusted residuals to identify outliers, which were answers from respondents at a particular university that significantly differed from the expected value. We performed these calculations using the IBM SPSS 28 application. We analysed differences in factors that motivate people to work in IT, factors that discourage them, IT competencies, and academic topics that students interested in working for an IT company want to study at their university.

4. Results and discussion

In March and April 2024, a survey was conducted using the CAWI method in four well-known academic centres. The survey included several sections, such as:

- identifying respondents who work in the labour market,
- their opinions on the benefits and drawbacks of starting a career as an IT specialist, their preferences for working in this field,
- necessary competencies required to perform the job and how to acquire them,
- students' ideas about the beginnings of a career and the areas of duties of a future IT specialist,
- competencies acquired at the university and those that should be supplemented there,
- social, economic, and technological reasons for career changes of an IT specialist,
- professional changes in IT specialist work and degree of the current basic development trends will prevail in future enterprises.

The initial section of the survey focused on the respondents' year of study. Most respondents (over 41%) were in their second year of studies. This was mainly due to the high number of respondents from UW (95%). In second place (27%) were first-year students, with most of them (53%) registered at MCSU Lub. The percentage of students participating in the third year of studies or the second Master's or Bachelor's studies was minimal. UE Kat had the most even distribution, with 33% of students completing the survey from the second year of studies, and slightly fewer (26%) from the first and fourth years (22%). Therefore, UE Kat had the lowest values for both variance (1.88%) and standard deviation (13.17%).

The Euclidean distance showed the highest variation (117%) between UW and MCSU Lub. Similarly, a high variation (50-60%) was observed between UW and other universities due to the lack of respondents from the third year of studies at UW. The smallest variation (5%) was identified between CUT and UE Kat.

The next question in the survey was about the respondents' professional status. On average, 44% of individuals answered that they were students and did not work. Most of these individuals were from MCSU Lub. (64%), followed by CUT (43%), UW (32%), and UE Kat. (36%). The second most common response (29%) was from individuals working casually under a commission or employment contract. Due to the sizeable labour market in Warsaw and its vicinity, UW students had the highest percentage (40%) in this category. However, they now have to compete with workers from Ukraine for remuneration.

The most significant variation in terms of the Euclidean distance (18%) was found between MCSU Lub. and UE Kat. and a similar variation was observed (15%) between UW and MCSU Lub. Other differences were two-three times smaller.

The second part of the survey focused on identifying the requirements for pursuing a career as an IT specialist. The results showed a significant emphasis (averaging at 28%) on high salaries, which showed a continuous upward trend. Interestingly, the responses in this category were almost identical across all universities analysed, ranging from 23-24% at UE Kat. and CUT to 31% at UW. The second most important factor was the certainty of finding employment both now and in the future, with an average of 22% (ranging from 17% at UE Kat. to 23% at UW). The possibility of remote work came in third place with 21% (17% at CUT to 22% at UW). However, with recent changes to labour laws, it remains to be seen if remote work will stay so popular. These were the top three categories, with other factors such as flexible working hours (10%), opportunities for continuous development (6%), or acquiring new skills (5%) being of less importance during these times of economic uncertainty.

When it comes to job preferences, certain factors like working with a great team, accelerated promotion possibilities unless it is connected with a pay increase, and choosing between human interaction or computer work are no longer the top priorities. UW had the most diverse data on this topic, with the highest variance (1.23%) and standard deviation (11.11%). The biggest differences in opinions were between respondents from UW and UE Kat.

The variation in attitudes toward high salaries, employment opportunities, and continuous development caused a 1.96% difference in Euclidean distance. The results are shown in Figure 1.

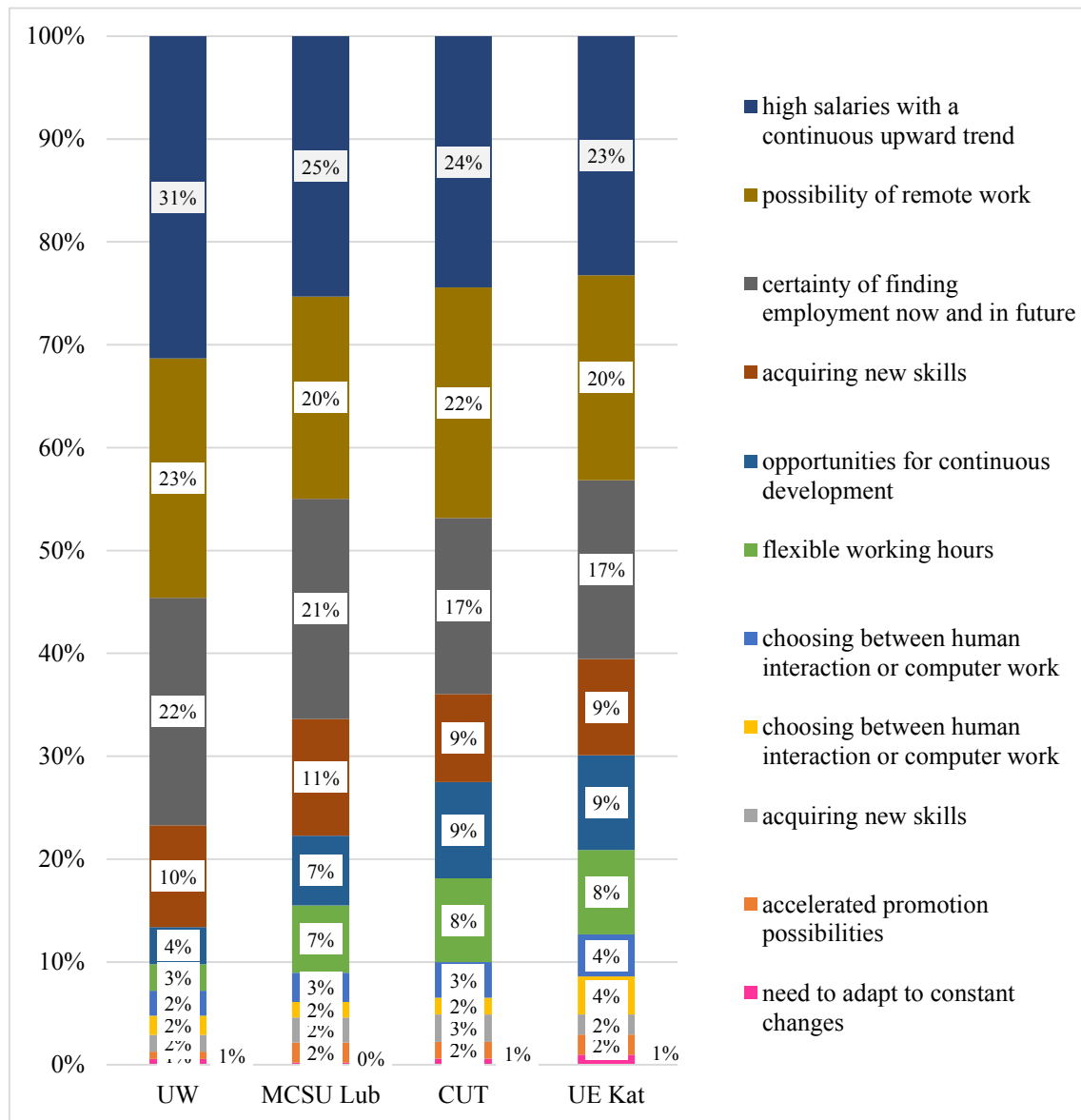


Figure 1. Requirements for pursuing a career as an IT specialist.

Source: own study.

Respondents had varying opinions on employment security, salary levels, remote work, skill acquisition, and continuous development. UW students prioritized employment security the most, while UE Katowice students did not find it as crucial. High salaries with a rapid upward trend were the most important for UW students, with nearly 90% of them agreeing. A significant percentage of UW students (63%) were also interested in remote work, while only 47.2% of the CUT students found it appealing. Statistical analysis using the Chi2 test confirmed previous observations obtained with the Euclidean distance. The University of Warsaw respondents were least interest-ed in acquiring new skills and continuous development, as shown in Table 1.

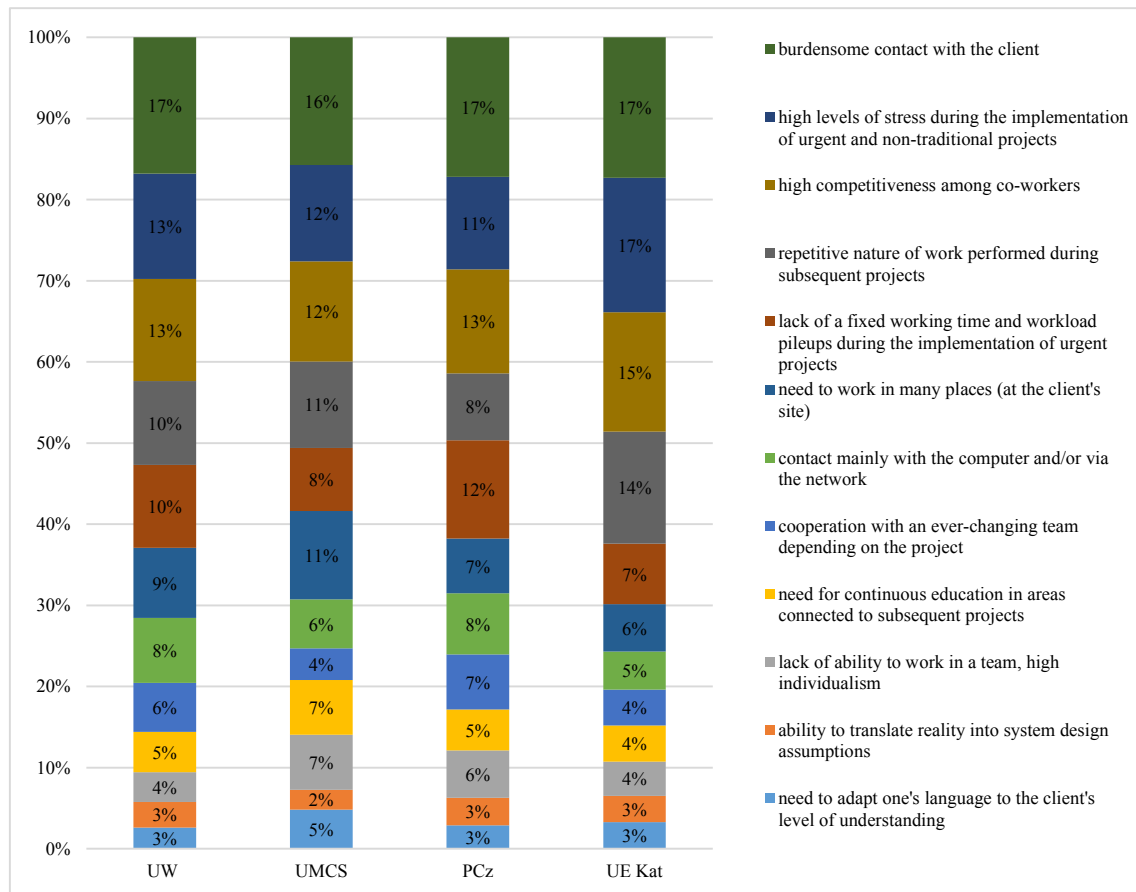
Table 1.*Differences in requirements for pursuing a career in an IT profession*

What would incline you to work in the IT specialist profession?	UW		MCSU Lub.		CUT		UE Kat.		Chi2	p
	n	%	n	%	n	%	n	%		
Employment security	200	66.7%(+)	90	54.50%	110	61.80%	89	49.4%(-)	16.01	0.001
High salaries with a rapid upward trend	269	89.7%(+)	116	70.3%(-)	120	67.4%(-)	119	66.1%(-)	50.23	0.001
Flexible working hours	85	28.30%	52	31.50%	42	23.60%	42	23.30%	4.257	0.235
Possibility of remote work	190	63.3%(+)	98	59.40%	84	47.2%(-)	102	56.70%	12.22	0.007
Acquiring new competencies	22	7.3%(-)	30	18.20%	40	22.50%	48	26.70%	35.71	0.001
Cooperation with a great team	14	4.70%	11	6.70%	13	7.30%	19	10.60%	6.111	0.106
Accelerated promotion possibilities	21	7.00%	13	7.90%	17	9.60%	10	5.60%	2.217	0.529
Choosing between human interaction or computer work	16	5.30%	7	4.20%	8	4.50%	21	11.7%(+)	11.39	0.010
Opportunities for continuous development	31	10.3%(-)	31	18.80%	47	25.8%(+)	47	26.1%(+)	26.14	0.001
Need for improvement of competencies	6	2.00%	9	5.50%	8	4.50%	10	5.60%	5.269	0.153
Need for change adaptation	5	1.70%	1	0.60%	3	1.70%	5	2.80%	2.433	0.487

n – number of respondents who gave an affirmative answer, % – the percentage of respondents who gave an affirmative answer, Chi2 – the value of chi-square statistics, p – significance level (when $p < 0.05$ there is a statistically significant relationship), (-) – negative adjusted residual value $Z < -1.96$ (downward outlier); (+) – the positive value of the adjusted residual $Z > 1.96$ (upward outlier).

Source: own study.

Such unanimity of opinion cannot be observed in the case of factors dissuading from taking up a career as an IT specialist. The distribution of responses is more even in this case (Fig. 2). Nevertheless, in all universities, attention is drawn to high levels of stress during the implementation of urgent and non-traditional projects (at the level of 17%), contact mainly with the computer and/or via the network (from 6% at UE Kat. to 13% in the others) and high competitiveness among co-workers (11-15% most in UE Kat.). Equally minor differences occur concerning the following categories: burdensome contacts with the client, lack of a fixed working time, and workload pileups during the implementation of urgent projects (10% each). The least cumbersome (3% UE Kat.) seems to be adapting one's language to the client's level (5%), resulting in errors in the implementation or adaptation of the software to the client's needs. The variance in the data collected from each university was relatively small (0.31%), as was the standard deviation (5.51%).



Other: inability to work in a team, high individualism, ability to translate reality into system design assumptions.

Figure 2. Factors discouraging students from starting a career as an IT specialist.

Source: own study

According to the respondents, the main reasons for avoiding a career as an IT specialist are high levels of stress, the need to work mostly with computers, and the lack of a fixed work schedule. However, opinions vary on other factors such as the repetitive nature of the work, the need for continuous education, the lack of a permanent workplace, dealing with clients, and adapting language to their needs. UW students find continuous education and computer work particularly discouraging, while MCSU Lub. students struggle more with adjusting their language to clients. Interestingly, the CUT students are less averse to repetitive work and dealing with clients. UE Katowice respondents find constant education and computer work less problematic compared to other universities.

According to the survey, more than 40% of respondents expressed interest in pursuing a career as an IT specialist – response option: *that's what I wanted: sometimes, always*. This was the most popular choice among respondents, with over 40% (mostly 87% from UE Kat. given analysed fields of studies) selecting it as their desired career path. However, the least amount of interest came from CUT, which may come as a surprise as it is a university with a polytechnic profile. When considering those who were undecided or unsure based on the response options: *sometimes I wanted and I don't know*, an average of 67% of respondents were considering a career in IT (ranging from 65% at CUT to 88% at UE Kat.). The largest variation

in data was found at UE Kat., with a variance of 5.09% and a standard deviation of 22%, followed by UW.

The biggest variation in responses from individual universities was observed between CUT and UE Kat., with a Euclidean distance of 36.42%. This was mainly due to opposite answers regarding interest in pursuing a career as an IT specialist, with some respondents selecting *No, I never thought of being an IT specialist* and others selecting *I always thought so*.

Other questions in the survey asked about the necessary competencies for an IT specialist, ways to acquire them, and the role of universities in the process. The survey also addressed the need to supplement competencies to start a career as an IT specialist.

Based on the feedback received, the main requirement for IT specialists is their ability to analyse business data, which was cited by 15% of respondents on average. At MCSU Lub., this proportion was even higher at 19%. Application Development was the second most important skill, with an average of 11%. UE Kat had the highest share of respondents at 16%. Unfortunately, the Use of Office Applications ranked third at 10%. This misconception has persisted for several years and results from the belief, in-stilled by economics and management faculties, economics and polytechnics scientists, other academic subjects, and even university management, that knowledge of applications like MS Office is a basic skill for IT specialists. This shows a lack of awareness of what the IT specialist profession entails among many university students. Other important skills were Database Service and Designing E-business Applications. However, competencies such as IT project management, system architecture design and development, or traditional management systems were not highly valued by respondents, receiving only 1-5% of responses. The UW data had the largest dispersion among the data, with a variance of 0.29% and a standard deviation of 5.43%. The most considerable differences between universities, as measured by Euclidean distance, were observed between UW and UE Kat, with a difference of 5.75%.

When asked about their experience with computer science and informatics education, most respondents (36% on average, with 45% from CUT) reported having taken courses in these fields during their primary and secondary school years. The next most common source of education was higher education at the Bachelor's and Master's levels (21% on average). Self-education (19% on average, with 22% from UE Kat.) and peer support through friends (9% on average) were also significant sources of education. Interestingly, despite many respondents expressing interest in IT as a profession, only a small percentage (1-7%) sought additional training through short courses, specialized university pro-grams, or internships in IT projects.

When considering a career as an IT specialist, many management students believe that proficiency in office software is crucial. 32% of respondents who were asked about the competencies acquired during their studies in existing IT systems and related activities during their studies indicated proficiency in software such as editors, spreadsheets, and databases. The second most common competency was in programming languages such as C*, Java, and

VBA (14%), with a higher percentage (21%) among students at UE Kat. The third most common competency was in subsystems of integrated systems (financial accounting, HRM, warehouse, procurement, and sales) at 12%. Additionally, around 10% of respondents had competencies in network services and business intelligence systems for reporting and analysis. However, many respondents lacked competencies that are essential for IT specialists, such as system analysis and design tools, project management tools, business process optimization tools, IT service management, and database and data warehouse management. These essential competencies have either been removed from curricula due to cost efficiencies at universities. This lack of targeted competencies may hinder students' career prospects in the early years of their studies.

The data show significant variations in competencies among different universities, with the highest differentiation of 10.15% observed between UW and UE Kat. (variance 1.29%, standard deviation 11.37%) and CUT and UE Kat. (10.11%). This variation is mainly due to differences in attitudes toward the ability to use office software, integrated systems, and programming knowledge.

Table 2.

Differences in competencies in the existing, most popular IT systems and activities related to their creation and operation

Student's competencies in existing IT systems	UW		MCSU Lub.		CUT		UE Kat.		Chi2	p
	n	%	n	%	n	%	n	%		
Integrated system's subsystems	89	29.70%	36	21.80%	83	46.6%(+)	19	10.6%(-)	61.852	0.001
Business Intelligence	53	17.70%	30	18.20%	30	16.90%	46	25.60%	5.848	0.119
Business process optimization tools	12	4.0%(-)	15	9.10%	13	7.30%	19	10.6%(+)	8.55	0.036
System analysis and design tools	12	4.0%(-)	17	10.30%	6	3.4%(-)	25	13.9%(+)	22.663	0.001
Project management tools	11	3.7%(-)	12	7.30%	9	5.10%	25	13.9%(+)	19.478	0.001
Programming	71	23.7%(-)	54	32.70%	26	14.6%(-)	120	66.7%(+)	131.48	0.001
Application modification and development	8	2.7%(-)	10	6.10%	5	2.8%(-)	59	32.8%(+)	135.201	0.001
Database application programming	9	3.0%(-)	8	4.8%(-)	5	2.8%(-)	56	31.1%(+)	126.212	0.001
IT services management	6	2.0%(-)	12	7.30%	10	5.60%	21	11.7%(+)	19.416	0.001
Database and data warehouse management	18	6.0%(-)	14	8.50%	8	4.5%(-)	47	26.1%(+)	60.324	0.001
Office Software	271	90.3%(+)	107	64.8%(-)	126	70.80%	110	61.1%(-)	66.131	0.001
Cloud application implementation and integration	14	4.70%	8	4.80%	22	12.4%(+)	10	5.60%	12.604	0.006
Network services	64	21.3%(+)	20	12.10%	32	18%	10	10.0%(-)	13.298	0.004

n – number of respondents who gave an affirmative answer, % – the percentage of respondents who gave an affirmative answer, Chi2 – the value of chi-square statistics, p – significance level (when $p < 0.05$ there is a statistically significant relationship), (-) – negative adjusted residual value $Z < -1.96$ (downward outlier); (+) – the positive value of the adjusted residual $Z > 1.96$ (upward outlier).

Source: own study.

Table 2 analysis reveals significant differences in IT competencies among respondents from various universities, particularly UE in Katowice. Eight out of thirteen competencies were found to be significantly higher in respondents from UE in Katowice compared to other universities. Interestingly, UW students showed lower competencies in IT management, specifically in process optimization, system design, project management tools, programming, IT service management, and data warehouse and service management. However, UW students showed a significantly higher level of competence in office software and network services. In contrast, MCSU Lub. respondents displayed a well-balanced set of competencies, not significantly different from the average catalogue of competencies of all respondents, except for office software and database programming skills.

As a result, the question arises: if students have a low opinion of their universities' role in acquiring IT competencies, what specific competencies do they desire? Among all competencies, Business Intelligence systems were the most desired (15%) (with UW having a slight advantage at 19%), followed by learning programming languages (13%). The highest proportion of answers came from MCSU Lub. (16%), followed by analysis and system design tools (9%) (mostly MCSU Lub. at 11%). Additionally, nearly 8% of respondents expressed an interest in application modification and development (programming).

In the common perception, making a career is reflected in the acquisition of successive, increasingly higher positions that prove the status in a specific activity, in this instance in the broadly understood profession of an IT specialist. In this case, it is about the expectations of future graduates after potential training and gaining additional competencies. According to the findings of this part of the survey, 14% of students are interested in beginning their IT careers as business contact consultants or managers, based on acquired competencies beyond just IT. Out of all the surveyed students from UW, 20% felt the most confident pursuing this type of position, while 13% were interested in project team leadership or consulting in sales and marketing. However, the position of helpdesk service manager was the least popular, with only 3% expressing interest. Jobs that require direct interaction with users, such as implementation consultant, system start-up, and maintenance manager, were considered difficult and only 5-7% of students were interested in them.

The responses to the question about a future IT professional's possible interests and responsibilities yielded similar results. The top choice, at 18%, was the role of a business data analyst (with the highest percentage at UW being 22% and MCSU Lub. being 18%). The second choice, at 10%, was an IT security analyst (with the highest percentage at MCSU Lub. being 12%), and the third choice was a data architect (with the highest percentage at UE Kat. being 13%).

Table 3.*Areas of a future IT specialist's possible interests and responsibilities*

Future position/University	UW WZ	MCSU Lub.	CUT	UE Kat	Mean
IT Security Analyst	8%	12%	10%	11%	10%
IT Security Adviser	4%	4%	8%	6%	5%
Chief Security Officer	6%	4%	11%	7%	7%
Network Analyst	7%	8%	6%	4%	6%
IT Profitability Analyst	6%	5%	6%	4%	6%
Business Intelligence Analyst	22%	19%	17%	13%	18%
Data Scientist	6%	7%	4%	13%	7%
Library Scientist	1%	3%	3%	2%	2%
Data Architect	6%	8%	6%	13%	8%
Director of Analytics	11%	7%	6%	5%	7%
IoT Network Architect	3%	4%	2%	2%	3%
Digital Business Architect	2%	3%	3%	5%	3%
Enterprise Business Architect	6%	5%	4%	4%	5%
Knowledge Analytics	6%	8%	5%	7%	6%
Knowledge Manager	5%	5%	8%	4%	6%
Total	100%	100%	100%	100%	100%
Variance	0.23%	0.16%	0.15%	0.16%	5.57%
Standard deviation	4.85%	4.03%	3.89%	3.97%	23.60%

Source: own study.

However, all scientific and conceptual positions, such as knowledge analyst, business enterprise architect, data scientist, application profitability analyst, etc., do not appeal to the respondents.

We determined the significance of substantive and psychophysical competencies for a future IT specialist from the previous questions. The most important competency was the ability to rapidly acquire new information and IT knowledge, with over double the number of responses compared to the other competencies (averaging 26%). The other five competencies had an average of 11%: openness to non-standard methods, the ability to work in a project team, mental resilience to real or perceived shortcomings, the ability to recognize key tasks and focus on them, and intelligence and independence of action. Other characteristics, such as business knowledge or concern for the project's success, were not deemed as important, with an average of 5% of responses. Interestingly, the ability to defend one's views had the lowest position, with only 1% of responses, while intelligence and independence of action were valued at 10%. With these findings, it appears that the future IT professional may be considered a conformist, but this may also be due to logical errors in the survey responses.

Responses from the analysed universities had similar diversity. However, the differences between the surveyed universities were negligible, with the largest variance between UW and CUT at 0.66%.

According to the respondents, the requirements for employment in the IT profession are slightly different. Technical skills, which refer to the ability to operate IT equipment and application software, were considered the most important (19%) and this was consistent across all universities surveyed. Length of service in the profession and experience in the IT industry were ranked second (less than 19% on average), as they impact the specific routine and work

flexibility. Additionally, more than 11% of the respondents highlighted the importance of logical thinking, independent problem-solving, language skills, education, and the ability to learn and acquire knowledge. Ambition and the desire for a high salary were not considered significant factors (and may even contradict the employment conditions). However, knowledge of economic issues, enthusiasm for the profession, and mental predispositions were not valued. So where does this leave a person's desire to pursue a career in IT?

The most varied answers were given at UW, with a variance of 0.55% and a standard deviation of 7.43%. Interestingly, responses at other universities were quite similar. Therefore, the Euclidean distance in all cases was minimal, with the highest value of 0.79% between MCSU Lub. and UW.

When asked about skills they would like to acquire for a career in IT, respondents emphasized skills they would like to learn at universities with an average of 16%. The most requested skill was application programming, with the ability to design IT systems following closely behind (12% on average with the highest percentage at UW of 16%). These practical skills are crucial for employment but have sadly been neglected at universities in recent years. They should be reintroduced into the curricula of universities of economics, along with courses on database management and design (10% on average and 14% at UW). Theoretical knowledge of IT systems and their applications (almost 12% on average) and systems analysis and design (almost 11% on average and 15% at UW) were also important to respondents. Additionally, understanding the latest IT products and their development was requested at 10% on average and 15% at UE Kat. This content seems to have been included in course materials for years, but either the content is outdated or insufficient. On the other hand, non-specialist practical knowledge, such as time management of designated and performed tasks and awareness of incomplete knowledge, was undervalued (3-8% on average). Respondents expressed that they had adequate knowledge of organizational and legal issues and how the economy operates.

5. Conclusions

This research explored the awareness of Generation Z about pursuing a career as an IT specialist. We aimed to prepare this generation for embarking on the IT profession at universities, departments, or faculties of economics, management, econometrics, or business informatics. We focused on examining cross-regional differences in this analysis. However, we recognize that other factors impact the diversity of approaches to this topic. Higher education institutions in Poland have various organizational structures, which include institutes, faculties, specialties, and majors. They offer different types of studies, such as full-time, evening, and extramural studies, which can be conducted in either Polish or foreign languages. Additionally, they run various study programs after introducing a new division of

specializations that cut down subjects that the university authorities do not perceive as closely related to a given specialization for economic reasons. Universities' perception plays a vital role in determining what is essential for graduates to get a job. They consider what is modern and necessary for the country's future development, not just economically. However, this perception is often biased by a particular approach to science, in which the university authority's field of research seems to be the most important.

This analysis does not cover all those matters. We are also aware that although we have been in this profession for years, our imagination may not have covered all the problems of this market and the conditions for entering this market for our students. Nevertheless, it seems that it may be interesting both for students looking for a job and career paths, for their potential employers, as well as university authorities involved in modernizing study programs and plugging a knowledge gap necessary for a career in IT.

The research carried out so far in this area allows us to draw the following conclusions:

- the survey results show that the most essential IT competencies appear to be the complete basics of IT, often reduced to the knowledge of the MS Office package, supported to a limited extent by the basics of business analytics, which is the answer to the research question RQ1,
- the quoted data resulting from the research mostly confirm the existence of myths about the profession of an IT specialist and their impact on the answers given. This applies in particular, this applies to the expected level of salaries for a specific job position and employment security, (which answers research question RQ2),
- knowledge of the broadly understood profession of an IT specialist and the related competency needs among students is low. Few individuals realize that competencies related to process and project management (sometimes learned at universities without any supporting software) are more critical and better paid than software development. Few individuals know what implementing IT systems is all about and how necessary knowledge of economics and finance is in it, (which answers RQ3),
- learning about IT use in economics and management should not rely on the already mentioned issues and most of the respondents are well aware of it, paying attention to academic courses that, in their understanding, would open the possibility of a career in the profession of IT specialist and to the fact that learning broadly understood IT cannot rely on lectures and presentations, but on laboratories, workshops, and projects. evidently, this is at odds with the policy of the university authorities because these study programs are relatively "expensive" compared to lectures, for example. it seems that this matter is reasonably balanced at those universities that accounted for the teams dealing with business informatics in their organizational units (institutes, faculties) though to a limited extent (e.g., UE Kat.) – which gives the answer to RQ4.

Detailed conclusions and related discussion are included in the previous section.

There were some limitations in the study mentioned above. First, the survey only included four universities, but they were diverse enough to draw some general conclusions. Second, the survey only looked at location diversity. Third, the study did not consider the opinions of foreign students and potential foreign partners. Fourth, the results were not broken down by demographics such as gender, place of residence, employment status, etc. Lastly, the research did not determine the type and year of studies of respondents.

These limitations suggest possible areas for future research. To carry out this research, data collection would need to be extended to other universities, the survey structure would need to be adjusted, and research partnerships would need to be established with universities outside of Poland.

The authors plan to pursue these avenues in a step-by-step manner, hoping to contribute to the improvement of the IT job market in Poland.

References

1. Barak, M. (2018). Are digital natives open to change? Examining flexible thinking and resistance to change. *Computers & Education*, 121, 115-123. <https://doi.org/10.1016/j.compedu.2018.01.016>
2. Berger, T., Frey, C. (2016). Structural transformation in the OECD: Digitisation, deindustrialisation and the future of work. *OECD Social, Employment and Migration Working Paper*, 193. Paris: OECD. <https://doi.org/10.1787/5jlr068802f7-en>
3. Boyatzis, R.E. (2008). Competencies in the 21st century. *Journal of Management Development*, 27(1), 5-12. <https://doi.org/10.1108/02621710810840730>
4. Bradford, L. (2024). *15 Things you didn't know about working in tech*. Retrieved from: <https://skillcrush.com/blog/myths-about-working-in-tech/> on May 8, 2024.
5. Chapman, C. (2020). *20 Myths you probably still believe about working in tech*, *The muse*. Retrieved from: <https://www.themuse.com/advice/20-myths-you-probably-still-believe-about-working-in-tech> on May 8, 2024.
6. Charalampous, M., Grant, C.A., Tramontano, C., Michailidis, E. (2019). Systematically reviewing remote e-workers' well-being at work: A multidimensional approach. *European Journal of Work and Organizational Psychology*, 28(1), 51-73. <https://doi.org/10.1080/1359432X.2018.1541886>
7. Chillakuri, B. (2020). Understanding Generation Z expectations for effective onboarding. *Journal of Organizational Change Management*, 33(7), 1277-1296. <https://doi.org/10.1108/JOCM-02-2020-0058>

8. Chmielarz, W., Zborowski, M. (2019). *On the assessment of students' knowledge about cloud computing*. ICERI2019 Proceedings (pp. 5972-5980). <https://doi.org/10.21125/iceri.2019.1449>
9. Davenport, T.H. (2011). Rethinking knowledge work: A strategic approach. *McKinsey Quarterly*, 1(11), 88-99.
10. Deming, D.J. (2017). The growing importance of social skills in the labor market. *The Quarterly Journal of Economics*, 132(4), 1593-1640. <https://doi.org/10.1093/qje/qjx022>
11. Dolot, A. (2018). The characteristics of Generation Z. *E-mentor*, 74(2), 44-50.
12. Dumonceaux, G. (2023). *3 Myths about women working in tech*, *Techopedia*. Retrieved from: <https://www.techopedia.com/3-myths-about-women-working-in-tech-busted/2/34713> on June 2, 2024.
13. Eurostat (2024). *ICT specialists in employment*. Retrieved from: https://ec.europa.eu/eurostat/statisticsexplained/index.php?title=ICT_specialists_in_employment on May 8, 2024.
14. Falck, O., Heimisch-Roecker, A., Wiederhold, S. (2021). Returns to ICT skills. *Research Policy*, 50(7), 104064. <https://doi.org/10.1016/j.respol.2020.104064>
15. Godin, B. (2006). The knowledge-based economy: conceptual framework or buzzword? *The Journal of Technology Transfer*, 31, 17-30. <https://doi.org/10.1007/s10961-005-5010-x>
16. Grant, C.A., Wallace, L.M., Spurgeon, P.C. (2013). An exploration of the psychological factors affecting remote e-worker's job effectiveness, well-being and work-life balance. *Employee Relations*, 35(5), 527-546. <https://doi.org/10.1108/ER-08-2012-0059>
17. Grebski, W., Grebski, M. (2018). Keeping higher education aligned with the requirements and expectations of the knowledge-based economy. *Production Engineering Archives*, 21(21), 3-7. <https://doi.org/10.30657/pea.2018.21.01>
18. Gruzdev, M.V., Kuznetsova, I.V., Tarkhanova, I.Y., Kazakova, E.I. (2018). University graduates' soft skills: the employers' opinion. *European Journal of Contemporary Education*, 7(4), 690-698.
19. Jelonek, D., Chomiak-Orsa, I. (2018). *The application of modern teaching methods as the development determinant of personal and interpersonal competences of students-future employees*. EDULEARN18 Proceedings, IATED, 5259-5266. <https://doi.org/10.21125/edulearn.2018.1275>
20. Jelonek, D., Nitkiewicz, T., Koomsap, P. (2020). Soft skills of engineers in view of industry 4.0 challenges. *Conference Quality Production Improvement-CQPI*, 2(1), 107-116. <https://doi.org/10.2478/cqpi-2020-0013>
21. Jelonek, D., Stepniak, C. (2014). Evaluation of the usefulness of abstract thinking as a manager's competence. *Polish Journal of Management Studies*, 9, 62-71.

22. Kaatib, A. (2022). *10 Myths and facts about remote work*. Retrieved from: <https://www.makeuseof.com/myths-facts-about-remote-work/> on May 10, 2024.
23. Kianto, A., Shujahat, M., Hussain, S., Nawaz, F., Ali, M. (2019). The impact of knowledge management on knowledge worker productivity. *Baltic Journal of Management*, 14(2), 178-197. <https://doi.org/10.1108/BJM-12-2017-0404>
24. Kulej-Dudek, E., Kuceba, R., Jedrzejczyk, W., (2018). Testing transversal competences in the process of practical teaching of students. In: F. Bylok, A. Albrychiewicz-Słocińska, L. Cichoblażinski (Ed.), *Leadership, innovativeness and entrepreneurship in a sustainable economy* (pp. 727-733). Częstochowa Publishing House of the Faculty of Management, Częstochowa University of Technology.
25. Li, T., Kirk, C., Oseguera, L. (2024). STEM Career as a Pathway: Stability and Dynamics of Students' STEM Occupational Intention After High School. *The Journal of Higher Education*, 96(5), 804-829. <https://doi.org/10.1080/00221546.2024.2406734>
26. Lima, R.M., Dinis-Carvalho, J., Sousa, R.M., Arezes, P., Mesquita, D. (2017). Development of competences while solving real industrial interdisciplinary problems: a successful cooperation with industry. *Production*, 27(spe), e20162300. <http://dx.doi.org/10.1590/0103-6513.230016>
27. Lloyd, C., Payne, J. (2023). Digital skills in context: Working with robots in lower-skilled jobs. *Economic and Industrial Democracy*, 44(4), 1084-1104. <https://doi.org/10.1177/0143831X22111114>
28. Martín-Gutiérrez, J., Mora, C.E., Añorbe-Díaz, B., González-Marrero, A. (2017). Virtual technologies trends in education. *Eurasia Journal of Mathematics, Science and Technology Education*, 13(2), 469-486. <https://doi.org/10.12973/eurasia.2017.00626a>
29. Maruta, R. (2012). Transforming knowledge workers into innovation workers to improve corporate productivity. *Knowledge-Based Systems*, 30, 35-47. <https://doi.org/10.1016/j.knosys.2011.06.017>
30. Ngayo Fotso, G.M. (2021). Leadership competencies for the 21st century: a review from the Western world literature. *European Journal of Training and Development*, 45(6/7), 566-587. <https://doi.org/10.1108/EJTD-04-2020-0078>
31. Palombini, A. (2024). *Top 13 Myths and Misconceptions About Pursuing a Career in Tech*. Retrieved from: <https://tietalent.com/en/blog/17/top-13-myths-and-misconceptions-about-pursuing-a-career-in-tech> on May 8, 2024.
32. Parris, J. (2024). *10 Common myths about remote work*. Retrieved from: <https://www.flexjobs.com/blog/post/remote-work-myths-and-truths/> on May 10, 2024.
33. Rudder, C. (2019). *10 soft skills every IT team needs*. *The Enterprisers Project*. Retrieved from: <https://enterpriseproject.com/article/2019/10/10-soft-skills-it-teams> on May 12, 2024.
34. Schroth, H. (2019). Are you ready for Gen Z in the workplace? *California Management Review*, 61(3), 5-18. <https://doi.org/10.1177/0008125619841006>

35. Skakni, I., Kereselidze, N., Parmentier, M., Delobbe, N., Inouye, K. (2025). *PhD graduates pursuing careers beyond academia: a scoping review*. Higher Education Research & Development, 1-20. <https://doi.org/10.1080/07294360.2025.2515211>
36. Sweeney, M. (2022). *Common misconceptions about working in tech*. Retrieved from: <https://www.zdnet.com/education/computers-tech/common-misconceptions-working-in-tech/> on May 4, 2024.
37. Tirziu, A.M., Vrabie, C. (2015). Education 2.0: E-learning methods. *Procedia-Social and Behavioral Sciences*, 186, 376-380. <https://doi.org/10.1016/j.sbspro.2015.04.213>
38. Valberg, S. (2020). ICT, gender, and the labor market: A cross-country analysis. In: D. Maiti, F. Castellacci, A. Melchior (Eds.), *Digitalisation and development: Issues for India and beyond* (pp. 375-405). Singapore: Springer. https://doi.org/10.1007/978-981-13-9996-1_15
39. Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *Journal of Strategic Information Systems*, 28(2), 118-144. <https://doi.org/10.1016/j.jsis.2019.01.003>
40. Wilczek, M. (2021). *Poland facing shortage of 100,000 IT specialists, NFT*. Retrieved from: <https://notesfrompoland.com/2021/09/21/poland-facing-shortage-of-100000-it-specialists/> on May 10, 2024.
41. Willcoxson, L., Chatham, R. (2006). Testing the accuracy of the IT stereotype: Profiling IT managers' personality and behavioural characteristics. *Information & Management*, 43(6), 697-705. <https://doi.org/10.1016/j.im.2004.04.009>
42. Zhang, K., Aslan, A.B. (2021). AI technologies for education: Recent research & future directions. *Computers and Education: Artificial Intelligence*, 2, 100025. <https://doi.org/10.1016/j.caeai.2021.100025>

DISCLAIMER OF OPINION AS A TYPE OF MODIFIED AUDIT OPINION – AN EMPIRICAL STUDY

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Purpose: The article aims to answer the question of what grounds formed the basis for auditors' 'disclaimers of opinion,' which audit firms issued such opinions, and in relation to how many companies the 'disclaimer of opinion' modification was applied.

Design/methodology/approach: The study covered independent auditors' reports on the audit of 2023 financial statements. A total of 390 (out of 410) reports on the audit of annual financial statements of 390 (out of 410) Warsaw Stock Exchange Main Market-listed companies were examined. The method of audit report content analysis was used, with a focus on the 'Opinion' and 'Basis for Opinion' sections.

Findings: 'Disclaimers of Opinion' accounted for 1.8% of all opinions issued and 38.9% of modified opinions, relating exclusively to smaller companies outside the WIG20, mWIG40, sWIG80 indices. The disclaimers were issued by 9.8% of the auditors who examined the financial statements of the population analyzed - exclusively entities outside the so-called Big Four. A recurring basis for issuing a 'disclaimer of opinion,' in 85.7% of the disclaimers, was the inability to obtain sufficient and appropriate audit evidence. In 71.4% of the disclaimers, the description of the matters triggering the modification indicated problems with going concern. All disclaimers were preceded by the issuance of a modified opinion in the previous year. The narrative employed to describe the reasons for issuing the 'disclaimers of opinion' may indicate the auditors' use of impression management techniques. Comparing the results obtained with the results of a 2001-2006 study, auditors currently much more frequently issue 'disclaimers of opinion' when modifying their opinions.

Research limitations/implications: The study was limited to content analysis of 2023 financial statement audit reports concerning companies listed on the Main Market of the Warsaw Stock Exchange, available on websites. The article may inspire further empirical research, including comparative studies covering subsequent periods, particularly on the use of impression management methods in audit reports.

Originality/value: The article contributes to partially filling the research gap in empirical studies on 'disclaimers of opinion' concerning financial statements of companies listed on the Polish stock exchange, providing a practical study of the disclosures underlying the issuance thereof.

Keywords: disclaimer of opinion, modified audit opinion, independent auditor's report, auditor's opinion.

Category of the paper: Research paper.

1. Introduction

An auditor's opinion on an entity's financial statement comprises the outcome of the audit process, presented in a report referred to as an 'independent auditor's report,' pursuant to the International Standards on Auditing and Poland's National Standards on Auditing (Polish: Krajowe Standardy Badania, KSB). It constitutes "the most essential final part of the audit process" (Nurhidayah et al., 2024, p. 2). Expression of an opinion on whether the financial statement has been prepared, in all material respects, in accordance with the applicable financial reporting framework, fulfills the audit objective of enhancing the level of intended users' confidence in the financial statement (KSB 200 in the wording of ISA 200 "Overall Objectives of the Independent Auditor and the Conduct of an Audit in Accordance with International Standards on Auditing", para. 3). In issuing an opinion, the auditor must respond to the expectations and needs of various categories of information users, in particular financial and commercial creditors, current or potential shareholders and partners, employees, management, the public, and other stakeholders (Mořoc, 2022). As noted by Qiong and Rahmat (2024), the examinations conducted by auditors verify the quality of accounting information, while "[...] audit opinions serv[e] as vital cues for investment decisions by individual and institutional investors," and "significantly influence how listed companies manage issues before disclosures". The opinions issued by independent auditors, confirming the reliability of the information contained in the financial statements, can entail serious consequences. The type and content of the opinion, providing the basis for decision making by stakeholders, may determine their reactions, which gains particular significance in the case of listed companies. By the same token "[...] adverse opinions and disclaimers are signals that the financial statements are presented unfairly, dishonestly and may not be reliable [...]", as stated by Nguyen et al. (2021, pp. 85-86). Such opinions furthermore show a stronger association with negative company events than other modified opinions (Nguyen et al., 2021).

The article aims to answer the question of what grounds formed the basis for independent auditors' 'disclaimers of opinion' in the audit reports on the financial statements of Warsaw Stock Exchange Main Market-listed companies, which audit firms were responsible for issuing such opinions, and how many companies were subject to a 'disclaimer of opinion' modification. To implement the objective, the content of independent auditors' reports on the audit of 2023 financial statements was analyzed. A total of 390 (out of 410) reports on the audit of annual financial statements of 390 (out of 410) Warsaw Stock Exchange Main Market-listed companies were examined. The content analysis of the auditors' reports was carried out with a focus on the 'Opinion' and 'Basis for Opinion' sections. Examined was whether the auditors modified their opinions, determining which audit firms had audited the financial statements. In cases of a modified opinion, identified was whether it entailed a 'disclaimer of opinion'. Additionally, the disclosures were analyzed to determine the bases for the 'disclaimers of

opinion'. The study was carried out by grouping the companies into four categories: large, medium, and small entities, classified under the WIG20, mWIG40, and sWIG80 stock indices, respectively, and a group of other entities not included in the above-named indices (GPW Benchmark Indices, 2023). The first stage of the empirical study aimed to identify how many companies were subject to a modification in the form of a 'disclaimer of opinion', and which audit firms were responsible for issuing such opinions, as well as to present these results against the results obtained for modified opinions in total. The second stage was aimed at answering the question of what grounds formed the basis for the auditors' 'disclaimers of opinion'.

The study employed such research methods as: analysis of legal regulations, review of literature on the subject, detailed analysis of the content of auditors' reports on the audit of companies' financial statements, as well as inductive reasoning and synthesis, to formulate conclusions. The article represents the publication of the second part of the results obtained by the Author in her study of modified opinions issued by independent auditors on the financial statements of listed companies. The first portion of the results has been presented in the Author's study entitled "Audit opinion modifications on the example of Warsaw Stock Exchange-listed companies" (in press). In the present article, the Author drew on selected data from the above-mentioned study concerning the overall modified opinions, cited as background to the results on the 'disclaimers of opinion'.

While many subject-literature publications have focused on potential determinants of modified opinions, the vast majority of these articles concerned modified opinions overall, and did not factor in determinants by the type of opinion issued, with 'disclaimer of opinion' included. There appear to be relatively few analyses in the area of modified opinions, including 'disclaimers of opinion' on the financial statements of Warsaw Stock Exchange-listed companies. Most apparently, no empirical research has been conducted on the triggers of the 'disclaimers of opinion' issued by auditors in the reports on the audit of Polish listed companies' financial statements, that is, the grounds for issuing such opinions, as disclosed by the authors of these modifications, have not been analyzed. Therefore, the Author of the present article has intended to contribute to partially filling the research gap in the field of empirical research on 'disclaimers of opinion' concerning the financial statements of Warsaw Stock Exchange listed companies. The article also provides a practical study of the disclosures underlying the 'disclaimers of opinion', from the perspective of the authors of these modifications, i.e., the auditors who issued these opinions. The study paves the way for further empirical research, while the subject matter raised merits further elaboration in subsequent publications.

2. Theoretical Background

In accordance with the National Auditing Standards (NSA) and the International Auditing Standards (IAS), a ‘disclaimer of opinion’ on a financial statement represents one of the types of modified opinions issued by auditors. Modified opinions are issued when, based on the audit evidence obtained, it can be concluded that the financial statement as a whole contains material misstatements, or if sufficient and appropriate audit evidence cannot be obtained to conclude that the statement is free of material misstatements (KSB 700 (Z) in the wording of ISA 700 (Revised) “Forming an Opinion and Reporting on Financial Statements”). By expressing an opinion on whether the financial statement has been prepared in all material respects in accordance with the applicable financial reporting framework, the auditor can achieve the objective of the audit, which is to increase the level of intended users' confidence in the financial statement (KSB 200). Auditors' opinions confirm the reliability of the information presented in financial reports. There is a view presented in the literature on the subject that these opinions influence stakeholder decision-making, and even the very companies whose reports have been audited (Tian, Xin, 2017; Qiong, Rahmat, 2024). As noted by Tian and Xin (2017), they are vitally significant in terms of the capital market and shareholders. Of key relevance is the type and content of the opinion issued. When it comes to companies listed on developed country stock exchanges, ‘disclaimers of opinion’ are a rarity, but nevertheless trigger numerous effects (Malau et al., 2021). These disclaimers “[...] contain the most severe audit issues, if not the worse form of any audit opinion, which forbids any reliance on the financial accounts being audited for decision making” (Malau et al., 2021, p. 7), and provide no level of assurance as to the reliability of the financial statements (Cipriano et al., 2016).

According to the regulations contained in NSA 705 (Z), in the wording of ISA 705 (Revised), “Modifications to the Opinion in the Independent Auditor's Report”, a ‘disclaimer of opinion’ on a financial statement is issued under the following circumstances (para. 9-10):

- when the auditor is unable to obtain sufficient and appropriate audit evidence to form the basis for an opinion, and the possible impact of any undetected misstatements on the financial statement could prove both material and extensive; as well as
- in extremely rare circumstances involving multiple uncertainties, when, despite obtaining sufficient appropriate audit evidence for each individual uncertainty, the auditor is unable to express an opinion on the financial statement due to the potential interaction of the uncertainties and the possible cumulative effect thereof on the financial statement.

This standard also regulates the form and content of the audit report. If the auditor issues the above-described modification, the section specifying the type of opinion is headed ‘Disclaimer of Opinion,’ while the section specifying the basis on which the opinion was issued is headed ‘Basis for Disclaimer of Opinion’.

If the issuance of such an opinion is caused by the former of the circumstances listed above, the auditor states that they express no opinion on the financial statement. In addition, they include a statement that, due to the significance of the matters described in the ‘Basis for Opinion’ section, they were unable to obtain sufficient and appropriate audit evidence to form the basis for an opinion, replacing the wording “the financial statement has been audited” with “engaged to audit this financial statement” (KSB 705 (Z), para. 19).

The auditor is required to provide a range of information in the ‘Basis for Opinion’ section, including a description of the matter causing the ‘disclaimer of opinion’. A material misstatement in the financial statement, concerning specific amounts in that statement, requires a description thereof, along with a quantification of the financial impact or a statement that it is not practicable to quantify the impact. If it concerns qualitative disclosures, the auditor explains how the disclosures have been misstated. If the material misstatement pertains to a lack of disclosure, the auditor describes the type of information omitted and, having sufficient and appropriate audit evidence of such information, includes the omitted disclosures. A ‘disclaimer of opinion’ resulting from the inability to obtain sufficient and appropriate audit evidence involves inclusion of information about the reasons therefor. (KSB 705 (Z) pars. 20-24). The cited standard also requires the auditor to disclose information describing the reasons for and effects of any other matters of which they are aware, requiring a modification of the opinion. (KSB705 (Z) para. 27).

The literature on the subject presents numerous publications dedicated to modified opinions. These articles likewise discuss ‘disclaimers of opinion,’ as they constitute one of the types of modification. Empirical research on the issuance of only one type of modified opinion is rather scarce, concerning mainly ‘qualified opinions’, with relatively few studies on ‘disclaimers of opinion.’ Studies on opinion modifications feature literature reviews (Habib, 2013; Tian, Xin, 2017; Lu, 2020; Matonti et al., 2024; Nurhidayah et al., 2024; Simões, Carvalho, 2024) and empirical studies (Wielgórska-Leszczynska, 2008, 2010; Gromis di Trana, Bava, 2013; Zhao, Lin, 2015; Moazedi, Khansalar, 2016; Tahinakis, Samarinas, 2016; Tommasetti et al., 2018; Włodarczyk, Białek-Jaworska, 2018; Carp, Georgescu, 2019; Malau et al., 2021; Nguyen et al., 2021; Ruban, Hațegan, 2022; Moțoc, 2022; Matonti et al., 2024; Qiong, Rahmat, 2024; Simões, Carvalho, 2024). The authors have focused, inter alia, on topics related to the consequences of issuing such opinions, including the reaction of the market and the audited entities (Zhao, Lin, 2015; Cipriano et al., 2016; Tahinakis, Samarinas, 2016; Carp, Georgescu, 2019; Nguyen et al., 2021; Moțoc, 2022), the likelihood of the issuance of such opinions, depending on the occurrence of various factors (Habib, 2013; Moazedi, Khansalar, 2016; Tommasetti et al., 2018; Włodarczyk, Białek-Jaworska, 2018; Ruban, Hațegan, 2022; Matonti et al., 2024; Qiong, Rahmat, 2024; Simões, Carvalho, 2024), the correlation between such opinions and the occurrence of fraud (Malau et al., 2021) or between such opinions and going concern issues (Gromis di Trana, Bava, 2013). Publications present the potential determinants of modified opinions in a breakdown into internal, i.e., company-related, and external,

i.e., auditor-related (Habib, 2013; Matonti et al., 2024). The researchers analyzed the relationship between the issuance of modified opinions and such factors as: the size of audited entity, debt, liquidity, leverage, return on assets, current and previous year financial results; as well as other variables, including: the size of the auditing firm and its affiliation with the so-called Big Four, change of auditor, modification of the opinion issued in the previous fiscal year, audit report lag, auditor's gender, auditor industry, audit firm and partner tenure, level of non-audit fees, and audit fees. Synthetic summary of the results of research on the above-listed potential determinants of modified opinions can be found, *inter alia*, in the publications by Habib (2013), Simões and Carvalho (2024). For some of the factors analyzed, the impact on the issuance of a modified opinion is not explicit, and the results obtained by researchers may vary depending on the country (Lu, 2020), or the sector which the audited entity operates in, including the private and public sectors (Simões, Carvalho, 2024). A selection of authors have also analyzed the impact on the issuance of a modified opinion of, *inter alia*, the amount of information disclosed by the company to the public (Qiong, Rahmat, 2024), intellectual capital (Matonti et al., 2024), and earnings management practices (Moazedi, Khansalar, 2016; Tommasetti et al., 2018). With regard to the Polish stock exchange, research into the determinants of modified opinions was conducted by Włodarczyk and Białek-Jaworska (2018). The results obtained by the authors indicate that the following factors exert a significant impact on the issuance of such opinions: liquidity, debt, corporate governance approximated by the share of significant shareholders in the share capital, profitability, company size, and the risk of bankruptcy. They also found that stronger corporate governance - a higher share of significant shareholders in the share capital - reduces the likelihood of such an opinion being issued. The study did not confirm any significant relationship between the quality of audit services – approximated by the reputation and size of the Big Four audit firm – and the likelihood of a modified opinion being issued (Włodarczyk, Białek-Jaworska, 2018). Results of a research on the opinions of independent auditors were also published under the editorship of Wielgórska-Leszczyńska (2008), based on the analysis of opinions from the examination of 1407 financial statements of listed companies for the years 2001-2006. The study provides an interesting reference from the perspective of the present article, although it does not address the question of the grounds for issuing modified opinions. Conclusions regarding the market for the auditors of Warsaw Stock Exchange-listed companies were also published by one of the audit firms (Grant Thornton, 2025). The study did not, however, present a detailed description of the methodology used to draw the conclusions, and the results were based on a limited number of observations due to the lack of available data at the time of the analysis. Both these points raise the Author's doubts as to the validity of comparing the results obtained with those of the said study. Furthermore, the study did not address the grounds for issuing modified opinions.

The above-cited analyses of potential determinants of modified opinion issuance covered modified opinions as a whole. These studies made no distinction between factors potentially influencing the issuance of specific types of such opinions, with ‘disclaimer of opinion’ included. Nor did they analyze the reasons underlying the issuance of modified opinions, disclosed by auditors in their audit reports, i.e., no examination was made of the reasons from the perspective of the authors of these modifications. Only the study conducted by Çakali (2022) addressed the question of the grounds for issuing ‘disclaimers of opinion’, with an analysis of audit reports on the financial statements of Turkish companies, and empirical studies on modified opinions, including ‘disclaimers of opinion,’ in the context of financial statements of Warsaw Stock Exchange-listed companies are scarce.

3. Empirical Research Methodology

The analysis covered the content of independent auditors' reports on the audit of listed companies' financial statements. Reports on the audit of 2023 annual financial statements prepared by entities listed on the Main Market of the Warsaw Stock Exchange were examined. In cases of a fiscal year not corresponding to the calendar year, auditors' reports on the financial statements for the period beginning in 2023 and ending in 2024 were analyzed. Entities preparing consolidated financial statements were subject to an analysis of the consolidated statement audit report; otherwise, audit reports on separate financial statements were examined. The content analysis of the auditors' reports was focused on the ‘Opinion’ and ‘Basis for Opinion’ sections in particular.

A total of 390 (out of 410) audit reports on the annual financial statements of 390 (out of 410) WSE Main Market-listed companies, included in the list as of March 6, 2025, were examined. Twenty entities were excluded from the analysis due to non-publication of financial statement audit reports on the Warsaw Stock Exchange and/or company websites. Two of these entities made their stock market debut after 2023.

In the first stage of the empirical study, analyzed was whether the auditors modified their opinions, while determining which audit firms conducted the financial statement audits. In cases of modified opinions, specified was whether a ‘disclaimer of opinion’ was involved. The content analysis of the auditors' reports was carried out in a division into four groups of companies: large, medium-sized, and small entities included in the WIG20, mWIG40, and sWIG80 stock indices, respectively, and other entities. For this purpose, the content of the audit reports was examined, with particular emphasis on the headers and the wording in the ‘Opinion’ sections. At this stage of the study, companies were divided using the following dichotomous coding: (1) entities for which the auditors issued modified opinions and (0) entities without modified opinions on their financial statements. In the next step, groups were identified

among the companies with modified opinions, employing again a dichotomous coding system: (1) a group of entities that were issued ‘disclaimers of opinion,’ and (0) a group of entities that received an auditor’s opinion modification other than a ‘disclaimer of opinion’. Subsequently, based on their inclusion in a given stock exchange index, these entities were classified into several groups using the following coding: (1) entities included in the WIG20 index, (2) the mWIG40 index, (3) the sWIG80 index, and (4) other entities not included in the above-named indices.

In the second stage, the auditors' reports with a ‘disclaimer of opinion’ were examined, analyzing the grounds on which the auditors based their ‘disclaimers of opinion’. This step involved a content analysis of the audit reports, with particular emphasis on the ‘Opinion’ and ‘Basis for Opinion’ sections.

The article represents the publication of the second part of the results obtained by the Author in the study of independent auditors' modified audit opinions on the financial statements of listed companies. Accordingly, the methodology used in the present work is analogous to that employed in the Author's previous publication entitled “Audit opinion modifications on the example of Warsaw Stock Exchange-listed companies” (in press). The results presented in the article follow from the analysis of a total of 390 auditor’s reports on the 2023 financial statements of 390 companies, encompassing: 20 companies comprising the WIG20 index, 39 entities classified in the mWIG40 index, 79 entities classified under the sWIG80 index, and 252 companies not included in the above-mentioned indices.

4. Research Results

In the first stage of the study, determining the quantity of companies in reference to which a modification in the form of a ‘disclaimer of opinion’ was issued, the analysis of the financial statement audit reports, with particular emphasis on the ‘Opinion’ sections, revealed that a ‘disclaimer of opinion’ was issued for 7 out of the 390 examined companies. The auditors issued a total of 18 modified opinions and 372 unmodified opinions.

The financial statements of the analyzed population were examined by independent auditors from 41 entities authorized to audit financial statements, four of which issued ‘disclaimers of opinion’ in their reports. No ‘disclaimers of opinion’ were issued by the Big Four auditing firms. Modified opinions were issued by 10 auditing firms, and in the case of 31 entities auditing the financial statements, the auditors concluded that no modification to the opinion was required. The number of the ‘disclaimers of opinion,’ relative to the total number of modified opinions, in distribution by the entities that audited the financial statements, is presented in a graph (Figure 1a, Figure 1b).

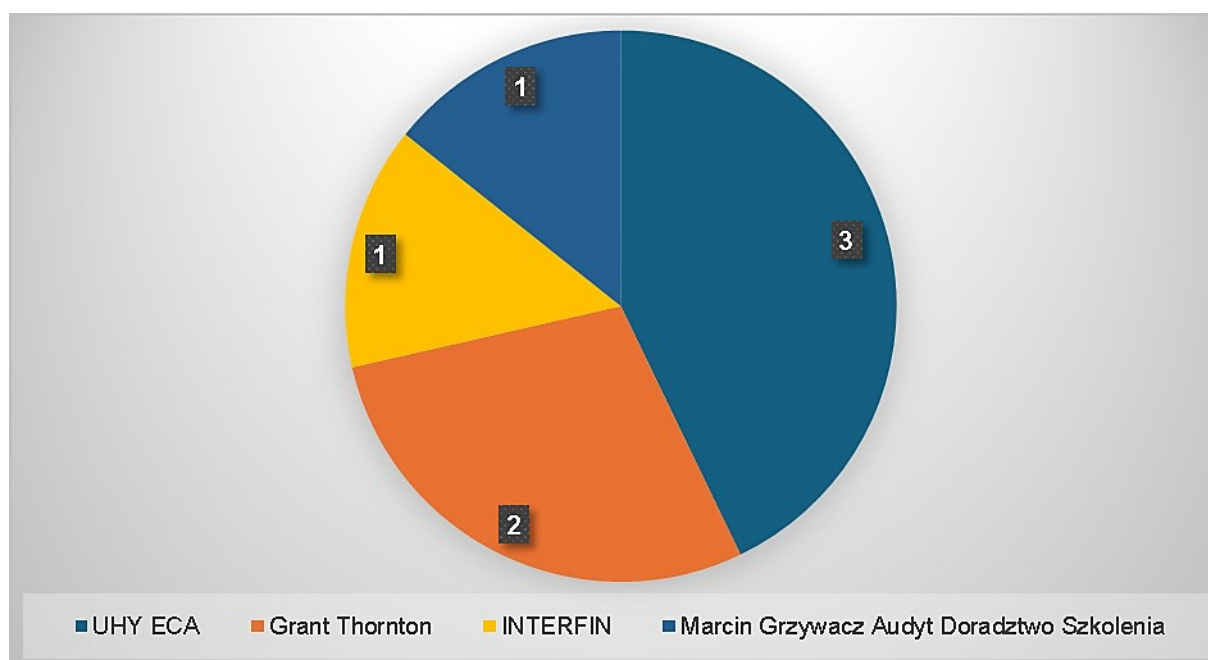


Figure 1a. Total number of ‘disclaimers of opinion’ – in distribution by auditing firms conducting financial statement audits.

Source: Own elaboration based on independent auditors’ reports on the audit of companies’ financial statements.

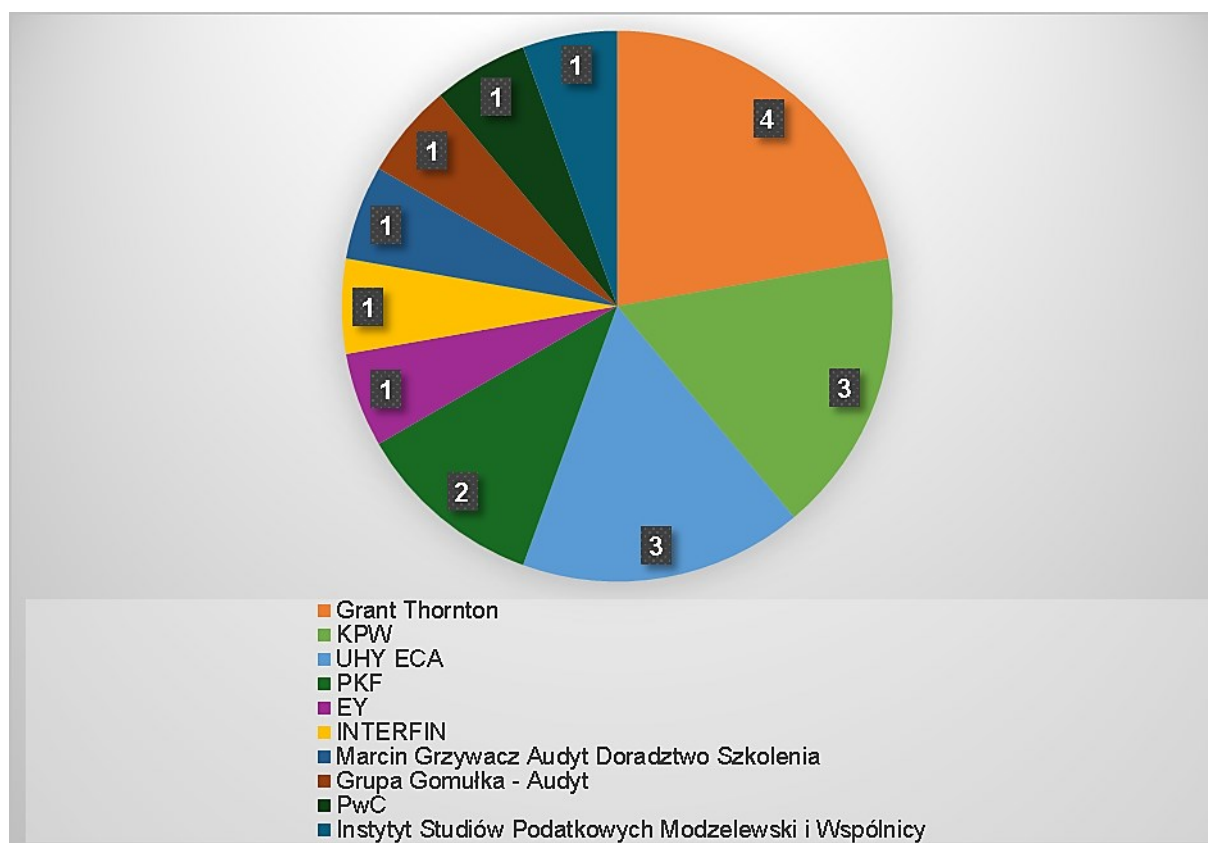


Figure 1b. Total number of modified opinions – in distribution by auditing firms conducting financial statement audits.

Source: Own elaboration based on independent auditors’ reports on the audit of companies’ financial statements.

The share of ‘disclaimers of opinion’ for auditing firms that issued more than 10 opinions, relative to the share of total ‘modified opinions’, in the number of opinions issued by a given entity is presented in Table 1.

Table 1.

The share of ‘disclaimers of opinion’, relative to the total number of ‘modified opinions’, in the number of opinions issued by a given audit firm - entities that issued more than 10 opinions

Audit firm name	UHY ECA	PWC	Grant Thornton	EY	KPW	BDO	KPMG	PKF	Misters Audytor	Mazars	Moore Polska	4AUDYT	INTERFIN
Percentage share of ‘disclaimers of opinion’ in the number of opinions issued by the audit firm	7.1	0	5.1	0	0	0	0	0	0	0	0	0	9.1
Number of ‘disclaimers of opinion’ issued by the audit firm	3	0	2	0	0	0	0	0	0	0	0	0	1
Percentage share of modified opinions in the number of opinions issued by the audit firm	7.1	2.5	10.3	3.7	11.1	0	0	10.5	0	0	0	0	9.1
Number of modified opinions issued by the audit firm	3	1	4	1	3	0	0	2	0	0	0	0	1
Number of opinions issued by the audit firm	42	40	39	27	27	25	24	19	18	14	14	13	11

Note. The data is arranged from left to right according to the number of opinions issued, starting with the leftmost entity that issued the most opinions.

Source: Own elaboration based on independent auditors’ reports on the audit of companies’ financial statements.

Among audit firms that issued more than 10 opinions, the share of ‘disclaimers of opinion’ in the number of opinions issued by a given entity ranged from 0% to 9.1%. Comparatively, the share of modified opinions in the number of opinions issued by a given entity ranged from 0% to 11.1%, and in the case of the Big Four group of companies - from 0% to 3.7%.

The analysis revealed no ‘disclaimers of opinion’ in relation to the financial statements of companies included in the WIG20, mWIG40, and sWIG80 stock market indices. Cases of disclaimers applied to the group of entities not included in the above-named indices only. ‘Disclaimers of opinion’ in distribution by individual companies whose financial statements were audited by independent auditors are presented in Figure 2.



Figure 2. ‘Disclaimers of opinion’ in individual companies.

Source: Own elaboration based on independent auditors’ reports on the audit of companies’ financial statements.

In the second stage of the study, identifying the grounds forming the basis for the auditors' issuance of the ‘disclaimers of opinion,’ an analysis of the content of the audit reports was conducted, with particular emphasis on the ‘Opinion’ and ‘Basis for Opinion’ sections. The results from the analysis of the empirical material are presented in distribution by individual companies, employing the numbering in Figure 2. To facilitate a better understanding of the below description of the results, it is worth noting that only in the case of two companies, the fourth and sixth, the financial statements were prepared without the going concern assumption. In the case of the remaining five entities, the statements were prepared on a going concern basis.

In the report on the financial statement audit of the first company, the ‘Opinion’ section was titled ‘Disclaimer of Opinion on Going Concern’, and the section justifying the type of the modified opinion issued - ‘Basis for Disclaimer of Opinion on Going Concern’. Despite the headings indicating a disclaimer of opinion, the auditor clearly stated that they “conducted an audit” of the financial statement and it does not present a true and fair view, even though it was prepared based on correctly maintained accounting records and in compliance, in form and content, with the legal regulations and provisions of the articles of association applicable to the entity. The justification for the opinion indicated that the audit evidence was insufficient to express an opinion on the company's ability to continue as a going concern. The auditor was unable to confirm whether, to what extent, and in what area the company would continue its operations. The entity incurred a loss, reported negative equity, and was required to convene a shareholders' meeting to adopt a resolution on the company's continued existence, but the meeting was never convened. In addition, the financial statement for the previous year had not

been approved either. The entity operated with limited capacity in the year under review, due to court rulings in connection with guarantee agreements concluded in previous years and ongoing enforcement proceedings. There are no financial plans for the coming year. Additionally, the war in Ukraine, high inflation, and the economic slowdown exert a difficult-to-estimate impact on the company's operations. The Author's attention was drawn to the narrative used by the auditor in the justification of the opinion issued, in which the words "the company achieved a loss" were used to describe the loss incurred. The use of an expression with positive connotations when referring to a loss, which is a negatively connoted concept, may indicate employment of one of the impression management techniques in the narratives contained in this report. These techniques, serving to build a desired image of an entity, have been discussed by, *inter alia*, Masztalerz (2016), or Czajkowska (2024).

In the case of the second entity, the auditor stated that they were unable to obtain sufficient and appropriate audit evidence to express an opinion on its financial statement. They pointed to a number of uncertainties crucial to the assessment of going concern. A significant legal and economic risk arose from the criminal and fiscal charges brought by the Public Prosecutor's Office against persons sitting on the entity's statutory bodies, involved in its activities. The Public Prosecutor's Office issued a decision to enforce a security interest on the company's assets, in connection with the ongoing proceedings concerning criminal and fiscal offenses, consisting in securing the threatened forfeiture of the financial gains from the offenses, by establishing a prohibition on alienation and encumbrance of real estate. The entity therefore created provisions for this event and disclosed the contingent liabilities. The auditor was unable to verify the value of the provisions created and the contingent liabilities disclosed. The scale, impact, and ultimate consequences of the previous management board's actions, including the potential impact thereof on the financial statement, were stated to be unknown. They concluded that, due to the possible interaction of uncertainties and the potential cumulative impact thereof on the financial statement, it was impossible to express an opinion.

The report on the audit of the third entity's consolidated financial statement likewise stated that the auditor was unable to obtain sufficient and appropriate audit evidence to form the basis for an opinion. Neither were they able to confirm whether the going concern assumption was valid, pointing to significant risks to the continuity of operations. Attention was drawn to the loss incurred by the capital group, negative equity, and the existence of short-term liabilities exceeding current assets by more than 12 times. Indicated was that this surplus resulted mainly from the provision created for the cost of CO₂ emission rights, which the subsidiary was obliged to redeem, and the penalty for untimely redemption of 2020 emissions. The auditor emphasized that control over the subsidiary was lost after the balance-sheet date, following the sale of 51% of its share capital to an entity with a major stake in the parent company. They also stated that the said subsidiary has presented negative equity and negative financial results for years, and may not be able to generate positive cash flows in the long term. As a result of failing to settle the emission allowances on time, the entity was imposed an administrative fine for 2020,

with proceedings initiated to impose a fine for 2021. The company also failed to timely settle its emission allowances for subsequent years. The capital group created no provisions for the aforementioned potential fines for 2021-2022, and the auditor is of the opinion that it is unable to generate sufficient cash flow in the near future to repay these fines. In addition, the capital group failed to create provisions for the court order of payment to the creditor received by the subsidiary, filing an objection to this order with the court.

In the case of the fourth consolidated financial statement, the auditor indicated several grounds for a 'disclaimer of opinion', noting that they were unable to obtain sufficient appropriate audit evidence to form a basis for an opinion. The first matter highlighted in the 'Basis for Disclaimer of Opinion' concerns the subsidiary included in full consolidation, whose fixed assets constituted a significant portion of the consolidated balance-sheet total in previous reporting periods. These assets had been valued as of the end of 2022, and the property appraiser's valuation was not updated as of the end of 2023. For consolidation purposes, the management board of the parent company decided to write down 100% of the value of the fixed assets held by the aforesaid subsidiary, charging the consolidated financial result for 2022. In the auditor's opinion, the property appraiser's valuation of the assets is questionable and carries a high risk. The auditor was unable to comment on the correctness of the accounting-book valuation of the fixed assets held by the subsidiary, nor on whether the group should adjust the impairment losses on these fixed assets. The second matter described by the auditor concerned the inability to verify the correctness of the deferred tax calculated and recognized in the consolidated financial statement. In particular, they were unable to comment on whether the recognized deferred income tax asset required a revaluation write-down. In their opinion, the entity's current results and situation did not provide a basis for assuming its ability to utilize this asset. The third matter raised by the auditor concerned the inability to express an opinion on whether the inventories presented in the consolidated financial statement required write-downs. As they noted, the audit report for the previous year contained a similar 'qualification'. The fourth matter involved the auditor's opinion that the consolidated balance sheet was not reliable, and the documents and explanations obtained provided no confirmation of the amounts reported in the consolidation balance sheet and the consolidated financial statement.

The report on the audit of the fifth entity's financial statement indicated that sufficient and appropriate audit evidence to express an opinion could not be obtained. It stated that the parent company was subject to remedial proceedings, which, in the auditor's opinion, could indicate a risk to the entity's ability to continue as a going concern. After the balance-sheet date, a resolution was adopted on the acceptance of an arrangement by the creditors in the remedial proceedings. As of the date of the audit report, the arrangement had not been approved by the court. In the opinion of the auditor, the parent company did not fully implement the restructuring plan assumptions for the year under review. Given the potential interaction of uncertainties, the auditor was unable to express an opinion on the correctness of the assumption regarding the parent company's ability to continue as a going concern.

The 'disclaimer of opinion' on the financial statement of the sixth entity likewise resulted from insufficient and inappropriate audit evidence. It concerned the same matters as the 'disclaimer of opinion' issued in the year preceding the year under audit. The auditor was unable to confirm the completeness of recognition and the correctness of valuation with respect to: the liabilities recognized as a result of a revocation of an arrangement; the trade payables arising until the commencement date of the remedial, and subsequently the liquidation, proceedings; the provisions for liquidation costs, and the effects of ongoing court proceedings; as well as the trade payables not covered by the arrangement, and the information on disputes and court proceedings. Furthermore, neither were they able to confirm the completeness of contingent liabilities, i.e., sureties, guarantees, and similar agreements, nor the classification thereof as contingent liabilities. The 'Basis for Disclaimer of Opinion' also included information that the liquidator had not signed the consolidated financial statement.

In the case of the seventh entity, it was concluded that, despite obtaining sufficient and appropriate audit evidence regarding each of the uncertainties, an opinion on the financial statement could not be expressed due to the potential interaction of these uncertainties and the possible cumulative impact thereof on the financial statement. The auditor drew attention to a significant threat to the going concern, resulting from a number of uncertainties, indicating the following as key to the group's continued operation: debt reduction through conversion of convertible bonds and arrangement claims into shares, acquisition of a strategic investor, sustenance of financial liquidity, securing of new sources of financing enabling acquisition and implementation of new contracts, execution of the arrangement with creditors, settlement of contracts the execution of which has been interrupted, renegotiation of contract terms with customers, reconstruction of the order portfolio. The entity is undergoing restructuring proceedings and is negotiating with creditors and subcontractors. The financial situation requires additional bridge financing to ensure current liquidity and timely repayment of liabilities, including those under the arrangement. Failure to successfully complete the conversion of shares and arrangement claims, and to obtain bridge financing, may significantly jeopardize the company's ability to attract a new investor and continue operation. The fulfillment of arrangement obligations hinges on the liquidity capabilities, the conclusion of conversion agreements with key creditors, and the success of the investment process. In addition, the auditor emphasized that the fixed asset impairment tests were based on financial plans taking the effects of restructuring measures and plans to attract an investor into account. They were also unable to obtain audit evidence regarding the indicated amount of the subsidiary's revenue. Emphasized was also that one of the contracts may involve significant consequences arising from its termination and a withdrawal from the related settlement, the annex to the loan agreement provides no financing for new contracts, and arrangement proceedings have been opened with respect to the subsidiary. In the Author's opinion, noteworthy, in the case of the seventh entity, is the rhetoric employed to describe the grounds

for the ‘disclaimer of opinion,’ wherein disclosures are phrased through the prism of remedial actions.

Of the seven companies issued with ‘disclaimers of opinion’ on their financial statements for 2023, only in the case of two the auditor’s report included information that a modified opinion had also been issued on the financial statement for the year prior. Based on the reports on the audit of financial statements for 2022, in turn, it can be concluded that modifications regarding their 2022 financial statements were issued for all seven of the above-described companies: 5 ‘disclaimers of opinion’, 1 ‘qualified opinion’, and 1 ‘adverse opinion’.

5. Conclusion

The article aimed to answer the question of what grounds formed the basis for auditors' issuance of ‘disclaimers of opinion’ in the audit reports on the financial statements of Warsaw Stock Exchange Main Market-listed companies, which audit firms were responsible for issuing such opinions, and in relation to how many companies the ‘disclaimer of opinion’ modification was applied. This objective was achieved through content analysis of independent auditors' reports on the audit of the 2023 annual financial statements of WSE Main Market-listed companies, resulting in the study of disclosures within the scope of ‘disclaimers of opinion’ in listed companies.

The results of the study yield the conclusion that in the population under study, independent auditors issued ‘disclaimers of opinion’ on the financial statements of 7 out of the 390 companies, with modified opinions issued for 18 of the companies. Accordingly, ‘disclaimers of opinion’ in the analyzed audit reports accounted for 1.8% of all opinions issued and 38.9% of modified opinions. Noteworthy is also the fact that these opinions concerned companies not included in the WIG20, mWIG40, and sWIG80 stock market indices. Four audit firms out of 41 entities conducting financial statement audits were responsible for issuing ‘disclaimers of opinion,’ and 10 auditors for issuing all modified opinions. This means that ‘disclaimers of opinion’ were issued by independent auditors representing 9.8% of the entities auditing financial statements in the population under review. Furthermore, the share of ‘disclaimers of opinion’ in the number of opinions issued by a given entity ranged from 0% to 9.1% for audit firms that issued more than 10 opinions, with the share of modified opinions ranging from 0% to 11.1%. Of importance seems to be that ‘disclaimers of opinion’ were issued by entities outside the so-called Big Four. In the Author’s view, a comparison of the results obtained with the findings of the study of independent auditors' opinions on financial statements for the years 2001-2006, published under the editorship of Wielgórska-Leszczyńska (2008), may provide a valuable reference in the context of longitudinal analysis. According to the results of this study among Warsaw Stock Exchange-listed companies, ‘disclaimers of opinion’ accounted for

only 0.21% of all opinions issued and 1.96% of modified opinions in 2001-2006. These opinions concerned one company and were issued by one audit firm from the so-called Big Four. Comparing the results of both studies, it can be observed that in the present study, independent auditors resorted more frequently to a 'disclaimer of opinion' when issuing a modified opinion than in the cited study from 2001-2006.

The analysis of empirical data to identify the grounds based on which the auditors issued 'disclaimers of opinion' revealed that in the case of 6 out of 7 entities, i.e., 85.7% of the 'disclaimers of opinion', the auditors were unable to obtain sufficient and appropriate audit evidence to form the basis for a financial statement audit opinion. Only in the case of one company, accounting for 14.3% of the 'disclaimers of opinion', the auditor was able to obtain such evidence, but concluded an opinion on the financial statement could not be expressed due to the potential interaction of uncertainties and the possible impact thereof on the financial statement. In addition, five of the analyzed auditor's reports employed the phrase "engaged to conduct the audit", with the remaining two expressing that "the financial statement audit was conducted". In the case of three companies, no opinion on the financial statement could be expressed due to potential interaction of described uncertainties. Among the recurring matters leading to a 'disclaimer of opinion' in 5 out of the 7 companies, accounting for 71.4% of these disclaimers, problems with going concern were identified. Not without significance is the fact that in the remaining two companies, the financial statements were prepared without the assumption of going concern, thus this matter could not form the basis for a 'disclaimer of opinion'. In the case of all 7 companies concerning which the auditors issued 'disclaimers of opinion' on the financial statements prepared for 2023, the audit reports for the year prior likewise contained modifications to the opinion: 5 'disclaimers of opinion', 1 'qualified opinion', and 1 'adverse opinion'. Worth noting is the narrative employed by the auditors when describing the grounds for issuing the 'disclaimers of opinion'. In the Author's opinion, it may indicate the use of impression management methods, manifested, *inter alia*, in the use of words with positive connotations to describe concepts of negative connotation, or in the disclosure of information through the prism of remedial measures. Emphasized should also be that in the case of one of the companies, the 'Opinion' section heading was titled "Disclaimer of Opinion on Going Concern", and the content of this section included the statement that "the financial statement does not present a true and fair view of the Company's financial position", which in the auditing standards represents a wording reserved for a 'negative opinion'.

The study bears several limitations. The analysis covered the auditors' reports on the audit of financial statements for 2023 only, concerning exclusively companies listed on the Main Market of the Warsaw Stock Exchange, available on the companies' websites and/or the stock exchange website. Solely the method of content analysis of auditors' reports was employed, limiting the study to the perspective of a specific auditor issuing a 'disclaimer of opinion' on a specific financial statement. No analysis of the market's, company management boards' or other auditors' reactions to the opinions issued was carried out, in which other research methods

would be applicable. Furthermore, the analysis also did not cover the aspects of the relatedness of the opinion issued to corporate governance factors or to auditor-client interaction. The conclusions presented in the present work apply exclusively to the auditors' reports covered by this study.

The analysis presented in the article may inspire further empirical research, including studies covering subsequent periods. The Author intends to conduct in-depth research on the use of impression management methods in audit reports. Furthermore, worth testing in future research would, in the Author's opinion, be a hypothesis whereby part of the 'disclaimers of opinion' issued by auditors, including those concerning Warsaw Stock Exchange-listed companies, are formulated in a manner characteristic, according to international auditing standards, of 'adverse opinions'.

References

1. Çakali, K.R. (2022). Bağımsız Denetim Kanıtlarının Yetersizliği ve Görüş Bildirmekten Kaçınma [Insufficient Independent Audit Evidence and Disclaimer of Opinion]. In: M.N. Seyman, A. Dalcı (Eds.), *2nd International Symposium of Scientific Research and Innovative Studies Proceedings Book* (pp. 185-196). Retrieved from: https://www.researchgate.net/publication/367376497_Bagimsiz_Denetim_Kanitlarinin_Yetersizligi_ve_Gorus_Bildirmekten_Kacinma_Insufficient_Independent_Audit_Evidence_and_Disclaimer_of_Opinion, 27.08.2025.
2. Carp, M., Georgescu, I.E. (2019), The Influence of Audit Opinion on the Degree of Real Earnings Management. The Case of Romanian Listed Companies. *Audit Financiar*, Vol. XVII, No. 4(156), pp. 666-679, doi: 10.20869/AUDITF/2019/156/026
3. Chrostowska, E. (in press). Audit opinion modifications on the example of Warsaw Stock Exchange-listed companies. *Scientific Papers of Silesian University of Technology. Organization and Management Series*.
4. Cipriano, M., Hamilton, E.L., Vandervelde, S.D. (2016), Has the lack of use of the qualified audit opinion turned it into the "Rotten Kid" threat? *Critical Perspectives on Accounting*, Vol. 47, pp. 26-38. Retrieved from: <https://doi.org/10.1016/j.cpa.2016.10.001>, 27.08.2025.
5. Czajkowska, K. (2024). *Narracje w rachunkowości jako narzędzie zarządzania wrażeniem*. Poznań: Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu, pp. 1-334.
6. Grant Thornton (2025). *Audyt spółek giełdowych w Polsce. Rynek biegłych rewidentów badających sprawozdania finansowe spółek notowanych na Giełdzie Papierów Wartościowych w Warszawie*. Retrieved from: <https://grantthornton.pl/wp-content/uploads/2025/02/Audyty-spolek-gieldowych-w-Polsce-edycja-2025-GT.pdf>, 05.03.2025.

7. Gromis di Trana, M., Bava, F. (2013). Going-Concern Assumption and Disclaimer Opinion: The Italian Case. *GSTF Journal on Business Review (GBR)*, Vol. 2, No. 4, pp. 6-11. Retrieved from: https://www.researchgate.net/publication/277180582_Going-Concern_Assumption_and_Disclaimer_Opinion_The_Italian_Case, 27.08.2025.
8. Habib, A. (2013). A meta-analysis of the determinants of modified audit opinion decisions. *Managerial Auditing Journal*, Vol. 28, No. 3, pp. 184-216, doi: 10.1108/02686901311304349
9. *Indeksy GPW Benchmark* (2023). Retrieved from: https://gpwbenchmark.pl/pub/BENCHMARK/files/PDF/opis_indeksow/IndeksyGPWB_0923.pdf, 15.03.2025.
10. *Krajowy Standard Badania 200 w brzmieniu Międzynarodowego Standardu Badania 200 Ogólne cele niezależnego biegłego rewidenta oraz przeprowadzanie badania zgodnie z międzynarodowymi standardami badania*. Krajowa Rada Biegłych Rewidentów (2019).
11. *Krajowy Standard Badania 700 (Z) w brzmieniu Międzynarodowego Standardu Badania 700 (zmienionego) Formułowanie opinii oraz sprawozdawczość na temat sprawozdania finansowego*. Krajowa Rada Biegłych Rewidentów (2019).
12. *Krajowy Standard Badania 705 (Z) w brzmieniu Międzynarodowego Standardu Badania 705 (zmienionego) Modyfikacje opinii w sprawozdaniu niezależnego biegłego rewidenta*. Krajowa Rada Biegłych Rewidentów (2019).
13. Lu, B. (2020). Literature Review of Audit Opinion. *Modern Economy*, Vol. 11, No. 1, pp. 28-36, doi: 10.4236/me.2020.111004
14. Malau, W., C., Oalehi, P., Badr, E.S., Yekini, K. (2021). Fraud interpretation and disclaimer audit opinion: Evidence from the Solomon Islands public sector (SIPS). *Managerial Auditing Journal*, 36(2), pp. 240-260, <https://doi.org/10.1108/MAJ-04-2018-1867>
15. Masztalerz, M. (2016). Kreatywna sprawozdawczość 2.0 - czyli o zarządzaniu wrażeniem w raportach. *Studia i Prace Kolegium Zarządzania i Finansów*, No. 152, pp. 41-51. Retrieved from: https://econjournals.sgh.waw.pl/SiP/zeszyt_naukowy_152, 27.08.2025.
16. Matonti, G., Iuliano, G., Vlismas, O. (2024). Organization capital and modified audit opinion. *Measuring Business Excellence*, Vol. 28, No. 2, pp. 255-274, doi: 10.1108/MBE-09-2023-0123
17. Moazedi, E., Khansalar E. (2016). Earnings Management and Audit Opinion. *International Journal of Economics and Finance*, Vol. 8, No. 4, pp. 113-122, doi: 10.5539/ijef.v8n4p113
18. Moțoc, M.-M. (2022). The Influence of Audit Opinion on Companies' Insolvency Risk. Evidence for Romania. *Audit Financiar*, Vol. XX, No. 4(168), pp. 655-667, doi: 10.20869/AUDITF/2022/168/023
19. Nguyen, V.K., Nguyen, T.L.H., Vy, B.C., Nguyen, T.H.M., Nguyen, L.C.T., Cu, T.H.L. (2021). The impact of audit opinion on cost of debt: Evidence from Vietnam. *Ho Chi Minh City Open University Journal of Science – Economics and Business Administration*, 11(1), pp. 83-93, doi:10.46223/HCMCOUJS.econ.en.11.1.1067.2021

20. Nurhidayah, N., Sudarma, M., Djamhuri, A., Atmini, S. (2024). Audit opinion research: overview and research agenda, *Cogent Business & Management*, Vol. 11, No. 1, pp. 1-16, <https://doi.org/10.1080/23311975.2023.2301134>
21. Qiong, Z., Rahmat, M.M. (2024). The Effect of the Information Quantity Announcement on Modified Audit Opinion – Evidence from Chinese A-Shares Listed Companies. *Asian Journal of Accounting and Governance*, Vol. 21. Retrieved from: <http://dx.doi.org/10.17576/AJAG-2024-21-06>, 27.08.2025.
22. Ruban, D., Hațegan, C.-D. (2022). Impact Factors on the Audit Opinion – Case Study. *Audit Financiar*, Vol. XX, No. 4(168), pp. 668-680, doi: 10.20869/AUDITF/2022/168/024
23. Simões, M., Carvalho, C. (2024). Determinants of Qualified Audit Opinion: Empirical Study of Portuguese Private Sector Hospitals. *Journal of Risk and Financial Management* vol. 17, No. 571, pp. 1-20, <https://doi.org/10.3390/jrfm17120571>
24. Tahinakis, P., Samarinas, M. (2016). The incremental information content of audit opinion. *Journal of Applied Accounting Research*, Vol. 17, Iss. 2, pp. 139-169, <https://doi.org/10.1108/JAAR-01-2013-0011>
25. Tian, J., Xin, M. (2017). Literature Review on Audit Opinion. *Journal of Modern Accounting and Auditing*, Vol. 13, No. 6, pp. 266-271, doi: 10.17265/1548-6583/2017.06.003
26. Tommasetti, R., Bastos, F., Santos, N.M., da Silva Macedo, M.A., Sarlo Neto, A. (2018). Relationship between Modified Audit Opinion, Earnings Management and Auditor Size: evidence from Brazil. *Pensar Contábil*, Vol. 20, No. 72, pp. 50-57. Retrieved from: https://www.researchgate.net/publication/353934792_Relationship_between_Modified_Audit_Opinion_Earnings_Management_and_Auditor_Size_evidence_from_Brazil#fullTextFileContent, 27.08.2025.
27. Wielgórska-Leszczńska, J. (2010). Przydatność efektów badania sprawozdań finansowych. In: E. Zyżelewicz (Ed.), *Rewizja finansowa w obrocie gospodarczym* (pp. 95-103). Warszawa: KiBR.
28. Wielgórska-Leszczńska, J. (Ed.) (2008). Analiza opinii biegłych rewidentów z badania sprawozdań finansowych spółek giełdowych. In: *Sprawozdania finansowe i ich ocena przez biegłych rewidentów* (pp. 75-259). Warszawa: SKwP.
29. Włodarczyk, A.M., Białek-Jaworska, A.A. (2018). Determinants of Disclaimers in the Auditor's Opinion on the Financial Statement. *Acta Universitatis Lodzensis. Folia Oeconomica*, 5(338), pp. 157-182, doi: 10.18778/0208-6018.338.10
30. Zhao, Z., Lin, M. (2015). Information Content of Text in Chinese Audit Opinions. *China Accounting and Finance Review*, Vol. 17, No. 3, pp. 41-96, doi: 10.7603/s40570-015-0008-8

THE IMPORTANCE OF CYBERSECURITY AND ITS ROLE IN THE SUCCESSFUL IMPLEMENTATION OF E-SERVICES

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Purpose: This study aims to assess the awareness, knowledge and digital skills of young people, students from Warsaw universities, in the field of cybersecurity related to e-services. The survey investigates the respondents' awareness and knowledge related to various cyber threats, their perception, frequency and scale, and self-assessment of cybersecurity competence and practices.

Design/methodology/approach: The study involving 278 young e-consumers, students of universities in Warsaw, was conducted using a survey questionnaire (CAWI technique). The selection of the sample was purposive and convenient. Respondents were asked about their perception of cybersecurity threats, self-assessed ability to defend against attacks and their use of various cybersecurity measures. The research examined key variables such as gender, age (two groups: 19-22 and 23-26 years), employment status and place of residence (large vs. small city). Statistical analyses were performed using IBM SPSS Statistics 29.0

Findings: The results indicate high levels of cybersecurity awareness among young e-consumers. Many respondents recognize cyber threats and their potential consequences. However, they also lack confidence in their abilities and the effectiveness of cybersecurity measures and tools. The study highlights the gap between the awareness regarding cyber threats and practical skills or the ability to mitigate them effectively.

Research limitations/implications: The sample included a group of young e-consumers, students from major universities in Warsaw. Thus, the findings cannot be generalized to the broader population. However, due to their specific characteristics (level of education and digital skills, age and place of residence), the respondents may be regarded as a suitable group for pilot studies in cybersecurity awareness and skills development.

Practical implications: The findings indicate a need for adequately targeted educational initiatives to enhance cybersecurity competence and skills among young e-consumers.

Originality/value: This study examines the cybersecurity awareness of young people in the context of e-services, which is a topical yet underexplored issue. The study results can be valuable for educators, policymakers and cybersecurity professionals aiming to enhance cybersecurity awareness among young e-consumers.

Keywords: cybersecurity awareness and knowledge, digital skills, e-services, e-consumers, consumer safety.

Category of the paper: research paper.

Introduction

The rapid development of new technologies and the servitization of the economy have transformed many aspects of consumer functioning. The pandemic has also contributed to the development of new digital competencies among people of all ages. On the one hand, the immediate threat and fear for one's health and life, and on the other hand, the new opportunities and choices associated with the internationalization and globalization of services, have led consumers to increasingly turn to e-services instead of traditional services. As Wolny (2020, p. 90) states, “the emergence of electronic services (e-services), which refer to a form of service provision using the Internet, including, in particular, the presentation of the service, the ordering of the service, the payment for the service and the use of the service through this network, with the proviso that for selected services, their consumption takes place in the real (non-virtual) world”. Due to the ubiquity of Internet access and the availability of technology in the form of platforms, systems and applications, e-services are becoming very popular among consumers. As Jaciow et al. (2015) emphasize, “the Internet is not only a primary source of information (informational function) but also an excellent place to conduct business (transactional function), including - selling products. From the consumer's point of view, the Internet is not just a source of information or an opportunity to spend leisure time. For modern consumers, the Internet is an opportunity to establish and maintain contact with others, engage in work and entertainment, but most importantly a place to make purchases and use e-services (regardless of where you live)” (Jaciow et al., 2015, p. 5).

As Kotlorz (2013, p. 7) points out, technological development determines the availability of e-services, but also increases the demand for them. More and more people are using a variety of communication channels, tools and instruments to access or purchase various types of services, such as: e-administration, e-banking, e-education, e-commerce, e-culture, e-tourism, e-insurance and e-health (Wolny, 2013, p. 23). As Jaciow et al. stress (2015, p. 5), the development of the e-services market “is determined by economic, demographic, social, cultural and technological factors. Technological changes are increasingly important for economic development, which translates into innovation of market players, both on the supply side (producers, intermediaries) and demand side (individual and institutional consumers)” (Jaciow et al., 2015, p. 5). As Wolny stresses (2013, p. 8), we may observe increased servitization, which is “associated with the increasing role of services in socio-economic relations, including an advanced stage of development of the service sector”. Kotlorz (2013, p. 9) states that this development is affected by outsourcing and offshoring of services, technological progress, demographics, e.g. the ageing process and the changing structure of households, changes in labor productivity and the convergence of the service and manufacturing sectors. Jaciow et al. (2015, p. 5) stress that we are witnesses to “the virtualization of socio-economic life”, and Papińska-Kacperek (2013, p. 132) emphasizes

the role of this sector stating that “all citizens are potential recipients of digital services”. Given the scale and scope of the phenomenon, consumer safety and cybersecurity in e-services are important and topical issues that policymakers, practitioners and researchers need to consider and explore.

Safety of consumers is a very wide concept referring to consumer protection in terms of product safety and executing and protecting consumer rights, which is particularly important when dealing with power imbalance or information asymmetry (Kozłowska, 2019, pp. 107-109). According to Kozłowska (2019, pp. 107-109), the term also encompasses counteracting and punishing illegal, unethical and unfair market practices in terms of sales, advertising and marketing communications. Assessing the level of e-consumers’ knowledge, awareness and competence is essential in order to provide them with resources and tools to execute their rights in the market (Dąbrowska et al., 2015; Bylok, 2019). Focusing on e-consumers’ safety is crucial because the e-services market is becoming more difficult and more complex to navigate due to the development of new information and communication technologies (ICT), such as big data analytics, artificial intelligence (AI), including generative AI, virtual reality (VR) and augmented reality (AR) or Internet of Things (IoT). In addition, recommendation systems operating on the basis of artificial intelligence algorithms that analyze vast amounts of data about Internet users and gain valuable knowledge about e-consumers (Mróz, 2020, p. 66) can offer new opportunities, such as personalized recommendations, advertising and communications (Nowacki, Fandrejewska, 2024), convenience, time savings and streamlining of the decision-making process. However, they can also exploit the information (Nowacki, Fandrejewska, 2025) and vulnerability of e-consumers (Mróz, 2020, p. 69) or intensify the threats which are already there due to human nature and psychological constructs in humans like behavioral traps (Mruk, 2020, p. 28).

Unfortunately, the great popularity and widespread adoption of e-services expose users to cybersecurity threats. Cybercriminals exploit vulnerabilities in online platforms to gain unauthorized access to sensitive information. Also, cyberattacks can take many forms and they are designed to exploit different vulnerabilities in systems or networks functioning as part of digital economy (Boratyńska et al., 2021, p. 21). It is worth noting that user behavior can also be the reason why cybercriminals can infiltrate the network or the system. Realizing that threats may take many forms and disguises, e.g. malware (viruses, worms, trojans), ransomware, spyware, adware or phishing, the role of cybersecurity cannot be underestimated. Directives and regulations impose new compulsory procedures, tasks and responsibilities on corporations, intermediaries and service providers. However, as indicated earlier, responsibility for safeguarding digital interactions related to e-services lies not only with service providers but also with consumers, who must be aware, cautious and vigilant about protecting their data and resources.

As a recent report by the Warsaw Banking Institute (*Postawy Polaków...*, 2024) indicates, cybersecurity is increasingly important for e-consumers because they depend on digital services and develop a greater awareness of threats such as phishing (for personal data and money), identity theft, disinformation, and cyberbullying. According to recent statistics, the most feared online scams among Poles are phishing (60%), financial fraud (52%), identity theft (51%), disinformation and fake news (42%), and cyberbullying, including hate speech and violations of personal dignity (30%). Also, the recent EY Future Consumer Index data points to increasing consumers' concern related to data security; 61% of digital service users fear their information may lead to identity theft, up six percentage points in just one year. Concerns about the use of cookies and the potential misuse of personal information are now widespread among internet users, with 65% planning to pay more attention to company data policies, though 28% remain willing to share their data if in return they can receive more personalized offers (Olak, 2024).

The research problem presented in this paper is also discussed in other publications. Research by Alkis and Kose (2022) shows that privacy concerns and consumer characteristics shape how people approach online shopping and social media advertising across 29 European countries. The authors stress that higher privacy risk knowledge and greater online information sharing are linked to increased e-commerce activity, while strong concern about online activity recordings lowers participation; consumers who take more protective actions are more likely to shop online and respond to social media ads, making privacy protection tools valuable for companies in the digital market. A study conducted by Fortes and Rita (2016) in Portugal involving 900 respondents indicates that greater privacy concerns decrease trust and increase perceived risk, which in turn reduce consumers' willingness to make online purchases. The study confirms these effects using a research model based on trust and risk theories, planned behavior, and technology acceptance frameworks.

As Wahab et al. (2023) note, cybersecurity in e-commerce is important for building consumer trust and confidence because security policies and protection measures may influence users' willingness to shop online. However, as the authors emphasize, simply perceiving risks or having fears about cybercrime does not automatically discourage consumers from making purchases online. Another research by Sadab (2023) reveals that, for online shoppers in Bangladesh, cybersecurity knowledge, website quality, secure payment systems, and concern for data privacy significantly influence their attitudes toward e-commerce, while demographics like age and gender do not. The study highlights that consumers' awareness of cybersecurity risks increased during the Covid-19 pandemic and remains high, directly improving their trust and willingness to shop online. A study carried out by Singh et al. (2024), with the participation of 780 respondents, examines how consumers perceive different security mechanisms implemented on e-commerce platforms and analyzes how they influence the level of consumer trust. The latter is vital to consider because this dependence can later translate into their willingness to use such platforms. Similarly to our study, it also assesses the potential effects of gender and age. The survey by Singh also considered the frequency of e-commerce and

structural equation modeling (SEM). The findings indicate that information integrity and confidentiality have a strongly positive impact on consumer trust, and this trust mediates the relationship between these factors and consumers' intention to use e-commerce platforms. As the authors stress (Singh et al., 2024), contrary to expectations, there were no significant correlations between gender or age and how respondents perceived trust or security; however, it was discovered that “moderating effect of frequency of use on the relationship between perceived information confidentiality and preventing unauthorized secondary data usage on trusting beliefs was found to be significant”. The research also points to critical safeguards that e-commerce platforms should develop to build user trust. Another study (Wisetpanich et al., 2025) based on a survey conducted among Gen Z representatives in Thailand, found that digital literacy including digital safety, content creation, and information management accounts for 77.5% of the variance in Generation Z's perceptions of data privacy security on Thai e-commerce platforms. Digital safety emerged as the most influential factor, and the findings highlight the importance of transparent data protection policies and tailored digital literacy initiatives aimed at strengthening user confidence and trust in online purchasing. Research conducted by Nguyen et al. (2024) reveals that digital literacy has a significant impact on both online security behaviors and the continued use of e-payments, with security behaviors serving as a mediator in the relationship between digital skills and users' willingness to continue using e-payment solutions.

New technologies emerge at an unprecedented pace, bringing numerous opportunities for innovation and progress. The fast development, increasing complexity and popularity of new technologies may result in the misuse of technology, and laws and legal regulations often lag behind, creating a gap that can lead to risks, vulnerabilities and potential threats. Ethical dilemmas and security concerns are serious issues raised by many experts, policymakers, business practitioners, researchers and users themselves. It is important to point out that even though cybersecurity is such an important and topical issue, very often the research on e-services cybersecurity is fragmented and focuses on narrow and highly specialized areas, like e-banking (Alrababah et al., 2024; Cele et al., 2024), retailers' loyalty programs (Chmielarz, Szumski, 2018), healthcare systems (Jalali et al., 2018; Ewuh, Vartiainen, 2024; Dąbrowska et al., 2025), public health (Mackey, Nayyar, 2016), smart cities (Adel, 2023) and administration and e-government (Hossain, 2024; Zhang, Kaur, 2024). The perspective of cybersecurity is more often examined from the standpoint of legal regulations or technological solutions. There are few studies that examine the competencies, knowledge, and skills of users themselves, even though these are crucial, as they can often improve the security and safety of consumers in the e-services market.

Rusayyis et al. (2022) state that “with the increasing importance of e-services in cyberspace, cybersecurity is essential for safety and trustworthiness. As Wolny (2020 after: Wasilewski, 2013, p. 233) indicates in general terms *cyberspace security* can be defined as “(...) a set of organizational, legal, technical, physical and educational measures aimed at ensuring the

uninterrupted functioning of cyberspace”. In the context of e-services cybersecurity is a multidimensional concept which includes the security of devices, networks, applications, identity and access management (IAM), cryptography and social engineering defence. Stallings and Brown (2019, p. 27) stress the need for “protecting information systems by ensuring that data, software, and hardware stay safe, reliable, and accessible”, and Cichosz (2017, p. 64) stresses that in the context of cybersecurity, apart from hardware and software, we should also consider the role of users interacting with cyberspace.

Analyzing the approach and behavior of individual users is very important from the point of view of ensuring the security of both technological solutions and systems which rely on them. Protection Motivation Theory (PMT) (Rogers, 1975), for instance, a theory which is commonly applied in research on cybersecurity behavior (Crossler et al., 2013; Sinopen et al., 2024), analyzes the relationship between protective behavior and threat assessment (its severity and vulnerability) and the assessment of one's own ability to cope with the threat (effectiveness of proposed actions, sense of self-efficacy, and costs of responding) (Kiran et al., 225). Users' decisions to take protective measures are determined by the extent to which they perceive the threat as serious and probable to occur, and their belief in the effectiveness of countermeasures and their own competence to apply them. It is worth noting that while this study does not directly apply Protection Motivation Theory (PMT), it is diagnostic in nature and its research questions address areas examined by PMT, such as threat awareness and perception, self-assessment of digital competence, sense of self-efficacy, and the need for digital skills education and improvement for oneself and others.

As indicated above, this issue can be analyzed from multiple perspectives. The studies can concentrate on cybersecurity-related behavior to improve understanding of the existing challenges and identify directions for further research (Almansoori et al., 2023), they may consider user behavior from the point of view of psychology, focus on individual differences that can influence cybersecurity practices, and recommend methods to improve user compliance with security policies (Moustafa et al., 2021). It is important to bear in mind that there exist factors which increase the risks associated with cybersecurity vulnerabilities that also need to be studied, e.g. new technologies like AI or IoT (Blessing et al., 2022), social engineering exploiting challenging circumstances like COVID-19 (Alzahrani, 2020) or multiple mobile entry points to systems, applications and devices (Ballagas et al., 2006 after: Cichosz, p. 69; Snopkiewicz, 2020, pp. 35-36)

Even though cybersecurity is a very important topic (Mocanu, 2013; Ćwiek, 2024; Oh, 2021; Lamond et al., 2022), the research is narrow in scope and fragmented, with few studies comprehensively analyzing the awareness, knowledge, and skills of young people in the context of cybersecurity. This research problem deserves attention because, contrary to expectations, despite young people spending a significant amount of time online and relying on their devices for many aspects of life, as research shows (Wilk, 2013, p. 25; Gwoździewicz,

2017 after: Gwoździewicz et al., 2025, p. 116), they do not always have sufficient practical cybersecurity skills or know how to protect themselves in cyberspace.

In their study, the authors attempted to assess the impact of various socio-demographic factors on the level of cybersecurity awareness and digital literacy among young people, users of e-services. The current study takes into account several factors that can potentially influence the level of cybersecurity awareness and digital skills: gender, age, education and place of residence. It is important to note that the selection of the research sample for the study was purposeful and convenient. Young people are a very important group of respondents due to their openness to new technologies, frequent use of various technological solutions, and level of advancement in terms of purchasing and using e-services. Analysis and assessment of the level of knowledge, digital skills, risk awareness and competence of e-consumers addresses a significant gap in cybersecurity research and may contribute to and support efforts to enhance cybersecurity and improve the safety of e-consumers in the market.

Methods

The issue of perception of cybersecurity was the subject of a CAWI survey conducted in October 2023 among young Poles. The study involved 278 people, diverse in terms of gender (56.8% women and 43.2% men), age (50.0% in two age groups: 19-22 and 23-26), professional activity (33.5% were full-time workers, 34.2% were working part-time and 32.4% were not working at all) and place of residence (divided into two categories: agglomerations with more than 2000 inhabitants or smaller towns - 65.1% and 34.9%, respectively). The sample selection was quota-based. The study was based on an original questionnaire consisting of five questions. Two questions, concerning knowledge about cyberattacks and the use of password managers, were closed-ended and based on simple nominal alternative scales. The next two questions concerned the security measures used by respondents and sources of information on cybersecurity – these questions were semi-open-ended and based on a conjunctive scale. The last question contained eight statements related to cybersecurity issues, which were evaluated on a five-point Likert scale. A seven-point scale was selected because of its proven advantages. Research shows that a smaller scale (e.g., 2- or 3-point) is not sufficiently detailed (Cox, 1980), while overly complex scales (e.g., 9- or 11-point) can weaken respondents' ability to differentiate values (Tarka, 2015). The validity and reliability of five- or seven-point scales have been confirmed by numerous studies (Alwin, 1997; Churchill, Peter, 1984; Matell, Jacoby, 1971; Schutz, Rucker, 1975). The questionnaire was developed on the basis of an analysis of literature sources and previous qualitative research, and was then pilot tested among a group of target respondents.

In the context of the described problem, the analysis focused mainly on the phenomena of knowledge about cyberattacks, the possibilities of protecting oneself against them and knowledge about cybersecurity. The results of the analyses were presented taking into account the variation due to four independent variables (gender, age, professional activity and place of residence). The relationships between the independent (explanatory) and dependent (explained) variables were determined using the non-parametric χ^2 test. All calculations were performed using IBM SPSS Statistics 29.0.

Results

The results obtained show that young consumers have a relatively high level of knowledge about cyberattacks occurring in their environment (Table 1). Every third person has come across information about such threats in the last 12 months. More than half have heard of at least one such attack. Only 12.2% indicated that they did not hear about any cyberattacks taking place in the last 12 months. In terms of specific correlation cross-sections, it should be noted that men, older age groups, full-time employees and residents of large urban areas are slightly more likely to declare greater knowledge of cyberattacks. The correlations between this question and the independent variables only occurred in the case of professional activity (employment status) and place of residence, but their strength is not high - the V-Cramér's coefficient does not exceed 0.2.

Table 1.

Knowledge about cyberattacks carried out in the last 12 months in general and according to the characteristics of the respondents

Specification	No, I haven't heard of it at all	Yes, I have heard of it a few times at most	Yes, I have heard of it many times	Test χ^2			Decision at p = 0.05
				Value (χ^2)	df	Critical level of significance (p)	
	Percentage share						
Gender				2.691	2	0.260	No dependency
Female							
Male							
Age				2.760	2	0.252	No dependency
19-22 years							
23-26 years							
Employment status				13.059	4	0.011	Weak dependency (Cramér's V coefficient = 0.153)
Not working							
Working part-time							
Working full-time							

Cont. table 1.

Place of residence				8.083	2	0.018	Weak dependency (Cramér's V coefficient = 0.171)
Town with up to 200,000 inhabitants	19.6	52.6	27.8				
City with up to 200,000 inhabitants	8.3	55.2	36.5				
Total	12.2	54.3	33.5	-	-	-	-

Source: own research, N = 278.

The respondents pointed out the need to increase the availability of cybersecurity education for consumers - almost 90% of respondents agree with this statement, with as many as half strongly agreeing with it. This is mainly due to the fact that more and more cyberattacks are being noticed and the belief that they threaten consumers' functioning. In the case of these two statements, the percentages of people agreeing are close to 80% and almost 90%. This is also confirmed by the fact that despite declaring knowledge of security measures and their use (compliance rates of 57.2% and 63.3%, respectively), the percentage of respondents indicating that their knowledge in this area is sufficient and the level of security is adequate is lower and amounted to approximately 34-36%. Every fourth respondent agrees with the statement that it is impossible to effectively protect against cyberattacks (Table 2).

Table 2.*Overall level of agreement with statements on cybersecurity*

Specification	Strongly disagree	Rather disagree	Neither agree nor disagree / difficult to say	Rather agree	Strongly agree
	% share of indications				
Cybersecurity education should be more accessible to average consumers.	1.1	4.0	6.8	33.5	54.7
My cybersecurity skills are sufficient.	3.2	26.3	34.5	28.1	7.9
I am well protected against cyberattacks.	6.5	25.5	33.8	27.0	7.2
Cyberattacks are a growing threat to consumers.	0.7	2.5	10.1	37.1	49.6
The number of cyberattacks is constantly increasing.	0.7	3.2	16.2	42.4	37.4
There is no way to effectively protect against cyberattacks.	7.2	32.0	37.1	18.0	5.8
I know the security measures to protect my personal data and devices from cyberattacks.	5.0	14.4	23.4	46.0	11.2
I apply security measures to protect my personal data and devices from cyberattacks.	4.3	8.3	24.1	48.6	14.7

Source: own research, N = 278.

The analysis of statements on the assessment of cybersecurity knowledge level in relation to independent variables shows relatively little variation. Of the 32 variants (eight statements times four independent variables), the level of significance of the χ^2 test value did not exceed the critical value of $p=0.05$ in only eleven cases, indicating the existence of a statistical

relationship between the variables. It is characteristic that this concerns the independent variable “gender” in six cases - in all these cases, the value of the V-Cramér’s coefficient ranges from 0.2 to 0.3, which means that there is a clear but low correlation. The highest value of the strength of the relationship was achieved in the case of the relationship between the statement “I am well protected against cyberattacks” and gender (0.261) - men declare this view much more often than women.

In the remaining five cases, a weak relationship was recorded four times (values between 0.171 and 0.195), and once a low relationship (value 0.227 - the relationship between the statement “The number of cyber-attacks is constantly increasing” and the variable “professional activity”). It is interesting to note that the weak relationship was three times higher for the statement “Cyberattacks are an increasing threat to consumers” and the only variable that showed no relationship was “gender” (Table 3).

Table 3.

Relationship between the degree of respondents' agreement with statements about cybersecurity and independent variables

Specification	Independent variable	χ^2 Test			Decision at $p = 0.05$
		Value (χ^2)	df	Critical significance level (p)	
Cybersecurity education should be more accessible to average consumers.	Gender	12.624	4	0.013	Weak dependency (V-Cramér’s coefficient = 0.213)
	Age	5.058	4	0.281	No dependency
	Employment status	7.487	8	0.485	No dependency
	Place of residence	4.857	4	0.302	No dependency
My cybersecurity skills are sufficient.	Gender	18.453	4	0.010	Low dependency (V-Cramér’s coefficient = 0.258)
	Age	0.945	4	0.918	No dependency
	Employment status	8.623	8	0.375	No dependency
	Place of residence	8.632	4	0.071	No dependency
I am well protected against cyberattacks.	Gender	18.868	4	<0.001	Low dependency (V-Cramér’s coefficient = 0.261)
	Age	2.775	4	0.596	No dependency
	Employment status	16.332	8	0.038	Weak dependency (V-Cramér’s coefficient = 0.171)
	Place of residence	6.086	4	0.193	No dependency
Cyberattacks are a growing threat to consumers.	Gender	6.006	4	0.199	No dependency
	Age	9.599	4	0.048	No dependency (V-Cramér’s coefficient = 0.188)

	Employment status	17.561	8	0.025	Weak dependency (Cramér's V coefficient = 0.178)
	Place of residence	10.554	4	0.032	Weak dependency (V-Cramér's coefficient = 0.195)
The number of cyberattacks is constantly increasing.	Gender	9.360	4	0.053	No dependency
	Age	4.493	4	0.343	No dependency
	Employment status	28.772	8	<0.001	Low dependency (V-Cramér's coefficient = 0.227)
	Place of residence	1.452	4	0.835	No dependency
There is no way to effectively protect against cyberattacks.	Gender	12.949	4	0.012	Low dependency (V-Cramér's Coefficient = 0.216)
	Age	5.035	4	0.284	No dependency
	Employment status	7.598	8	0.474	No dependency
	Place of residence	6.502	4	0.165	No dependency
I know the security measures to protect my personal data and devices from cyberattacks.	Gender	17.577	4	0.001	Low dependency (V-Cramér's coefficient = 0.251)
	Age	2.826	4	0.587	No dependency
	Employment status	11.186	8	0.191	No dependency
	Place of residence	4.550	4	0.337	No dependency
I apply security measures to protect my personal data and devices from cyberattacks.	Gender	13.918	4	0.008	Low dependency (V-Cramér's coefficient = 0.224)
	Age	6.286	4	0.179	No dependency
	Employment status	3.100	8	0.928	No dependency
	Place of residence	1.493	4	0.828	No dependency

Source: own research, N = 278.

In response to the growing threat of cyberattacks, various measures are being taken to protect personal data and devices from hacking. Although not all respondents are fully aware of the existing protection options, all respondents have declared that they take measures related to cybersecurity. An overwhelming majority (90.3%) do not open suspicious links or attachments received by e-mail. When using multiple applications, it is common for examined e-consumers to use two-factor authentication, e.g. via codes received via SMS (80.8% of indications). Antivirus programs (71.9%), regular operating system and software updates, and complex passwords (69.1% of responses each) are also popular. Just over a third of respondents regularly change their passwords and one in five uses virtual private networks (VPNs). However, only 28.1% of respondents use password managers to manage their passwords.

The aforementioned issue of cybersecurity education is related to preferences regarding sources of information on this topic. The conducted research shows that the Internet and social media are of key importance in this area – over 95% of respondents obtain information from these sources. Almost half of the respondents obtained valuable information at work or at university, and a similar share valued the opinions of relatives or friends in this regard. However, as reported by study participants, the importance of other mass media, apart from the Internet or printed publications on cybersecurity, is low.

Discussion

The study results suggest that the surveyed group of young individuals demonstrates a relatively high level of knowledge and awareness regarding cyber threats and they also understand the importance of cybersecurity. The findings of this research indicate a growing concern among young consumers, students of Warsaw universities, regarding cybersecurity threats in the area of e-services. A significant number of respondents acknowledge an increasing frequency of cyberattacks and recognize their impact on consumer security in the area of purchasing and using e-services. On the one hand, this suggests a heightened awareness of the risks associated with online activities; on the other, it points to a sense of vulnerability in the face of these threats.

A significant proportion of respondents (one in three) reported encountering information about several cyberattacks within the past 12 months, and more than half had heard of at least one such incident. Only 12.2% of participants stated that they had not heard about cyberattacks at all, which further confirms the widespread awareness of digital threats.

Moreover, a statistically significant relationship was found between cybersecurity knowledge and specific demographic factors, including gender and age (men and slightly older respondents declared higher levels of knowledge regarding cyberattacks). A similar situation could be observed in the case of survey participants who declared full-time employment and residence in larger cities. Perhaps individuals who are already active in the job market are more aware of the cybersecurity risks and living in larger cities may be correlated with more exposure to information about cyberattacks or cybersecurity threats. However, the authors would like to note that while these relationships are statistically significant, their strength is not high. This indicates that while these factors influence cybersecurity awareness to some extent, other variables may also play a role regarding the level of cybersecurity knowledge and awareness or shaping attitudes toward cybersecurity.

An overwhelming majority of participants (nearly 90% agree, and around 50% strongly agree with the statements) emphasize the need for accessible cybersecurity education, which stresses the need recognized by respondents to expand their knowledge and improve their

digital safety skills. While a large share of respondents report knowing and adopting preventive measures (57% and 63% respectively), such as using two-factor authentication and updating antivirus software, their confidence in their cybersecurity knowledge or practical skills remains relatively low (around 35%). This demonstrates a gap between cybersecurity awareness and respondents' perceived competence in this area.

It is important to note that around 25% share of respondents believe that it is impossible to fully defend against cyberattacks, which may be a reason for concern because the sense of helplessness might be a discouraging factor for respondents to take initiatives like pursuing education opportunities, proactively developing practical cybersecurity skills or investing time, money and effort in building cybersecurity and safe use of devices, systems or platforms. The findings of the study point to the need to develop technical knowledge and devise strategies to enhance e-consumers' confidence in the effectiveness of cybersecurity practices. Addressing these issues using targeted educational initiatives could bridge the gap between e-consumers' awareness and their actions and behavior, which in turn will lead to the development of better cybersecurity habits among young users.

Summary

The study analyzes cybersecurity awareness, knowledge and practices among young e-consumers, students from Warsaw universities. The research findings indicate that nearly 90% of the respondents had encountered information about cyberattacks in the past year and many study participants reported using preventive measures and tools. However, the confidence of respondents regarding their cybersecurity knowledge remained cautious, with one in four believing cyberattacks cannot be fully prevented. The study results suggest a strong need for accessible cybersecurity education in order to bridge the gap between awareness and effective security practices and measures.

It is important to indicate that this study has certain limitations that should be considered. The use of a purposive and convenient sample does not allow for the findings to be generalized beyond the surveyed group. While some correlations were found, i.e. higher cybersecurity awareness among men, older individuals, full-time employees and urban residents, they were relatively weak. Also, self-reported data may not always reflect actual behaviors since increased media coverage and popularity of the topics related to cyberattacks or cyber threats may lead to higher awareness among young e-consumers; however, as the findings of the study suggest, it may not necessarily translate into practical skills or proactive security measures undertaken by this group.

As cyberattacks and cyber threats become more frequent, complex and widespread, e-consumers must expand their knowledge and develop effective cybersecurity practices. Well-informed and proficient users can recognize and prevent, or at least mitigate, potential cyber risks or threats. The awareness and preventive measures play a key role in increasing cybersecurity resilience, both on a personal and organizational level. It is also important to indicate that individual actions can contribute to greater security of networks, systems, and platforms and reduce threats and risks associated with cyberattacks.

Future research should expand its scope to examine cybersecurity awareness, knowledge, skills and behaviors across different populations. Further studies on cybersecurity should also include respondents from smaller towns and rural areas. The studies involving different samples could explore how access to digital resources and technological solutions or cybersecurity education opportunities influence both users' awareness and practices they learn to rely on. In addition, the study could incorporate and test the relationship between the perceived threat (its significance and likelihood), skills and competence of different individual users and the sense of agency, self-efficacy and motivation to protect themselves, for example with the consideration of well-established theories and models, e.g. Protection Motivation Theory by R.W. Rogers. A larger, more diverse sample would also allow for more reliable comparisons and provide a more comprehensive picture of how different demographic groups approach and employ cybersecurity measures and tools. Investigating specific behaviors, e.g. password management, multi-factor authentication, verifying the sources of information or contacts, checking reliability and security of networks, systems or regular updates of software or applications could offer insights into the gap existing between knowledge, awareness and practice. Moreover, understanding how individuals apply digital security measures and tools could help devise and implement targeted strategies to improve digital security competence and practical cybersecurity skills among e-consumers.

References

1. Adel, A. (2023). Unlocking the Future: Fostering Human–Machine Collaboration and Driving Intelligent Automation through Industry 5.0 in Smart Cities. *Smart Cities* 2023, 6, pp. 2742-2782. <https://doi.org/10.3390/smartcities6050124>
2. Al Rusayyis, W., Bakry, S.H., Arafah, M.A. (2022). E-Services Cybersecurity Assessment Model. *International Journal of Smart Education and Urban Society*, 13(1), <https://doi.org/10.4018/IJSEUS.300737>
3. Alkis, A., Kose, T. (2022). Privacy concerns in consumer E-commerce activities and response to social media advertising: Empirical evidence from Europe. *Computers in Human Behavior*, 137. <https://doi.org/10.1016/j.chb.2022.107412>

4. Almansoori, A., Al-Emran, M., Shaalan, K. (2023). Exploring the Frontiers of Cybersecurity Behavior: A Systematic Review of Studies and Theories. *Applied Science*, 13, 5700. <https://doi.org/10.3390/app13095700>.
5. Alrababah, H., Iqbal, H., Khan, M.A. (2024). The Effect of User Behavior in Online Banking on Cybersecurity Knowledge, *International Journal of Intelligent Systems*, <https://doi.org/10.1155/int/9949510>
6. Alwin, D.F. (1997). Feeling thermometers vs. 7-point scales. *Sociological Methods & Research*, 25(3), 318-351.
7. Alzahrani, A. (2020). Coronavirus Social Engineering Attacks: Issues and Recommendations. (*IJACSA*) *International Journal of Advanced Computer Science and Applications*, Vol. 11, No. 5. <https://doi.org/10.14569/ijacsa.2020.0110523>
8. Ballagas, R., Borchers, J., Rohs, M., Sheridan, J.G. (2006). The Smart Phone: A Ubiquitous Input Device, *IEEE Pervasive Computing*, Vol. 5, No. 1, pp. 70-77.
9. Blessing, G., Azeta, A., Misra, S., Osamor, V.C., Fernandez-Sanz, L., Pospelova, V. (2022). The Emerging Threat of AI-driven Cyber Attacks: A Review. *Applied Artificial Intelligenc.* <https://doi.org/10.1080/08839514.2022.2037254>
10. Boratyńska, K., Cieślik, E., Kacperska, E., Łukasiewicz, K., Milewska, A. (2021). *Gospodarka cyfrowa we współczesnym świecie – kraje V4*. Warsaw: SGGW.
11. Bylok, F. (2019). Wyzwania dla edukacji konsumenckiej w budowaniu świadomości konsumenckiej. In: M. Janoś-Kresło, M. (ed.), *Bezpieczeństwo konsumentów. Ochrona i edukacja konsumencka*. Warsaw: SGH.
12. Bytniewski, A. (ed.) (2013). *Systemy informatyczne a rozwój społeczeństwa informacyjnego*. Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.
13. Cele, N.N., Kwenda, S. (2024). Do cybersecurity threats and risks have an impact on the adoption of digital banking? A systematic literature review. *Journal of Financial Crime*, <https://doi.org/10.1108/jfc-10-2023-0263>
14. Chmielarz, W., Szumski, O. (2018). Cyber Security Patterns Students Behavior and Their Participation in Loyalty Programs. *International Journal of Ambient Computing and Intelligence*. April 20189(2). IGI Global Scientific Publishing, pp. 16-31, <https://doi.org/10.4018/IJACI.2018040102>
15. Churchill, G., Peter, P. (1984). Research design effects on the reliability of rating scales: A meta-analysis. *Journal of Marketing Research*, 21(4), pp. 360-375.
16. Cichosz, J. (2017). Społeczny wymiar problematyki bezpieczeństwa obywateli Unii Europejskiej w cyberprzestrzeni. Analiza porównawcza. In: J. Trubalska, Ł. Wojciechowski (Ed.), *Bezpieczeństwo osób w cyberprzestrzeni*. Lublin: Innovatio Press Wydawnictwo Naukowe Wyższej Szkoły Ekonomii i Innowacji w Lublinie, 63-78.
17. Cox, E.P. (1980). The optimal number of response alternatives for a scale: A review. *Journal of Marketing Research*, 17(4), pp. 407-422.

18. Crossler, R.E., Johnston, A.C., Lowry, P.B., Hu, Q., Warkentin, M., Baskerville, R. (2013). Future directions for behavioral information security research. *Computer Security*, 32, pp. 90-101, <https://doi.org/10.1016/j.cose.2012.09.010>
19. Ćwiek, M., Maj-Serwatka, K. (2024). Digital Competence of Young Adults in Poland. *Folia Oeconomica. Acta Universitatis Lodzensis*, 3(368), DOI: <https://doi.org/10.18778/0208-6018.368.03>
20. Dąbrowska, A., Fandrejewska, A., Stańczyk, E., Szalonka, K. (2025). *Consumer and Innovations in e-Health Services*. New York: Routledge, Taylor&Francis.
21. Dąbrowska, A., Bylok, F., Janoś-Kresło, M., Kiełczewski, D., Ozimek, I. (2015). *Kompetencje konsumentów. Innowacyjne zachowania, zrównoważona konsumpcja*. Warsaw: PWE.
22. Dudycz, H., Krawiec, Ł. (2018), Propozycja procedury badania użyteczności witryn internetowych, *Informatyka Ekonomiczna*, No. 3(49), pp. 65-77.
23. European Commission: Directorate-General for Research and Innovation, MacCallum, D., Moulart, F., Leubold, B., Mehmood, A. (2017). *Social innovation as a trigger for transformations – The role of research*. Publications Office, <https://data.europa.eu/doi/10.2777/68949>
24. Ewoh, P., Vartiainen, T. (2024). Vulnerability to Cyberattacks and Sociotechnical Solutions for Health Care Systems: Systematic Review. *Journal of Medical Internet Research*, 26, <https://doi.org/10.2196/46904>
25. Fortes, N., Rita, P. (2016). Privacy concerns and online purchasing behaviour: Towards an integrated model. *European Research on Management and Business Economics*, 22, 3, 167-176. <https://doi.org/10.1016/j.iedeen.2016.04.002>
26. Gwoździewicz, S., Prokopowicz, D., Grzegorek, J. (2025). Chapter 4. Zastosowanie zaawansowanych narzędzi przetwarzania danych w dobie cyfryzacji. In: A. Laskowska-Rutkowska (ed.), *Cyfryzacja w zarządzaniu. Second edition*. Warsaw: CeDeWu.
27. Hossain, S.T., Yigitcanlar, T., Nguyen, K., Xu, Y. (2024). Local Government Cybersecurity Landscape: A Systematic Review and Conceptual Framework. *Applied Sciences*, No. 14, 5501, <https://doi.org/10.3390/app14135501>
28. Jaciow, M., Wolny, R. (2011). *Polski e-konsument. Typologia, zachowania*. Katowice: Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach.
29. Jaciow, M., Wolny, R., Stolecka-Makowska, A. (2015). *E-konsument w Europie. Komparatywna analiza zachowań*. Katowice: Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach.
30. Jalali, M.S., Razak, S., Gordon, W., Perakslis, E., Madnick, S. (2019). Health Care and Cybersecurity: Bibliometric Analysis of the Literature. *Journal of Medical Internet Research*, 21(2), <https://doi.org/10.2196/12644>
31. Janoś-Kresło, M. (ed.) (2019). *Bezpieczeństwo konsumentów. Ochrona i edukacja konsumentów*. Warsaw: Oficyna Wydawnicza SGH.

32. Kiran, U., Khan, N.F., Murtaza, H., Farooq, A., Pirkkalainen, H. (2025). Explanatory and predictive modeling of cybersecurity behaviors using protection motivation theory. *Computers & Security*, 149, <https://doi.org/10.1016/j.cose.2024.104204>.
33. Kotlorz, D. (2013). *Serwicyzacja polskiej gospodarki – przemiany wewnątrzsektorowe*. Katowice: Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach.
34. Kozłowska, A. (2019). Chapter 8. Poszanowanie praw konsumenta: czy reklama może być uczciwa? In: M. Janoś-Kresło (ed.) (2019). *Bezpieczeństwo konsumentów. Ochrona i edukacja konsumencka*. Warsaw: Oficyna Wydawnicza SGH.
35. Lamond, M.L., Renaud, K.V., Wood, L.A., Prior, S. (2022). SOK: Young children's Cybersecurity Knowledge, Skills & Practice: A Systematic Literature Review. *EuroUSEC'22: proceedings of the 2022, European Symposium on Usable Security*, <https://doi.org/10.1145/3549015.3554207>
36. Laskowska-Rutkowska, A. (ed.) (2025). *Cyfryzacja w zarządzaniu. Second edition*. Warsaw: CeDeWu.
37. Mackey, T.K. Nayyar, G. (2016). Digital danger: a review of the global public health, patient safety and cybersecurity threats posed by illicit online pharmacies. *British Medical Bulletin*, Vol. 118, Iss. 1, 110-126, <https://doi.org/10.1093/bmb/ldw016>
38. Matell, M.S., Jacoby, J. (1971). Is there an optimal number of alternatives for Likert scale items? Study: Reliability and validity. *Educational and Psychological Measurement*, 31(3), 657-674.
39. Mocanu, F. (2013). Digital Literacy Among Young Adults in Romania. *Management Dynamics in the Knowledge Economy*, Vol. 6, No. 3, pp. 449-470; <https://doi.org/10.25019/MDKE/6.3.06>
40. Moustafa, A., Bello, A., Maurushat A. (2021). The Role of User Behaviour in Improving Cyber Security Management. *Frontiers in Psychology*. <https://doi.org/10.3389/fpsyg.2021.561011>
41. Mróz, B. (2020). Chapter 5. Prywatność i ekshibicjonizm w przestrzeni wirtualnej: implikacje dla bezpieczeństwa konsumentów. In: *Bezpieczeństwo konsumentów na rynku tradycyjnym i wirtualnym*. Warsaw: Oficyna SGH, pp. 65-76.
42. Mróz, B. (ed.) (2020). *Bezpieczeństwo konsumentów na rynku tradycyjnym i wirtualnym*. Warsaw: Oficyna SGH, pp. 25-36.
43. Mruk, H. (2020). Chapter 2. Pułapki behawioralne a zdrowie . In: B. Mróz (ed.) (2020). *Bezpieczeństwo konsumentów na rynku tradycyjnym i wirtualnym*. Warsaw: Oficyna SGH, pp. 25-36.
44. Nguyen, T.T., Tran, T.N.H., Do, T.H.M., Dinh, T.K.L., Nguyen, T.U.N. , Dang, T.M.K. (2024). Digital literacy, online security behaviors and E-payment intention. *Journal of Open Innovation: Technology, Market, and Complexity*, 10, 2, <https://doi.org/10.1016/j.joitmc.2024.100292>

45. Nowacki, R., Fandrejewska, A. (2024). Nowacki Robert, Fandrejewska Alicja, Consumer Trust in Online Advertising - How Negative Perception Impacts its Effectiveness. *Current Social Sciences*, Vol. 2, <https://doi.org/10.2174/012772316x276725240130110311>
46. Nowacki, R., Fandrejewska, A. (2025). Next tech a prywatność danych i bezpieczeństwo użytkowników Internetu – perspektywa przedstawicieli pokolenia Z. In: M. Twardzik, L. Shulhina (eds.), *Bezpieczeństwo konsumenta na rynku nowych technologii i wybranych rynkach usług*. Warsaw: Oficyna Wydawnicza SGH.
47. Oh, S.S., Kim, K.A., Kim, Minsu, Oh, J., Chu, S.H., Choi, J. (2021). Measurement of Digital Literacy Among Older Adults: Systematic Review. *Journal of Medical Internet Research*, Vol. 23, Iss. 2, e26145, <https://doi.org/10.2196/26145>
48. Olak, R. (2024). *Badanie EY: Rosną obawy konsumentów o bezpieczeństwo ich danych*. 17 September 2024. https://www.ey.com/pl_pl/newsroom/2024/09/rosna-obawy-konsumentow-o-bezpieczenstwo-ich-danych
49. Papińska-Kacperek, J. (2013). Podaż i popyt na usługi cyfrowe w Polsce. In: A. Bytniewski, (ed.), *Systemy informatyczne a rozwój społeczeństwa informacyjnego*. Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.
50. *Postawy Polaków wobec cyberbezpieczeństwa 2024 – Wybrane dane z badania*. July 2024, https://cyber.wib.edu.pl/wp-content/uploads/2024/07/fragment-badania-Postawy-Polakow-wobec-cyberbezp._VII-2024.pdf
51. Rogers, R.W. (1975). A protection motivation theory of fear appeals and attitude change. *The Journal of Psychology*, 91(1), pp. 93-114.
52. Sadab, M. (2023). *Key Factors Related to Cyber Security Affecting Consumer Attitude in Online Shopping - A Study in Bangladesh*. MA thesis. Faculty of Science and Technology, University of Canberra. https://researchsystem.canberra.edu.au/ws/portalfiles/portal/93581530/Mostofa_Sadab.pdf
53. Schutz, H.G., Rucker, M.H. (1975). A comparison of variable configurations across scale lengths: An empirical study. *Educational and Psychological Measurement*, 35(2), 319-324.
54. Singh, N., Misra, R., Quan, W., Radic, A., Lee, S.-M., Han, H. (2024). An analysis of consumer's trusting beliefs towards the use of e-commerce platforms. *Humanities and Social Sciences Communications*, 11, 899. <https://doi.org/10.1057/s41599-024-03395-6>.
55. Siponen, M., Rönkkö, M., Fufan, L., Haag S., Laatikainen, G. (2024). Protection motivation theory in information security behavior research: reconsidering the fundamentals. *Communications of the Association for Information Systems*, 53(1), pp. 1136-1165, <https://doi.org/10.17705/1CAIS.05348>.
56. Snopkiewicz, K. (2020). Przegląd zagrożeń w cyberprzestrzeni. *Studia Administracji i Bezpieczeństwa*, Iss. 9, pp. 29-41.
57. Stallings, W., Brown, L. (2019) *Bezpieczeństwo systemów informatycznych. Zasady i praktyka*, Vol. 1. Fourth edition. Pearson.

58. Tarka, P. (2015). Własności 5- i 7-stopniowej skali Likerta w kontekście normalizacji zmiennych Metodą Kaufmana i Rousseeuwa [Properties of the 5- and 7-point Likert scale in the context of variable normalization using the Kaufman and Rousseeuw method]. *Research Papers of Wrocław University of Economics*, 385, 286-295. <https://doi.org/10.15611/pn.2015.385.31>
59. Trubalska, J. Wojciechowski, Ł. (ed.) (2017). *Bezpieczeństwo osób w cyberprzestrzeni*. Lublin: Innovatio Press Wydawnictwo Naukowe Wyższej Szkoły Ekonomii i Innowacji w Lublinie, pp. 63-78.
60. Wahab, F., Khan, I., Kamontip, Hussain, T., Amir, A. (2023). An investigation of cyber attack impact on consumers' intention to purchase online. *Decision Analytics Journal*, 8. <https://doi.org/10.1016/j.dajour.2023.100297>.
61. Wasilewski, J. (2013). Zarys definicyjny cyberprzestrzeni. *Przegląd Bezpieczeństwa Wewnętrznego*, 9, pp. 225-234.
62. Wilk, A. (2013). *Kradzież tożsamości. Raport z Badań*. FELLOWERS, 3.10.2013, p. 25.
63. Wisetpanich, N., Wittayakom, S., Warrarith, S., Jadesadalug, V. (2025). Canonical Correlation Analysis of Digital Literacy and Perceived Data Privacy Security in E-Commerce Platform Usage Among Generation Z in Thailand. *Pakistan Journal of Life and Social Sciences*, 23(1).
64. Wolny, R. (2013). *Rynek e-usług w Polsce – funkcjonowanie i kierunki rozwoju*. Katowice: Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach.
65. Wolny, R. (2020). Rozdział 7. Świadomość istnienia niebezpieczeństw korzystania z e-usług wśród młodych konsumentów. In: B. Mróz (ed.) (2020). *Bezpieczeństwo konsumentów na rynku tradycyjnym i wirtualnym*. Warsaw: Oficyna Wydawnicza SGH, pp. 89-100.
66. Zhang, M., Kaur, M. (2024). Toward a theory of e-government: Challenges and opportunities, a literature review. *Journal of Infrastructure Policy and Development*, 8(10), 7707. <https://doi.org/10.24294/jipd.v8i10.7707>
67. Ziemia, E. (2017). *Zrównoważone społeczeństwo informacyjne*. Katowice: Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach.

THE USE OF ARTIFICIAL INTELLIGENCE IN THE RECRUITMENT OF GENERATION Z

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Purpose: The purpose of the study was to determine how Generation Z perceives the benefits and risks associated with the use of artificial intelligence (AI) in recruitment processes. The analysis examined the relationships between respondents' assessments and their gender, level of education, and professional experience in order to determine whether these characteristics differentiate the perception of AI's impact on the recruitment process.

Design/methodology/approach: The study was conducted in Poland in the second quarter of 2025 using the CAWI method (Computer-Assisted Web Interviewing) with a proprietary online questionnaire. The sample included 463 representatives of Generation Z (individuals born between 1995 and 2012). The sampling was purposive, encompassing both individuals who were professionally active or had experience with recruitment processes, as well as those without any professional experience. Respondents evaluated various aspects of the use of AI in recruitment, including benefits (such as process speed, job-offer matching, and objectivity) and risks (such as algorithmic errors and limited interpersonal contact), using a 5-point Likert scale. Nonparametric tests were applied to analyze the results: the Mann-Whitney U test, the Kruskal-Wallis test, and Spearman's rank correlation coefficient (R_s), which allowed for examining the relationships between variables and verifying (or rejecting) the research hypotheses.

Findings: Generation Z generally evaluates the use of artificial intelligence in recruitment positively, primarily recognizing the speed, convenience of applying, and objectivity of the selection process. These assessments do not differ significantly by gender, education level, or professional experience. Among the perceived risks, respondents most often indicated the limitation of interpersonal contact and the risk of algorithmic errors; however, these were not seen as factors that completely disqualify the use of AI. The evaluation of risks also showed no significant differences depending on socio-demographic characteristics.

Research limitations/implications: A limitation of the study is the sample size ($N = 463$), which does not allow for full generalization of the results to the entire Generation Z population. Additionally, due to space constraints, the analysis covered only two risk factors related to the use of artificial intelligence in recruitment—the limitation of interpersonal contact and the risk of algorithmic errors—thus narrowing the scope of result interpretation. In future research, it would be valuable to expand the sample and apply a mixed-methods approach (quantitative and qualitative), such as in-depth interviews or case studies, which would allow for a more comprehensive understanding of candidates' motivations, emotions, and expectations regarding the use of artificial intelligence in recruitment.

Practical implications: The study findings are relevant for employers and recruiters, indicating that: Generation Z expects recruitment processes to be fast, convenient, and transparent, while still maintaining human interaction; Artificial intelligence should be treated as a supporting tool, not as a replacement for recruiters; Combining automation with opportunities for human interaction at key stages of the process can enhance candidates' experience and their satisfaction with recruitment.

Originality/value: The study provides both scientific and practical value, as it analyzes Generation Z's perception of artificial intelligence in recruitment, taking into account both benefits and risks. The findings offer up-to-date insights into the expectations of young candidates regarding AI in recruitment processes, which can support employers and HR professionals in designing more efficient and transparent recruitment practices. The study also emphasizes the importance of combining automation with human involvement in candidate selection, representing a significant contribution to the literature on modern HR practices.

Keywords: artificial intelligence, recruitment, Generation Z, benefits and risks.

Category of the paper: science article.

1. Introduction

Recruitment is a key element of organizational functioning, as the achievement of its goals and the continuity of operations depend on the proper selection of employees. The recruitment process, understood as the acquisition and selection of individuals with appropriate qualifications and competencies, has today become a distinct business line of strategic importance (Karaboga, Vardarlier, 2020). It is a proactive activity aimed at attracting job-seeking candidates and motivating them to submit applications for positions defined by the organization (Garg et al., 2021). In this context, innovations play a key role in identifying, selecting, and retaining top talent, even under conditions of strong competition and economic downturn. They also have a social dimension, adding value to recruitment and hiring processes by creating more transparent and fair platforms, as well as inclusive training opportunities for all employees. Consequently, human resource management is evolving toward the integration of digital technologies, enhancing efficiency in developing and maintaining human capital, while the growing competition for talent necessitates the use of effective recruitment tools to meet the increased demand for employees (Allal-Ch'erif et al., 2021). In response to these challenges, artificial intelligence is playing an increasingly important role. As a widely used tool in the modern business world, AI supports—and in some areas even takes over—recruitment processes within human resources departments, enhancing efficiency and precision in talent acquisition and selection (Karaboga, Vardarlier, 2020).

In the context of recruitment research, increasing attention is being paid to the specific characteristics of Generation Z, i.e., individuals born between 1995 and 2012. This generation is characterized by high digital literacy, openness to new technologies, and rapid adoption of digital tools (Zhao et al., 2025). These traits may influence the way young candidates perceive

the benefits and risks associated with the use of artificial intelligence in recruitment processes, which in turn can affect their level of acceptance of modern technological solutions (EY, 2024).

2. Recruitment in the Context of Artificial Intelligence

Recruitment is the process of searching for and attracting candidates who possess an organization. Candidates submit their applications, which are then screened to identify competent and reliable employees (Girsang et al., 2023). In recent years, there has been a growing use of artificial intelligence (AI) in recruitment, with an increasing number of companies implementing AI-based solutions to streamline their hiring processes. This technology is applied at various stages of recruitment – from creating and posting job advertisements, to analyzing and screening CVs, evaluating candidates, and even supporting the onboarding process (Budhwar et al., 2022). According to Adel Ismail Al-Alawi et al. (2021) intelligent automation has facilitated talent acquisition by collecting candidate data and presenting it to recruiters in a more “accessible” format for analysis, enabling decision-making based on the gathered information. This process begins immediately, providing candidates with instant feedback. The implementation of artificial intelligence (AI) in human resources departments aims to identify candidates with potentially high competencies even before the job specification is posted and applications are submitted for a given position. Artificial intelligence supports employers in addressing recruitment and selection challenges, particularly when sudden employee departures increase the costs of acquiring new, qualified candidates. AI facilitates the analysis of a large number of applications and the review of costly CVs, while simultaneously reducing the risk of errors typical in traditional recruitment processes. Additionally, it helps avoid sending inappropriate messages to the wrong recipients—in situations where the recruitment process is rudimentary, unattractive, and lacks testing mechanisms, AI can enhance the candidate experience and improve the employer’s image (Albert, 2019). Artificial intelligence is increasingly being used to automate repetitive tasks, such as analyzing CVs, sending emails, issuing reminders, or organizing recruitment interviews. This enables the reduction of time-consuming activities related to candidate selection, including reviewing profiles and coordinating meetings. The use of AI allows recruiters to focus on building relationships with potential employees and attracting the best talent for the organization. The acceptance of new technologies by users has been widely studied in the information systems literature (Almeida et al., 2025). In the context of recruitment, it is important to understand how candidates perceive and adopt technological solutions, as this knowledge is crucial for designing effective AI-assisted recruitment processes (Acosta-Enriquez, 2024). From a theoretical perspective, models such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology

(UTAUT) suggest that perceived usefulness and perceived ease of use are key factors influencing technology acceptance (Koteczki, 2025; Almeida et al., 2025). In the case of Generation Z, characterized by high digital literacy and openness to new technologies, these factors may lead to a higher appreciation of AI applications in recruitment processes, increasing both perceived benefits and willingness to use automated tools. This technology can support companies in better understanding workforce needs, for example through the analysis of CV data, and can also reduce the impact of unconscious human biases in the evaluation and selection of candidates. Additionally, artificial intelligence could facilitate the creation of ideal candidate profiles for future positions, which would be a significant benefit for long-term workforce planning strategies (Ore, Sposato, 2021). In this context, it is no longer sufficient to assess only the skills required for a given position at the present moment – it is also important to consider knowledge, practical competencies, interpersonal skills, developmental potential, and the ability to pursue a long-term career path. This approach enables a better alignment of employees with the organization's needs in the context of future roles (Palacios-Marqués et al., 2021). The implementation of artificial intelligence in recruitment processes enables the automation of repetitive and time-consuming tasks, such as the initial screening of applications and candidate data analysis. This allows HR professionals to focus on strategic human resource management activities. AI systems facilitate automatic management of candidate databases, rapid matching of candidate skills to job requirements, and effective communication with potential employees. Automation also extends to scheduling interviews, sending reminders, and supporting referral programs, while the use of intelligent solutions in creating job descriptions enhances their clarity, inclusiveness, and accessibility to a wider pool of candidates (Oswal et al., 2020). With the growing use of artificial intelligence in recruitment processes, both benefits and concerns arise regarding its functioning and impact on candidates and organizations. Concerns about the use of AI in recruitment primarily relate to its reliability, accuracy, and data privacy issues. There is also an emphasis on the risk of discrimination and algorithmic bias, which raises ethical questions about the decisions being made. Another source of concern is the potential reduction or complete loss of human interaction in the hiring process (Bryson, Winfield, 2017). These concerns are closely linked to a lack of trust in AI technology. Doubts focus on whether algorithm-generated decisions are truly objective and error-free. Questions are also raised regarding the transparency of these systems and the extent to which their fairness and effectiveness in evaluating candidates can be relied upon (Hogg, 2019). On the other hand, it is emphasized that artificial intelligence can streamline recruitment processes by taking over monotonous and repetitive tasks, such as the initial analysis of candidate data or selection based on job requirements. This allows recruiters to quickly access key information and focus on more strategic aspects of hiring. Moreover, AI is designed to minimize the influence of common sources of bias—such as gender, age, name, race, or beliefs—creating the potential for a more impartial and fair evaluation of candidates (Fraij, Laszló, 2021).

3. Methodology

The aim of the study was to determine how Generation Z perceives the use of artificial intelligence (AI) in recruitment processes, taking into account both benefits and risks. The analysis examined the relationships between respondents' answers and their socio-demographic characteristics, including gender, education, and work experience. The study was conducted in the second quarter of 2025 among 463 Generation Z participants. The sample was purposively selected—respondents were chosen based on their membership in Generation Z (individuals born between 1995 and 2012). Within this group, both individuals who were professionally active or had contact with recruitment processes, as well as those without work experience, were included, allowing for an assessment of the benefits and risks of AI in recruitment from different perspectives. The study was conducted using the CAWI method (Computer-Assisted Web Interviewing) with a self-designed online questionnaire, in which respondents evaluated various aspects of AI use in recruitment on a 1-5 Likert scale. The collected data allowed for the verification of the proposed hypotheses through statistical analyses, including non-parametric tests (Mann-Whitney, Kruskal-Wallis, Spearman). Among the individuals who completed the online questionnaire, all correctly filled forms (N = 463) were included in the analysis. The characteristics of the study sample are presented in Table 1.

Table 1.
Characteristics of the research sample (N = 463)

Features of the study group	N	%	Sum
Sex:			
woman	233	50.3	463
man	230	49.7	
Education:			
Secondary	112	24.2	463
Bachelor/Engineer	207	44.7	
Master	117	25.3	
Other	27	5.8	
Work experience (years):			
none			463
<1 year	93	20.1	
1–3 years	122	26.3	
3–5 years	134	28.9	
5+ years	57	12.3	
	57	12.3	

Source: own study.

Based on the analysis of the literature on the subject in the researched areas, it seems interesting to find answers to several research questions as follows:

1. How does Generation Z perceive the benefits of using artificial intelligence in recruitment, including the speed and convenience of applying, objectivity and lack of bias in selection, and the effectiveness of matching job offers to candidates skills and

interests and do these assessments differ depending on respondents gender, level of education, and work experience?

2. How does Generation Z perceive the risks associated with the use of artificial intelligence in recruitment, including reduced interpersonal contact, the risk of algorithmic errors, lack of transparency in the recruitment process, and concerns about data privacy and do these assessments differ depending on respondents gender, level of education, and work experience?

For the purposes of this study, the following research hypotheses were formulated and verified:

H1: Representatives of Generation Z perceive the use of artificial intelligence in recruitment as beneficial, including the speed and convenience of applying, objectivity and lack of bias in selection, and the effectiveness of matching job offers to candidates' skills and interests, regardless of gender, level of education, or work experience.

H2: Representatives of Generation Z recognize risks associated with the use of artificial intelligence in recruitment, including reduced interpersonal contact and the risk of algorithmic errors, with the perception of these risks potentially varying depending on respondents' gender, level of education, and work experience.

The above research questions and formulated hypotheses serve as a starting point for analyzing Generation Z's perception of artificial intelligence in recruitment. Their verification will allow for the identification of both the benefits and risks associated with the use of AI in recruitment processes, as well as the assessment of the extent to which socio-demographic factors influence the perception of these aspects.

4. Results

To verify hypothesis H1, correlations were examined between respondents' perceptions of the benefits of using artificial intelligence in recruitment (in terms of the speed and convenience of the application process) and socio-demographic factors (gender, education, and professional experience). This hypothesis is fully confirmed. The results of the research in this area are presented in the table below.

Table 2.

The relationship between perceived benefits of AI in recruitment (speed and convenience of the application process) among Generation Z representatives and respondents' gender, education, and professional experience

Socio-demographic variable	Group	n	Median (AI benefits)	test	Test statistic value	p-value
Sex:	woman	233	4	U Manna-Whitneya	Z = 0,00	0,99
	man	230	4			
Education:	Secondary	112	4	Kruskal Wallis	H = 5,38	0,15
	Bachelor/Engineer	207	4			
	Master	117	4			
	Other	27	4			
Work experience (years)	none	93	4	Spearman	Rs = 0,06	0,20
	<1 year	122	4			
	1–3 years	134	4			
	3–5 years	57	4			
	5+ years	57	4			

Source: own study based on the Statistica 13.3 software.

Based on the analyses conducted using the Mann-Whitney U test, no statistically significant differences were found in the perception of the benefits of using artificial intelligence in recruitment between women and men from Generation Z ($p = 0.99$). Both women ($Me = 4$) and men ($Me = 4$) similarly rated the use of AI in the recruitment process as beneficial, particularly regarding the speed and convenience of applying. The results indicate a consistent approach among representatives of both genders toward the use of artificial intelligence in recruitment, confirming that gender does not influence the perceived benefits of this solution. The analysis of the ratings shows minor differences between education groups, with all respondents evaluating the benefits to a similar degree, confirming the relative uniformity in the perception of this aspect of recruitment. The Kruskal-Wallis test revealed no statistically significant relationship between the level of education and the perceived benefits of using AI in recruitment, indicating that education does not influence the assessment of the speed and convenience of the application process. The results suggest that the perception of AI benefits in recruitment is relatively consistent among Generation Z, regardless of work experience. The lack of a significant correlation confirms that the length of work experience does not have a meaningful impact on the evaluation of the speed and convenience of the application process using AI.

Table 3.

The relationship of perceived AI benefits in recruitment – objectivity and lack of bias in selection, as well as the effectiveness of matching job offers to candidates' skills and interests among Generation Z representatives, depending on respondents' gender, education, and work experience

Socio-demographic variable	Group	n	Median (objectivity and lack of bias in selection)	test	Test statistic value	P-value	Median (effectiveness of matching job offers to candidates' skills and interests)	Test statistic value	P-value
Sex:	woman	233	5	U Manna-Whitneya	Z = 0,00	1,00	3	Z = 0,00	1,00
	man	230	4				3		
Education:	Secondary	112	4	Kruskal Wallis	H = 0,00	1,00	3	H = 0,00	1,00
	Bachelor/Engineer	207	4				4		
	Master	117	5				4		
	Other	27	4				3		
Work experience (years)	none	93	5	Spearman	Rs=0,00	1,00	3	Rs = -0,01	1,00
	<1 year	122	5				4		
	1-3 years	134	5				3		
	3-5 years	57	4				3		
	5+ years	57	4				3		

Source: own study based on the Statistica 13.3 software.

Based on the conducted analyses, it can be stated that Generation Z perceives the benefits of using artificial intelligence in recruitment—specifically, objectivity and the absence of bias in selection—as important. Regarding gender, these benefits were more frequently indicated by women than men; however, the Mann-Whitney U test analysis showed no statistically significant differences between the groups, suggesting that gender does not determine the assessment of this benefit. The analysis of the relationship between education level and the perception of this benefit, using the Kruskal-Wallis test, revealed no significant differences, indicating that education does not significantly affect the evaluation of objectivity and lack of bias in selection. Similarly, in the case of work experience, the median ratings were highest in groups with shorter tenure (no experience 5, <1 year 5, 1-3 years 5) and slightly lower in groups with longer tenure (3-5 years 4, over 5 years 4), while Spearman's rank correlation coefficient $R_s = 0.00$ with $p = 1.00$ confirmed the absence of a significant relationship between work experience and the assessment of this benefit. The study indicates that Generation Z perceives the benefit of matching job offers to candidates' skills and interests in AI-supported recruitment as similar across groups, with a median of 3 for both women and men. The Mann-Whitney U test showed no statistically significant differences between genders, suggesting that gender does not influence the assessment of this benefit. The analysis of the relationship between education level and the perceived effectiveness of matching job offers, using the Kruskal-Wallis test, also revealed no significant differences, indicating that education level does not determine the evaluation of this benefit. In the case of work experience, Spearman's rank correlation coefficient confirmed the absence of a significant relationship between the length of professional experience and the assessment of the effectiveness of matching job offers.

To verify hypothesis H2, the perception of risks associated with the use of artificial intelligence in recruitment—such as the limitation of interpersonal contact and the risk of algorithmic errors—was analyzed in the context of respondents' socio-demographic variables (gender, education level, and work experience). The following table presents the study results in this area.

Table 4.

The relationship between perceived risks of using AI in recruitment (limitation of interpersonal contact, risk of algorithmic errors) and the gender, education level, and work experience of Generation Z respondents

Socio-demographic variable	Group	n	Median (limitation of interpersonal contact)	test	Test statistic value	p-value	Median (risk of algorithmic errors)	Test statistic value	p-value
Sex:	woman	233	3	U Mann-Whitney	Z = 0,00	1,00	4	Z = 0,00	1,00
	man	230	3,5				4		
Education:	Secondary	112	1	Kruskal Wallis	H = 1,56	0,66	4	H = 0,58	0,90
	Bachelor/Engineer	207	3				3		
	Master	117	3				4		
	Other	27	3				4		
Work experience (years)	none	93	3	Spearman	Rs = 0,02	1,00	4	Rs = -0,02	1,00
	<1 year	112	4				3		
	1–3years	134	3,5				4		
	3–5years	57	3				4		
	5+ years	57	3				4		

Source: own study based on the Statistica 13.3 software.

The analysis of the results indicates that both women and men from Generation Z perceive the threat related to the reduction of interpersonal contact to a similar extent, with median ratings of 3 for women and 3.5 for men. The Mann-Whitney U test showed no statistically significant differences between genders, suggesting that gender does not influence the perception of this type of risk in AI-assisted recruitment processes. Regarding the risk of algorithmic errors, the median rating was 4 for both women and men. The Mann-Whitney U test results ($Z = 0.00$) indicate no statistically significant differences between genders in the assessment of this threat. The level of education does not significantly differentiate the perception of risks associated with the use of artificial intelligence in recruitment processes. Regarding the threat related to the reduction of interpersonal contact, the median values for the various education groups indicate some variation, but these differences are not statistically significant. This means that respondents, regardless of their education level, similarly perceive reduced contact with recruiters as a potential consequence of AI implementation. A similar result was observed for the risk of algorithmic errors. The median ratings across different education levels, along with the non-significant Kruskal-Wallis test result, confirm the lack of a relationship between education level and the perception of this threat. The analysis of results indicates that work experience does not significantly influence the perception of risks associated with the use of artificial intelligence in recruitment. For the factor concerning the reduction of interpersonal contact, the median values across different levels of work experience suggest

a similar perception of this phenomenon among respondents, regardless of the number of years worked. The lack of a significant correlation ($R_s = -0.02$; $p = 1.00$) confirms that the length of work experience does not differentiate assessments in this area. Similarly, regarding the risk of algorithmic errors, where median values remain at a comparable level across all surveyed groups, no significant relationship was found between work experience and the evaluation of this threat.

5. Discussion and conclusions

The results of the conducted study indicate that Generation Z generally perceives the use of artificial intelligence (AI) in recruitment as beneficial, highlighting the speed, convenience of applying, and objectivity of the selection process. At the same time, they recognize potential risks, such as the reduction of interpersonal contact and the possibility of algorithmic errors. It is noteworthy that no significant differences were observed in these perceptions across analyzed groups (gender, education, work experience), suggesting a relatively uniform approach to the topic among Generation Z representatives. Similar conclusions are drawn from the research conducted by O. Ore and M. Sposato (2022), who indicate that AI in recruitment can enhance efficiency through the automation of routine tasks while emphasizing the need to maintain the role of professional recruiters in the selection process. J. Dima et al. (2024) also confirm that AI supports HR processes by increasing efficiency, optimizing data use, and enabling decision-making enhancements, and highlight the importance of preserving human-centric and relational aspects of work as well as addressing ethical challenges like bias. Furthermore, the findings of Md Sajjad Hosain et al. (2025) suggest that algorithm transparency and the possibility of human contact increase candidates' trust in AI-based recruitment processes. C. Rigotti and E. Fosch-Villaronga (2024) emphasize the importance of fairness and the elimination of biases in AI-supported selection. Meanwhile, studies by Kelvin M. Mwita and Felician A. Kitole (2025) and Zaker Ul Oman et al. (2024) demonstrate that properly designed AI systems can enhance recruitment efficiency while minimizing the risk of bias and supporting objective decision-making.

From a theoretical perspective, these findings allow for linking the observed attitudes to technology acceptance models, such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT), in which perceived usefulness and perceived ease of use play a key role. In the context of Generation Z, characteristics such as high digital literacy and openness to new technologies may lead to a greater appreciation of the benefits of AI in recruitment, as well as a higher willingness to use tools that automate selection processes.

From a practical standpoint, the findings suggest that organizations should implement AI in recruitment processes while maintaining transparency of procedures and opportunities for human interaction, which can increase trust among Generation Z candidates. The design of AI-assisted recruitment processes should consider both benefits and potential risks, with an emphasis on balancing automation with recruiter interaction. Based on the conducted study, it is recommended to continue research in the form of longitudinal studies, which would allow observing changes in the perception of AI in recruitment over time and across different organizational contexts. It is also valuable to employ mixed-methods approaches, combining quantitative and qualitative research, to gain deeper insights into the decision-making mechanisms of candidates and recruiters, as well as how the perception of benefits and risks affects the acceptance and effectiveness of implemented tools. Such an approach would also account for differences between generations, industries, and organizational cultures, providing valuable guidance for HR practice in the area of AI-assisted recruitment.

References

1. Acosta-Enriquez, B.G. (2024). *Acceptance of artificial intelligence in university contexts*. PMC.
2. Al-Alawi, A.I., Naureen, M., Al-Alawi, E.I., Al-Hadad, A.A.N. (2021). *The Role of Artificial Intelligence in Recruitment Process Decision-Making*, 2021 International Conference on Decision Aid Sciences and Application (DASA).
3. Albert, E.T. (2019). AI in Talent Acquisition: A Review of AI- applications used in recruitment and selection. *Strategic HR Review*, 18.
4. Allal-Ch'erif, O., Yela Ar'anega, A., Castaño Sánchez, R. (2021). Intelligent recruitment: How to identify, select, and retain talents from around the world using artificial intelligence. *Technological Forecasting & Social Change*, 169.
5. Almeida, F., Junça Silva, A., Lopes, S.L., Braz, I. (2025). Understanding Recruiters' Acceptance of Artificial Intelligence: Insights from the Technology Acceptance Model. *Applied Sciences*, 15(2), 746.
6. Bryson, J., Winfield, A. (2017). Standardizing ethical design for artificial intelligence and autonomoussystems. *Computer*, 50(5).
7. Budhwar, P., Malik, A., De Silva, M.T.T., Thevisuthan, P. (2022). Artificial intelligence – challenges and opportunities for international HRM: a review and research agenda. *The International Journal of Human Resource Management*, 33(6), 1065-1097. tandfonline.
8. Dima, J., Gilbert, M.H., Dextras-Gauthier, J., Giraud, L. (2024). The effects of artificial intelligence on human resource activities and the roles of the human resource triad: opportunities and challenges. *Frontiers in Psychology*, 15.

9. EY (2024). *New EY survey reveals crucial AI literacy training needs among Gen Z workforce*. EY Global Report.
10. Fraij, J., Laszló, V. (2021). A Literature Review: Artificial Intelligence Impact on the Recruitment Process. *International Journal of Engineering and Management Sciences (IJEMS)*, 6(1).
11. Garg, A., Gaur, S., Sharma, P. (2021). A Review Paper: Role of Artificial Intelligence in Recruitment Process. *International Journal of Management and Information Technology*, 6(1).
12. Girsang, R.M., Tarigan, W.J., Sipayung, T. (2023). The effect of recruitment and selection on employee performance. *Enrichment: Journal of Management*, 13(1).
13. Hogg, P. (2019). Artificial intelligence: HR friend or foe? *Strategic HR Review*, 18(2).
14. Hosain, M.S., Amin, M.B, Debnath, G.Ch., Rahaman, M.A. (2025). The use of Artificial Intelligence (AI) in the hiring process: Job applicants' perceptions of procedural justice. *Computers in Human Behavior Reports*, 19.
15. Karaboga, U., Vardarlier, P. (2020). Examining the use of artificial intelligence in recruitment processes. *Bussecon Review of Social Sciences*, 2(4).
16. Koteczki, R. (2025). A TAM and UTAUT-Based PLS-SEM and Cluster Analysis. *Education*, 15(8), 1044.
17. Mwita, K. M., Kitole, F.A. (2025). Potential benefits and challenges of artificial intelligence in human resource management in public institutions. *Discover Global Society*, 3(35).
18. Oman, Z.U., Siddiqua, A., Noorain, R. (2024). Artificial Intelligence and its ability to reduce recruitment bias. *World Journal of Advanced Research and Reviews*, 1.
19. Ore, O., Sposato, M. (2021). Opportunities and risks of artificial intelligence in recruitment and selection. *International Journal of Organizational Analysis*.
20. Oswal, N., Khaleeli, M., Alarmoti, A. (2020). Recruitment in tee era of Industry 4.0: Use of artificial intelligence in recruitment and its impact. *PJAEE*, 17(8).
21. Palacios-Marqués, D., Gallego-Nicholls, J.F., Guijarro-García, M. (2021). A recipe for success: Crowdsourcing, online social networks, and their impact on organizational performance. *Technological Forecasting and Social Change*, Vol. 165.
22. Rigotti, C., Fosch-Villaronga, E. (2024). Fairness, AI recruitment. *Computer Law, Security Review*, 53.
23. Zhao, L., An, J., Liu, Y. (2025). Exploring AI tool adoption in higher education: Evidence from a PLS-SEM model integrating multimodal literacy, self-efficacy, and university support. *Education and Information Technologies*, PMC.

IMPACT OF AUGMENTED REALITY TECHNOLOGY ON FIRMS' COMPETITIVENESS

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Purpose: This study investigates how augmented reality (AR) technology contributes to firm-level competitiveness and through which mechanisms these effects arise.

Design/methodology/approach: We employ a qualitative multiple-case study of four leading Polish AR software developers with international client portfolios. Semi-structured interviews with managers provide insights into how client firms apply AR and what outcomes they achieve.

Findings: Results show that AR enhances competitiveness primarily in marketing and retail by improving product visualization, enabling customization, intensifying customer engagement, and creating a strong “wow effect” that elevates brand image. In some cases, AR supports new business models, as illustrated by customizable furniture or interactive cultural projects. While effects on cost reduction were less visible, AR's impact on sales, consumer experience, and innovation signaling was consistently reported.

Originality/value: The study extends AR research beyond consumer acceptance by examining competitiveness outcomes at the firm level. It highlights the supplier-side vantage point, which captures cross-industry adoption patterns and identifies both opportunities and constraints in AR deployment. The findings suggest that AR can become a source of sustainable advantage when paired with complementary resources such as product data, analytics, and organizational readiness.

Keywords: augmented reality, technology management, innovation management.

Category of the paper: Research paper.

1. Introduction

Augmented reality (AR) allows for the visual alignment of virtual content with real-world contexts (Scholz et al., 2016). Applications of AR technology are vast, the major fields are industry, e.g., aviation (Crescenzo et al., 2011), military, education, medicine and healthcare, travel and tourism (Jung et al., 2018), retail and marketing (Martinez et al., 2014).

Technology is an important driver of competitive advantage (Prahalad, Hamel, 1994; Eisenhardt, Sull, 2001; Mauborgne, Chan Kim, 2007; Christensen, Bower, 1995). While AR is gradually gaining public attention, technology advisory agencies (e.g., Gartner, Accenture) and researchers already publish on how to take advantage of this emerging technology (e.g., Berman, Pollack, 2021; Javornik et al., 2021, Rauschnabel et al., 2022). This confirms that AR may be mature enough to be a factor affecting enterprises' competitiveness.

We would like to focus on AR's potential of raising competitiveness of enterprises and answer the question if AR can increase the competitiveness of an enterprise which employs it. We define competitiveness as a firm's ability to achieve superior performance relative to its rivals. It is reflected in short-term commercial outcomes such as higher sales, stronger conversion rates, and reduced product returns. It also appears in process outcomes such as faster cycle times, lower error rates, and reduced service costs. Finally, it includes long-term strategic outcomes such as stronger brand equity, improved customer loyalty, enhanced dynamic capabilities, and the development of new business models.

The multiple-case study method was chosen, as a more generalizable method allowing deeper understanding of studied phenomenon. As a result, managers in four companies creating AR software applications were interviewed. However, in this paper we concentrate on their clients - companies which use this technology directly in their business undertakings.

We investigate what are the benefits of AR to them and how they use it. While previous studies have mostly examined AR from the consumer perspective—focusing on user experience or acceptance—there is little evidence on how AR contributes to firm-level competitiveness. Our study addresses this gap by analysing AR's impact from the supplier–client viewpoint, linking observable advantages to commercial, process, and strategic outcomes. This perspective is original in two ways: it focuses on business applications rather than consumer perceptions, and it integrates insights from technology management and strategic management theories to explain how AR becomes a source of competitive advantage.

2. Literature review

2.1. Augmented Reality's characteristics

AR gained recognition in recent years, however, its origins date back to 1950s and 1960s. The term was coined in 1990 and in the following years this technology gained application mainly in aircraft. The general idea behind it is to augment the view of a real environment (e.g., video feed from a camera or the view behind the glasses) with virtual input such as video and graphics in real time. AR users may interactively gain information about the real world surrounding. Technically this technology consists of software and hardware – a camera,

computing unit and surface to display the image (e.g., a screen) (Martinez et al., 2014). Each of these elements is becoming more and more technologically advanced. Moreover, AR cooperates well with other emerging technologies such as Virtual Reality, 3D, beacons, Internet of Things, image, and gesture recognition. Therefore, we believe it is the technology of the future, but it already may be beneficial to companies in the context of their competitiveness.

Javornik (2016) assembled the most representative media characteristics of interactive technologies: interactivity, hypertextuality, modality, connectivity, location-specificity, mobility, and virtuality. All these features are crucial for positive user evaluation and all of them are existent to some extent in AR technology.

2.2. AR in various sectors of business

According to Porter and Heppelmann (2017) AR creates business value in two ways. Firstly, by becoming part of products themselves and creating better user interfaces and ergonomics. Secondly, by improving performance across the value chain - in product development, manufacturing, marketing, service, and many other areas. Berman and Pollack (2021) enumerate five benefits for companies implementing AR: increasing profits through higher sales; increasing profits through lower expenses; generating excitement for a brand, for retailers, or for a product; facilitating the consumer purchase process through increased product information; implementing and upgrading a firm's omnichannel strategy.

There is a variety of possible AR applications, ranging from industry and military, training and education, medicine and healthcare, travel and tourism (e.g., instantly translating text by pointing the smartphone's camera at the foreign text), retail and marketing (Martinez et al., 2014). AR can be a solution to "a wide range of problems (...), e.g., planning, design, ergonomics assessment, operation guidance and training" (Wang et al., 2016). Newer work confirms this direction: Marino et al. (2024) show that AR improves efficiency and reduces errors in industrial assembly tasks, while Treinen et al. (2024) document AR's effectiveness in quality inspection, assembly, and remote support. In healthcare, Lawson et al. (2023) demonstrate through a randomized controlled trial that AR/MR guidance lowers error rates during emergency medical care, highlighting the broader competitiveness benefits of immersive overlays for high-stakes tasks. Jetter et al. (2018) in their review noted that AR is gathering attention in various industrial areas, e.g., manufacturing in the aerospace industry (Frigo et al., 2016) and in shipbuilding (Fraga-Lamas et al., 2018), engineering analysis and simulation (Li et al., 2017) or architecture and construction (Chi et al., 2013). AR is "predicted to play a decisive role in the digital transformation of manufacturing" (Jetter et al., 2018). AR may also play an essential role in improving consumer experience in the restaurant sector (Batat, 2021).

The majority of AR business literature concentrates on consumers and factors influencing AR's acceptance, users' expectations, or experiences (e.g., Olsson et al., 2011; Martinez et al., 2014; Wojciechowski, Cellary 2016; Rese et al., 2017; Grzegorzczak et al., 2019; Kumar, 2021; Rauschnabel, 2021; Smink et al., 2020; Flavian et al., 2019; tom Dieck, Han, 2021).

The most important drivers of the AR adoption are reduction of costs, fast learning curve, curiosity, tangible 3D visualization and fun (Martinez et al., 2014). On the other hand, the most common bottlenecks are no common standard and little flexibility, limited computational power, inaccuracy of technology, social acceptance factor and excessive amount of information. Martinez et al. (2014) applied Roger's theory of diffusion of innovations to AR. According to them AR fulfills three out of five characteristics of Roger's technology acceptance model: relative advantage, ease of use and learning and trialability. Two characteristics that are missing are: conformity with social norms and observability (the degree to which the benefits of AR are evident).

Retail and marketing are often described as the “largest application opportunity for AR” (Gervautz, Schmalstieg, 2012). In retailing, the findings show that AR enables interactivity which improves shopping experience (Baier et al., 2015) and allows companies to provide additional product information (Adhani, Rambli, 2012). According to Baier et al. (2015) retailers may also use AR to engage consumers by “virtual trial and product education” and gamification to enhance the customer experience. Xu et al. (2024) provide evidence that specific AR features—such as vividness and interactivity—directly stimulate purchase intentions in e-commerce contexts. Moreover, AR allows firms to present additional product information which may support consumers in their product decisions (Rese et al., 2017). An example would be using the consumer's own image to interact with the product (Blazquez, 2014). Other marketing applications include navigation tools for locating stores and in-store navigation, as well as brand recognition and promotion (Gervautz, Schmalstieg, 2012).

Recent studies show that AR can impact various aspects related to the consumer retailing experience (Yang et al., 2020). Esch et al. (2019) studied how discomfort with AR affects attitude toward the brand. Rauschnabel et al. (2019) demonstrated how attitude toward the AR app and inspiration influence brand attitude, while Park and Yoo (2020) researched how controllability, responsiveness, and playfulness of AR relate to attitude toward a product.

Furthermore, Dacko (2017) enumerates benefits of AR shopping apps: improving conversion rates, reducing return rates, enlivening static retail inventories, providing a means to offer personalized pre-purchase evaluations. Dacko's findings show that AR shopping apps clearly add experiential value to retail settings. Tseng-Lung and Shuling (2015) confirmed that usefulness, ease of use, service excellence, aesthetics, and playfulness affect the adoption of AR. They set as an example IKEA's AR interactive catalogue, which by increasing playfulness and convenience can successfully inspire consumers to buy their products and improves a company's image. Another study confirms the usefulness of AR in brick-and-mortar shops as a tool to increase customer's satisfaction and present additional information about the shop's

offer (Spreer et al., 2012). However, for some shoppers, an AR app may be too slow or not dependable enough to use regularly (Ramakrishna et al., 2013). What is more, AR shopping app compatibility with the user's smartphone's operating system may be an issue (Dacko, 2017). Those issues, however, might have changed with time and technological progress.

As showed by Rauschnabel et al. (2022) AR is increasingly gaining in popularity among managers. According to their study 15% of managers are planning to use AR marketing in the foreseeable future, 17% already apply AR marketing in some areas, and 8% use it strategically. 60% are not using AR because of a lack of established AR Marketing tools within their specific industry (63%).

Eckert et al.'s (2019) review showed an increasing trend in the number of publications on benefits of introducing AR in the medical sector, not only in treatments but also training. AR also benefits consumers who may improve their health and fitness (Adapa et al., 2020). For instance, AR has the potential to engage its users more deeply in their healthcare, enhancing their commitment to treatments by increasing immersion, gamification and entertainment. AR tools offer individualized guidance on managing medications, practicing self-care, and performing exercises (Parekh et al., 2020). The bottlenecks for AR's diffusion are cost and privacy concerns. Finally, recent reviews emphasize AR's role in workforce training and Industry 4.0 assistance (Méndez, Velázquez, 2024), suggesting competitiveness gains may also arise through improved employee performance, knowledge transfer, and cost-efficient upskilling.

In summary, there still is little research on business applications of AR, whereas the strategic management theories indicate a direct link between new technology and firm's competitiveness. Some studies show that AR may be a viable tool for increasing sales by influencing the consumers. Therefore, basing on above mentioned literature we believe that there is a research gap considering the use of AR technology by companies to increase its competitive advantage. We intend to address this gap by examining how client firms use AR and by identifying the mechanisms through which AR can enhance competitiveness.

3. Methods

To assess what are the benefits of using AR technology compared to standard solutions without it, we interviewed companies which create AR applications for companies directly using them to achieve their business goals. Those latter companies were of our foremost interest in this paper. We have selected a multiple case study approach from an array of other methods. It is not only regarded as the most suitable research method for theory testing (Yin, 2013), but also for the potential theory development (Eisenhardt, 1989; Merriam, 1998). This method allows for the conclusion to be drawn about a larger group of companies than a single case

study, resulting in a more reliable coverage of the researched area. Purposeful sampling was used to select the participating companies (LeCompte, Preissle, 1993; Maxwell, 2005), with the criteria being the company's portfolios.

The chosen companies had to meet following criteria:

- a. leading portfolio of developed AR software applications among competitors,
- b. at least three years of experience in professional development of augmented reality based applications,
- c. providing their services to foreign international parties (no limit was set).

Three years of professional experience proves sufficient skills and knowledge of the researched field and secures a vast portfolio of finished projects. Features which were considered to evaluate the portfolio were as follows: quantity of realized projects, their level of technological advancement, their diversity and their clients' country of incorporation. This information was acquired from companies' websites and other mass media sources. Furthermore, providing services to foreign parties assures us that the company is competing on an international level which is the more demanding on various fields.

While we found twenty Polish companies which according to their websites develop AR applications, most of them had scarce experience, limited to creating either only single AR applications or more of them, but simple and repeatable. We excluded them from the study. Then, we filtered the companies without international or large clients listed in their "Clients" website section as well as those without their corporate websites available in English or other foreign language. This way we selected four Polish companies which outclass their rivals based on above-mentioned criteria. Especially, in terms of the quality and quantity of developed AR apps.

The research was conducted using either the direct interview method (Maxwell, 2005) or an online interview via Skype as well as the semi-structured interview method (Nikodemaska-Wołowik, 2008) based on a prepared questionnaire. It was therefore possible to interact directly with the respondents and obtain accurate information about the factors which had the greatest impact on the studied phenomenon. Chosen form of interview allowed to identify the factors that the respondent would not determine alone thanks to broadening important issues. Additionally, this approach eliminated the possibility that some questions would be unclear to the respondent, potentially leading to unreliable and imprecise responses. The managers who were interviewed were either co-owners or sole owners of the company, and held CEO or management board positions. All participants provided informed consent for audio recording and analysis. The interviews took approx. 60-90 minutes.

Poland as a research context offers a compelling case for studying AR's competitiveness effects. The country has become one of the fastest-growing IT hubs in Central and Eastern Europe, with a strong base of software houses serving global markets. Polish AR firms often compete internationally from the outset, working with foreign clients across industries. This environment creates a unique laboratory for examining AR's business value: companies

must meet demanding international standards while operating in an emerging but dynamic innovation ecosystem.

Equally important is the supplier-side vantage point adopted in this study. By focusing on AR developers rather than only client firms, we gain access to knowledge that spans multiple industries and use cases. Suppliers observe adoption patterns, common client challenges, and best practices across sectors, which makes their perspective especially valuable for identifying mechanisms of competitiveness and assessing where AR generates the strongest impact. This complements firm-level adoption studies and provides a more generalizable picture of AR's potential.

We analysed responses to six questions¹:

1. What are the biggest advantages of AR applications?
2. What is the size category of your AR applications business clients?
3. What branches do your clients represent?
4. What are your clients' main objectives for AR applications?
5. Are your clients aware of advantages of AR applications? If yes, to what extent?
6. Does AR technology in your projects benefits your clients' competitiveness? If yes, in what way? Can you give any examples?

Questions were aimed at obtaining subjective opinions of interviewees, based on their professional experience and knowledge. During the interview the laddering technique was used which helped to deepen the answers.

4. Results

The respondents underlined that AR apps encourage greater user engagement which was claimed to be directly linked to applications' better efficiency. "In order to verify it, we measure the number, frequency and length of looks given to the AR display and the viewer's profile (e.g. sex, age) and compare with a standard solution." Accordingly, the longer and the more intensive was users' attention drawn to the display using AR, the more often the advertised product was bought. Consequently, this respondent highlighted that the main advantage of AR applications was the efficiency in promoting a product or service and increasing sales.

Another manager stated that key benefit of AR is visual impressiveness and the "wow effect" which grabs attention of consumers. This "wow effect" is then transferred from the application to the promoted product or company. Moreover, AR is claimed to provide a synergistic effect with other emerging technologies such as beacons, motion and gesture

¹ A small part of the same interview material has been used in a separate manuscript that analyses consumer preferences. That article addresses a different research question and focuses on the demand side, whereas the present paper examines firm-level competitiveness. The reference is omitted to preserve double-blind review.

control, virtual reality and 3D. According to three interviewees AR is a big step forward regarding presentation of 3D objects. An example given by them is a visualisation of a building in its real surrounding before the commencement of the construction. Furthermore, AR was claimed to be of great help in terms of customization of products, aiding and simplifying the shopping process (an example of Ferrari's AR app was given which allows visualisation of various models of alloy wheels on a real car,). Moreover, one answer underlined that AR boosts spatial imagination. Ease of use was also mentioned.

Table 1.
Influence of observed AR advantages

Observed advantage of applying AR	Mechanism / usability effect	Commercial / strategic outcome
More frequent and longer visual attention	Captures and holds customer focus on product displays	Higher purchase frequency and increased sales conversion
"Wow effect" and impressiveness	Creates novelty and positive emotional response	Stronger customer attraction to promoted products and improved brand image
Synergy with other emerging technologies (e.g., beacons, gesture control, VR, 3D)	Enhances visualization and supports interactive demonstrations	More persuasive presentation of new ideas, projects, and large or complex products; improved customer understanding
Product customization	Enables interactive configuration of products in real time	Simplifies shopping process, increases personalization, and makes purchase experience more engaging and enjoyable

Source: authors' own elaboration based.

90% of the clients of the first studied company represent the pharmaceutical branch while 10% are mainly museums. In the case of the second respondent it was a full range of possible branches e.g., furniture manufacturing, car industry and European Space Agency. The third CEO pointed at technological companies (Nokia, Orange), real estate developers, car industry (Fiat, Peugeot), e-commerce and media industry (AMC Networks, Viacom, NC+). The last manager mentioned manufacturing business, education (publishing house, museum) and services branch (logistics and a shopping centre).

Every interviewee stated that all AR apps created by them are aimed either to promote or present a certain product, service or to improve firms' image in general. The most often declared final objective was to increase the sales. The second most often mentioned AR apps' aim was to deliver additional value to a product or service (e.g., a visualisation of building made for an architecture firm). Moreover, AR apps were also used to present information in a transparent and entertaining way, e.g. an exposition in a museum, an art project or statistical data.

The answers vary when it comes to the fifth question concerning clients' awareness of AR's advantages. One of the views is that clients underrate this technology viewing it only as a new trend, which needs to be implemented in order to stay up to date but is not of great practical importance. Another respondent stated that AR is regarded mainly as a useful addition to company's other (mainly promotional) undertakings, but still only an addition. In third company's opinion it depends on the client. Some of their clients are very fond of this

technology and aware of its benefits at the moment of their first contact and some are completely unaware of AR technology alone and need to be persuaded, if it is a more beneficial solution. Other view is that this situation has recently changed and companies directly using AR applications have become aware of its usefulness. The sources of this knowledge are their own experience and companies which create those applications, Internet sources and successful examples of AR applications of other companies. This may be indirectly confirmed by growing demand on such applications in the researched companies. In case of marketing agencies which often act as brokers between researched companies and their clients, they usually are fully aware of the potential of AR applications.

As far as the last question is concerned, every interviewee answered affirmatively that AR applications positively influence their clients' competitiveness. What varies is the extent of this influence. According to one CEO, it is small and limited to that of an innovative gadget. The reason for that is their client's unwillingness or inability to skilfully use this technology. "We must wait until the Polish market matures". Second interviewee agreed that this technology "makes sense not in simple, marketing appliances, but practical ones, because they do not reveal its full potential". Our respondent added that technical competences of the IT team are very valuable and hard to find. He and another CEO agreed that the business possibilities of AR technology are much bigger than current, typical ones, but they require innovativeness and creativity in their implementation. Two other respondents are much more positive about it. "Firstly, AR arouses curiosity. It shows that our client thinks about innovativeness and is up to date with new technologies. His customer's astonishment makes them look good. There are also clients who are more aware and sales oriented. For example, IKEA's AR application increased their sales. So, we have two possibilities: improving company's image and sales, although they often are combined". This correlated positively with a previous answer of other respondent concerning the increase of the sales as a result of bigger attention drawn to the promoted product. Another interviewee added that his clients use their AR applications to show a full spectrum of their offer at any place given, which would be impossible otherwise and in his opinion it must affect competitiveness. Same counts for very large products such as ships, cars and furniture, which can be presented so realistically and precisely only thanks to 3D and AR applications. "Wow effect" and impressiveness of this technology were mentioned as well. Additionally, the least tangible benefit for the client was improving their image by being identified with an innovative and impressive technology.

One of respondents is the cofounder of "tylko", a company which sells customizable furniture. Thanks to AR application it is possible to visualise a piece of furniture in your own house and basing on your preferences customize it so that it would fit perfectly and then order it online. AR application in this case is an inextricable element of whole business model and creates great value to its customers, contributing vitally to company's "tylko" competitive advantage. This was one of the main reasons it gained financial support from foreign investors.

Another example of successful implementation of AR was the project Operalab, an exhibition of competition entries held by The Polish National Opera and BMW. The core exposition was based on AR technology, which enabled to show different use-cases of each pavilion. The cofounder of “tylko” and “bridge”, the latter company being responsible for this implementation, stated that thanks to AR the image of whole project and its participants was significantly improved and it gained tangible benefits. It positioned Operalab as one of the main cultural events in Poland, widely commented by the mass media.

A different success story of AR product was a three-dimensional visualisation in AR of a “New Warsaw” car with additional, transparent information on plans of reinventing well known Polish car brand. The CEO behind this project believes that thanks to skilful implementation of new technologies, especially AR, the car gained public attention and more importantly – convinced investors into it. The first car is currently under construction.

Another case provided by another interviewee was a mobile AR application, which allows consumers to scan a label of a product in a shop. For example, after scanning a label of spaghetti packaging, it shows us what dish can we make with it, what other ingredients we should buy and then automatically adds them to our shopping list. “This opens completely new perspectives for our clients. We wanted the application to be promoting sales. This concept seems unique. It is a bridge between online and offline, merging e-commerce with brick-and-mortar shops. (...) Interestingly, brief did not mention AR, but it perfectly fits our client’s needs”. He added that this will improve not only his client’s image but also give him tangible increase in sales.

The fourth respondent could not think of a tangible situation but believes that their AR applications must be of noticeable benefit to their clients, as they often continue the cooperation, sometimes even quadrupling their orders.

5. Discussion

We interpret our results with a simple, integrated lens: AR only creates advantage when its visuals and interactivity are paired with basic complements such as clean product data, 3D assets, analytics, omnichannel IT, and trained staff. Our findings suggest that AR technology has a positive impact on company's competitive advantage. Unique features of this technology allow a company to outrun the competitors in respective fields, especially retail and marketing. Main advantages of this technology over standard solutions are intensification of user's experience, impressiveness, engaging character, ease of use and transparency of presented information. This is directly linked with increased attention towards promoted product or company, measured by one of our respondents and reported increased sales in comparison to standard solutions. Such findings are similar to the previous ones stating that attitude toward the AR app and inspiration influence brand attitude (Rauschnabel et al., 2019)

or attitude toward a product (Park, Yoo, 2020). In a head-to-head experiment, AR outperformed VR when persuasion relied on rational, information-rich appeals, whereas VR worked better for purely emotional appeals (Wu et al., 2025). Contrary to Berman's and Pollack's (2021) conclusion our study does not highlight lowering firm's expenses by AR's introduction, mainly because our cases are marketing-heavy and supplier-side. In operations and service settings, AR-based guidance and remote assistance could be where cost effects are most evident.

Table 1 captures the main advantages of AR reported in our interviews, but these remain case-specific. To generalize, we integrated our findings with prior research, highlighting how AR features translate into commercial, process, and strategic outcomes. Table 2 presents this synthesis as a broader framework of the pathways through which AR enhances competitiveness.

Table 2.

Pathways from AR features to competitiveness outcomes

AR feature / characteristic	Mechanism / usability effect	Underlying capability (RBV / DC lens)	Competitiveness outcome
Enhanced visualization & 3D spatial overlays	Clarifies product attributes; enables realistic product and environment simulation	Sensing – improves recognition and understanding of product attributes	Increased sales conversion; reduced product returns; stronger decision confidence
Customer engagement & “wow effect”	Captures and sustains consumer attention; creates novelty and emotional response	Seizing – turns attention into purchase and brand attachment	Improved brand image; stronger customer attraction; higher purchase frequency
Product customization & interactivity	Allows real-time configuration; personalizes shopping experience	Seizing – converts user input into tailored value	Greater customer satisfaction; higher willingness-to-pay; differentiation from rivals
Synergy with other technologies (VR, beacons, gesture control, IoT)	Expands functionality and immersion; supports omnichannel integration	Reconfiguring – enables integration and new workflows	New business models; enhanced omnichannel strategies; competitive edge in innovation signaling
Ease of use & transparency of information	Simplifies complex decision-making; presents data in intuitive ways	Sensing + Seizing – lowers cognitive load and improves decision accuracy	Faster purchase process; reduced cognitive load; enhanced customer loyalty
Experiential & marketing applications	Provides memorable experiences; signals innovativeness	Resource-based – builds unique and hard-to-imitate brand resource	Stronger brand equity; improved firm reputation; attraction of investors/partners
Potential in operations & services (guidance, remote assistance)	Supports training, error reduction, knowledge transfer	Reconfiguring – introduces new service routines and learning loops	Process efficiencies; lower error rates; cost reductions (future potential)

Source: Authors' elaboration based on own survey and reviewed literature.

AR helps to create a new type of experience for the customer, becoming an innovative form of experiential marketing (Haumer et al., 2020). Moreover, it was claimed that there is no other comparable solution in presenting customizable products in 3D or very large objects. Accurate 3D and spatial overlays make choices clearer and reduce user effort, which raises decision confidence. The use of AR results in improved (innovative) image of company. Another important advantage of this technology is the ability to deliver additional value to company or

a product, which in our opinion is of crucial significance, as those additional, completely novel features are what differs companies implementing AR from their competitors and what their clients may be looking for.

These findings are reinforced by recent controlled studies: Marino et al. (2024) found that AR improves assembly accuracy and reduces errors, while Treinen et al. (2024) show that AR in inspection and remote support enhances efficiency. Pitzalis et al. (2025) present a digital twin with AR interface for a gearbox assembly, using AR overlays to detect and inspect mechanical deviations in real time. Souza et al. (2025) review nineteen industrial assembly-task AR studies, documenting improvements in error reduction, operator guidance, and process alignment. Haider et al. (2025) examine advanced industrial manufacturing use cases, including spatial AR for force feedback visualization, safety alerts, and posture assessments in smart factories. In adjacent domains, Fathi et al. (2025) provide evidence from AEC and facility management operations, showing that AR/VR applications are used in maintenance, design coordination, and operation phases — giving insight into non-retail operational deployments.

In healthcare training, a randomized trial found that AR plus haptics increased student comfort and some self-rated performance measures, with a trend toward shorter procedure time (Felten et al., 2025). On the consumer side, Xu et al. (2024) confirm that interactivity and vividness drive e-commerce conversion. Together, these outcomes indicate that AR contributes to competitiveness through both revenue-enhancing and cost-reducing mechanisms, consistent with our three-horizon definition (commercial, process, and strategic).

We believe that those additional features delivered to products and services are the source of competitive advantage rendered by this technology. An example may be Google Translate, which allows consumers to instantly translate text by pointing the smartphone's camera at the text in the foreign language. It is much quicker and easier to use than standard online translators which require the user to type the translated phrase. Just those two traits are completely game-changing, as they allow not only to take over the users of competitive solutions, but also attract new users who are interested in translating text on the go (e.g. tourists), which previously was too time-consuming or uncomfortable. In the analysed case of “tylko”, AR allows the process of customizing and ordering furniture to be quicker, easier, more fun and accurate than their competitors.

The standing question is if AR will be the next disruptive technology, as defined by Christensen (1995, 2015)? It needs to be highlighted that technology is not disruptive from the very beginning. At first it is inferior in some aspects but provides some new performance attributes. With its development, it becomes disruptive, when it starts dominating the market and disrupting old technologies, products or services. We believe that AR is in the first stage of this process. It has some predispositions revealed by this study such as fun factor, visual attractiveness, convenience, synergistic effect with other emerging technologies, additional value for customer and its effectiveness. However, it is still underdeveloped on some fields to become a mass technology, both in the software and hardware field.

Compared to AR adoption drivers in the study of Martinez et al. (2014) our research confirms fun factor, curiosity and tangible 3D visualisation as positive traits of this technology leading to its popularization, but our respondents do not mention reduction of costs and fast learning curve in contrast to the mentioned article. No possible drawbacks of AR adoption were mentioned in our research. This may mean they are either insignificant or our respondents could have been biased in this matter, due to their profession as AR applications developers.

As presumed, every respondent stated that AR applications improve their clients' competitiveness because of aforementioned positive traits, which was the key issue of this research. Only one of them regards it as not significant yet (but still having undiscovered potential). This means that some companies are not yet prepared to skilfully implement this technology and it may be the reason for its partial undervaluation (in the sixth question). But it is claimed to be a matter of time. Our interviewees' clients are also becoming more aware of AR's potential. This finding corresponds with other authors' conclusion that sole technology is not enough to create competitive advantage and other factors are needed, such as organizational skills as underlined in dynamic capabilities theory, as well as ability to create value innovation (Mauborgne, Chan Kim, 2007). Our study results confirm the outcomes of Spreer et al. (2012) that AR influences positively user satisfaction and is helpful in information presentation. Moreover, Zabel (2024) demonstrates that AR technologies can strengthen dynamic capabilities—sensing, seizing, and reconfiguring—thus reinforcing the theoretical claim that AR, when properly embedded, can be a source of sustained competitive advantage.

Interestingly, AR-implementing companies had specific business-oriented aims for AR applications, which was increasing the sales by promoting the company or its product and (to a lesser extent) delivering additional value to their products and services. This contrasts with two responses that companies view AR mainly as an innovative gadget and addition to other company's undertakings. The reason behind those opinions may be higher cost of such applications which limits their usage and the fact that their scope is limited to certain group of customers. Additionally, we observed that visualising information with AR was an often-cited purpose chose only by non-commercial clients like museums or art projects. Research shows AR's excellent capability of improving visitors' immersive experiences in this sector (Allal-Cherif, 2022). However, recent studies caution that AR's novelty effects may erode with repeated exposure, reducing consumer responses over time (Söderström et al., 2024).

Despite claims of increasing industrial application of AR (e.g., Jetter et al., 2018) we were not able to confirm it. However, our findings confirm previous research (e.g., Gervautz, Schmalstieg, 2012; Martinez et al., 2014) which identified retail and marketing as one the five most popular fields of AR applications. Surprisingly, our findings almost completely omit other four areas. We believe that the lower cost and risk of implementing AR in this industry, as well as tangible benefits like increased sales, may be contributing factors, as well as the growing number of visible success stories and relative ease of implementation. On the other hand, other areas of implementation of this technology are much more demanding in the context of above-

mentioned terms and connected with pioneering costs (Porter, 1985) but may be more profitable. This suggests a potential niche for innovators, as these areas are likely to be explored next. Our study confirms Rauschnabel et al.'s (2018) findings that companies may still lack the know-how concerning AR's implementation in a specific branch. Surprisingly, our respondents did not mention AR application in the healthcare and fitness sectors, despite claims concerning its benefits for businesses and patients (consumers) (e.g., Parekh et al., 2020). This gap reflects our sampling and vantage point; the strongest and most durable effects should surface in assembly, inspection, and service where procedural guidance and remote help are core work.

AR is a part of third wave of IT-driven transformation: Internet of Things and "smart, connected products" (Porter and Heppelmann, 2014, 2015 and 2017). Similarly to AR, Internet of Things allows merging real and virtual words. According to the authors it will transform the competition and companies, especially in the field of manufacturing, but also the services. Smart, connected products reshape almost every function in company's value chain, including product development, IT, manufacturing, logistics, marketing, sales, and after-sale service. Our conclusion is coherent with claims of Porter and Heppelmann (2015) who predict that AR will be a great improvement in terms of efficiency and effectiveness of services e.g., when AR overlays are used to provide step-by-step repair instructions to the technician in the after sale service.

Our study makes three main contributions. First, it shifts the focus from consumer acceptance of AR to firm-level competitiveness, showing how AR applications create tangible commercial, process, and strategic outcomes. Second, it connects AR's core media characteristics with resource-based and dynamic capabilities perspectives, explaining how interactivity, visualization, and data overlay become sources of advantage when embedded in firm processes. Third, it identifies boundary conditions by demonstrating that AR effects are strongest when products are tangible or complex, when firms possess complementary technological readiness, and when industry contexts support omnichannel or experiential strategies.

6. Conclusions

Our findings confirm that AR can increase the competitiveness of an enterprise which employs it. The purpose of this article was to show in what way AR may influence company's competitiveness. The findings point that companies use AR mainly as a marketing tool, mainly to improve their sales or in order to upgrade their products or services to outrun their rivals. This technology proved to have numerous advantages over standard solutions in respective fields. Due to better spatial presentation and tangible 3D visualization it helps to project and then present large objects like buildings or ships to clients. AR renders a competitive advantage

in the presentation of data and introducing new sales methods to companies. Moreover, AR enables new business models which could not be implemented without it, e.g. an AR application allowing to sell customizable furniture on the internet, which is intuitive, fast, accurate and fun. One should be aware that a broader study may show other ways in which AR can improve the competitiveness of enterprises.

7. Limitations and Future Research

This study has several important limitations that should be acknowledged. The interviews were conducted with managers of AR development companies rather than with the adopting firms themselves. This supplier-side perspective offers breadth across industries but carries the risk of optimism bias and partial knowledge of client performance. The study also did not include objective performance indicators such as conversion rates, product return rates, or cost savings, and therefore relies on perceived outcomes reported by interviewees. The small sample of four Polish AR developers further limits generalizability, especially because the cases were concentrated in retail and marketing contexts. Another limitation is the positive skew of responses: none of the participants described unsuccessful projects or client dissatisfaction, which may reflect selection effects, social desirability bias, or the commercial interests of the interviewees. Finally, the findings are situated in a technological environment that is still evolving, and they may not fully apply once AR hardware and software reach greater maturity and standardization.

Future research can address these limitations in several ways. Studies should investigate the perspectives of adopting firms directly and complement qualitative interviews with objective key performance indicators such as sales uplift, error reduction, or cost-to-serve improvements. Research in additional industries such as manufacturing, logistics, healthcare, and education would clarify where AR generates the most significant competitiveness effects. Longitudinal studies could follow firms before and after implementation to test whether benefits persist, fade with novelty, or intensify as integration deepens. Experimental and survey research could examine boundary conditions, for example the role of product tangibility, firm readiness, or industry context, and could also test the durability of the “wow effect” over time. Further work is also needed to explore how AR interacts with other technologies such as the Internet of Things, artificial intelligence, or virtual reality to create synergistic competitiveness outcomes. Finally, future studies should investigate how AR enables entirely new value propositions and revenue models rather than only enhancing marketing or product presentation.

References

1. Adapa, K., Jain, S., Kanwar, R., Zaman, T., Taneja, T., Walker, J., Mazur, L. (2020). Augmented reality in patient education and health literacy: a scoping review protocol. *BMJ Open*, 10(9), e038416. doi: 10.1136/bmjopen-2020-038416. PMID: 32938599; PMCID: PMC7497551
2. Allal-Chérif, O. (2022). Intelligent cathedrals: Using augmented reality, virtual reality, and artificial intelligence to provide an intense cultural, historical, and religious visitor experience. *Technological Forecasting and Social Change*, 178(March). <https://doi.org/10.1016/j.techfore.2022.121604>
3. Ansoff, H.I. (1975). Managing Strategic Surprise by Response to Weak Signals. *California Management Review*, Vol. 18, No. 2.
4. Batat, W. (2021). How augmented reality (AR) is transforming the restaurant sector: Investigating the impact of “Le Petit Chef” on customers’ dining experiences. *Technological Forecasting and Social Change*, 172(November 2020), 121013. <https://doi.org/10.1016/j.techfore.2021.121013>
5. Berman, B., Pollack, D. (2021). Strategies for the successful implementation of augmented reality. *Business Horizons*, 64(5), 621-630. <https://doi.org/10.1016/j.bushor.2021.02.027>
6. Blazquez Cano, M. (2014). Fashion shopping in multichannel retail: the role of technology in enhancing customer experience. *International Journal of Electronic Commerce*, 18(4), 97-116.
7. Bower, J., Christensen, C. (1995). Disruptive Technologies: Catching the Wave. *Harvard Business Review*, Vol. 73, No. 1, pp. 43-53.
8. Bulearca, M., Tamarjan, D. (2010). Augmented Reality: A Sustainable Marketing Tool? *Global Business and Management Research*, Vol. 2, No. 2/3, pp. 237-252.
9. Čiutienė, R., Thattakath, E. (2014). Influence of Dynamic Capabilities in Creating Disruptive Innovation. *Economics and Business*, Vol. 26, pp. 15-21.
10. Dacko, S.G. (2017). Technological Forecasting & Social Change Enabling Smart Retail Settings via Mobile Augmented Reality Shopping Apps. *Technological Forecasting & Social Change*, 124. Elsevier Inc., 243-56. doi:10.1016/j.techfore.2016.09.032
11. Degryse, H., Di Giuli, A., Sekerci, N., Stradi, F. (2024). The Effects of Hype and Social Preferences on Crypto Investing. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4589810>
12. Eckert, M., Volmerg, J.S., Friedrich, C.M. (2019). Augmented Reality in Medicine: Systematic and Bibliographic Review. *JMIR Mhealth and Uhealth*, 7(4), e10967. doi: 10.2196/10967. PMID: 31025950; PMCID: PMC6658230.
13. Eisenhardt, K., Martin, J. (2000). Dynamic Capabilities: What Are They? *Strategic Management Journal*, Vol. 21, No. 10/11, p. 1105.

14. Eisenhardt, K.M. (1989). Building theories from case study research. *Academy of Management Review*, Vol. 14, No. 4, pp. 532-550.
15. Erickson, T., Magee, J., Roussel, P., Saad, K. (1990). Managing Technology as a Business Strategy. *Sloan Management Review*, Vol. 31, No. 3, pp. 73-78.
16. Fathi, S., Sabeti, S., Shoghli, O., Heydarian, A., Balali, V. (2025). Adoption of virtual and augmented reality in the architecture, engineering, construction, and facilities management (AEC-FM) industries: Mixed-method analysis of trends, gaps, and solutions. *Frontiers in Built Environment*, 11, Article 1580639. <https://doi.org/10.3389/fbuil.2025.1580639>
17. Felten, R., Bigaut, K., Wirth, T., Kremer, L., Gauer, L., Arnold, C., Ollivier, I., Godet, J., Scherlinger, M., Dubois, M., Sebbag, E., De Sèze, J., Gottenberg, J.E. (2025). Advancing medical training with augmented reality and haptic feedback simulator: outcomes of a randomized controlled trial on lumbar puncture. *BMC Medical Education*, 25(1). <https://doi.org/10.1186/s12909-025-07536-6>
18. Gervautz, M., Schmalstieg, D. (2012). Anywhere interfaces using handheld augmented reality. *IEEE Computer*, 45(7), 26-31.
19. Grant, R.M. (1991). The Resource-based Theory of Competitive Advantage: Implications for Strategy Formulation. *California Management Review*, Vol. 33, No. 3.
20. Grzegorzczak, T., Sliwinski, R., Kaczmarek, J. (2019). Attractiveness of augmented reality to consumers. *Technology Analysis and Strategic Management*, 1-13. <https://doi.org/10.1080/09537325.2019.1603368>
21. Haider, M. (2025). Applications of Augmented Reality in Industrial Manufacturing. *International Journal of Engineering and Advanced Production (IJEAP)*, 7(1), 45-52. <https://ijeap.org/ijeap/article/view/225>
22. Hamel, G., Prahalad, C. (1994). Competing for the Future. *Harvard Business Review*, Vol. 72, No. 4, p. 122.
23. Haumer, F., Kolo, C., Reiners, S. (2020). The impact of augmented reality experiential marketing on brand equity and buying intention. *Journal of Brand Strategy*, 8(4), 368-387.
24. Hidding, G.J., Williams, J.R. (2003). Are there First-Mover Advantages in B2B eCommerce Technologies? *Proceedings of the 36th Hawaii International Conference on System Sciences (HICSS'03)*, Vol. 7, January 6-9, 2003.
25. Javornik, A. (2016). Augmented Reality: Research agenda for studying impact of its media characteristics on consumer behaviour. *Journal of Retailing and Consumer Services*, 30, 252-261.
26. Javornik, A., Duffy, K., Rokka, J., Scholz, J., Nobbs, K., Motala, A., Goldenberg, A. (2021). Strategic approaches to augmented reality deployment by luxury brands. *Journal of Business Research*, 136(November), 284-292. <https://doi.org/10.1016/j.jbusres.2021.07.040>
27. Lawson, J., Martin, G., Guha, P., Gold, M., Nimer, A., Syed, S., Kinross, J. (2023). Effect of Mixed Reality on Delivery of Emergency Medical Care in a Simulated

- Environment A Pilot Randomized Crossover Trial. *JAMA Network Open*, 6(8), 1-10. <https://doi.org/10.1001/jamanetworkopen.2023.30338>
28. LeCompte, M., Preissle, J. (1993). *Ethnography and qualitative design in educational research*, 2nd ed. San Diego, Cal.: Academic Press.
 29. Marino, E., Barbieri, L., Bruno, F., Muzzupappa, M. (2024). Assessing user performance in augmented reality assembly guidance for industry 4.0 operators. *Computers in Industry*, 157-158(March), 104085. <https://doi.org/10.1016/j.compind.2024.104085>
 30. Martínez, H., Skournetou, D., Hyppölä, J., Laukkanen, S., Heikkilä, A. (2014). Drivers and Bottlenecks in the Adoption of Augmented Reality Applications. *Journal on Multimedia Theory and Applications*, Vol. 1.
 31. Maxwell, J.A. (2005). *Qualitative research design: An interactive approach*, 2nd ed., Thousand Oaks, CA: SAGE Publications.
 32. Medcof, J.W. (2000). The Resource-Based View And Transnational Technology Strategy. *Journal Of High Technology Management Research*, Vol. 11, No. 1, p. 59.
 33. Méndez, G.M., Velázquez, F. del C. (2024). Impact of Augmented Reality on Assistance and Training in Industry 4.0: Qualitative Evaluation and Meta-Analysis. *Applied Sciences*, 14. <https://doi.org/10.3390/app14114564>
 34. Merriam, S.B. (1998). *Qualitative Research and Case Studies Applications in Education*. San Francisco: Jossey-Bass Publications.
 35. Nikodemaska-Wołowik, A.M. (2008). *Klucz do zrozumienia nabywcy, Jakościowe badania marketingowe*. Warszawa: Grupa Verde.
 36. Olsson, T., Salo, M. (2011). *Online User Survey on Current Mobile Augmented Reality Applications*. 10TH IEEE International Symposium on mixed and augmented reality (ISMAR). 26-29 October, Basel, Switzerland.
 37. Parekh, P., Patel, S., Patel, N. et al. (2020). Systematic review and meta-analysis of augmented reality in medicine, retail, and games. *Visual Computing for Industry, Biomedicine and Art*, 3, 21. <https://doi.org/10.1186/s42492-020-00057-7>
 38. Patton, M.Q. (1990). *Qualitative evaluation and research methods*, 2nd ed., Newbury Park: Sage.
 39. Pitzalis, R.F., Giordano, A., Di Spigno, A., Cowell, A., Niculita, O., Berselli, G. (2025). Application of augmented reality-based digital twin approaches: a case study to industrial equipment. *International Journal of Advanced Manufacturing Technology*, 138(7), 3747-3763. <https://doi.org/10.1007/s00170-025-15755-w>
 40. Porter, M., Heppelmann, J. (2014). How Smart, Connected Products Are Transforming Competition. *Harvard Business Review*, Vol. 92, No. 11, pp. 64-88.
 41. Porter, M., Millar, V. (1985). How information gives you competitive advantage. *Harvard Business Review*, Vol. 63, No. 4, pp. 149-160.
 42. Porter, M.E. (1985). Technology and Competitive Advantage. *Journal Of Business Strategy*, Vol. 5, No. 3, p. 60.

43. Porter, M.E. (1990). The Competitive Advantage of Nations. (cover story). *Harvard Business Review*, Vol. 68, No. 2, pp. 73-93.
44. Porter, M.E. (1985). *Competitive advantage: creating and sustaining superior performance*. New York: Free Press.
45. Ramakrishna, V., Srivastava, S., White, J., Rajput, N., Srivastava, K., Bhattacharya, S., Chaudhary, Y. (2013). *An un-tethered mobile shopping experience*. *International Conference on Mobile and Ubiquitous Systems: Computing, Networking, and Services*. Springer International Publishing, pp. 409-421 (December).
46. Rauschnabel, P.A., Babin, B.J., Dieck, M.C., Krey, N., Jung, T. (2022). What is augmented reality marketing? Its definition, complexity, and future. *Journal of Business Research*, 142, 1140-1150. <https://doi.org/10.1016/j.jbusres.2021.12.084>
47. Rese, A., Baier, D., Geyer-Schulz, A., Schreiber, S., (2017). How Augmented Reality Apps Are Accepted by Consumers: A Comparative Analysis Using Scales and Opinions. *Technological Forecasting and Social Change*, 124. Elsevier Inc., 306-19. doi:10.1016/j.techfore.2016.10.010
48. Rogers, E.M. (1995). *Diffusion of innovations*. New York: Free Press.
49. Scholz, J., Smith, A.N. (2016). Augmented Reality: Designing Immersive Experiences That Maximize Consumer Engagement. *Business Horizons*, 59(2). Kelley School of Business, Indiana University, 149-61. doi:10.1016/j.bushor.2015.10.003
50. Söderström, C., Mikalef, P., Dypvik Landmark, A., Gupta, S. (2024). Augmented reality (AR) marketing and consumer responses: A study of cue-utilization and habituation. *Journal of Business Research*, 182(July). <https://doi.org/10.1016/j.jbusres.2024.114813>
51. Souza, B.J. (2025). *Towards an integration of augmented reality in industrial assembly tasks*. *Procedia Manufacturing*, (Review) — identifies AR types, methods, and limitations in industrial assembly contexts. <https://www.sciencedirect.com/science/article/pii/S1877050925001760>
52. Spreer, P., Kallweit, K., Gutknecht, K., Toporowski, W. (2012). Augmented Reality – Digital erweiterte Realität im stationären Handel. *Marketing Review St. Gallen*, Vol. 29, No. 5, pp. 28-33.
53. Stalk, G., Evans, P., Shulman E. (1992). Competing on Capabilities: The New Rules of Corporate Strategy. *Harvard Business Review*, March-April.
54. Teece, D.J., Pisano, G., Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, Vol. 18, No. 7, pp. 509-533.
55. Treinen, T., Kolla, S.S.V.K. (2024). Augmented Reality for Quality Inspection, Assembly and Remote Assistance in Manufacturing. *Procedia Computer Science*, 232, 533-543. <https://doi.org/10.1016/j.procs.2024.01.053>
56. Tseng-Lung, H., Shuling, L. (2015). A model of acceptance of augmented-reality interactive technology: the moderating role of cognitive innovativeness. *Electron Commer. Res.*, 15, 269-296.

57. Wojciechowski, R., Cellary, W. (2013). Evaluation of learners' attitude toward learning in ARIES augmented reality environments. *Computers and Education*, 62, 570-585.
58. Wu, J.F., Zhang, Z., Wu, Y., Tang, X.J. (2025). The effectiveness of immersive media in promoting consumer Products: Augmented vs. virtual reality. *Journal of Retailing and Consumer Services*, 86(May), 104323. <https://doi.org/10.1016/j.jretconser.2025.104323>
59. Xu, X.Y., Jia, Q.D., Tayyab, S.M. (2024). Exploring the stimulating role of augmented reality features in E-commerce: A three-staged hybrid approach. *Journal of Retailing and Consumer Services*, 77, 103682.
60. Yin, R.K. (2013). *Case study research, design and methods*, 3rd ed. Newbury Park: Sage Publications.
61. Zabel, C., O'Brien, D. (2024). Understanding dynamic capabilities in emerging technology markets: antecedents, sequential nature, and impact on innovation performance in the extended reality industry. *European Journal of Innovation Management*, 27(9), 305-336. <https://doi.org/10.1108/EJIM-07-2023-0574>

ECOLOGICAL AWARENESS AS A DETERMINANT OF EFFECTIVE WASTE MANAGEMENT IN CITIES

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Purpose: This paper addresses the persistent gap between ambitious waste management targets and insufficient practical progress in Poland and other EU Member States. The study explores how ecological awareness influences the effectiveness of municipal waste management, focusing on its treatment in key strategic documents such as KPGO 2028, CEAP, and selected EU directives.

Design/methodology/approach: The research uses qualitative document analysis of national and EU policy texts. Key elements analyzed include references to ecological awareness, education, communication, financing, monitoring, and implementation mechanisms. Content was analyzed according to key categories to identify goals, recommended actions, measurable indicators, and institutional responsibilities, enabling a comparative assessment of policy declarations and practical implementation.

Findings: Ecological awareness is recognized as important in both Polish and EU documents, but practical application is limited. Gaps include the absence of measurable indicators, unstable funding for educational programs, and weak coordination between central and local authorities. Monitoring data show Poland's recycling rates (41% in 2022) lag behind the EU average (49%), illustrating the implementation gap.

Research limitations/implications: The study relies on secondary data and does not include primary empirical research such as surveys or interviews. Methodological changes in reporting waste indicators limit comparability over time. Future research could include behavioral studies or surveys to assess awareness campaigns' effectiveness.

Practical implications: Policymakers should operationalize ecological awareness through measurable indicators, ensure stable financing for education campaigns, and integrate awareness initiatives with infrastructure improvements. These measures can enhance municipal waste management effectiveness.

Social implications: Raising ecological awareness promotes pro-environmental behavior, supports sustainable urban development, and fosters collective responsibility, contributing to improved quality of life and environmental protection.

Originality/value: The paper offers a comparative analysis of national and EU policy documents, highlighting the gap between declarations and implementation. It provides practical recommendations for policymakers, municipal managers, and stakeholders aiming to improve waste management outcomes.

Keywords: ecological awareness; waste management; sustainable development; EU policy; municipal waste.

Category of the paper: research paper.

1. Introduction

Municipal waste management remains a major challenge in contemporary urban policy, directly contributing to environmental degradation and affecting the quality of life in cities. The growing volume of municipal waste highlights the need for efficient strategies focused not only on technical and regulatory solutions but also on strengthening public ecological awareness.

Building ecological awareness plays a key role in fostering environmental responsibility and encouraging everyday pro-environmental behaviors. Limited environmental consciousness among citizens is often cited as one of the key barriers to achieving sustainable, zero-waste urban environments. Therefore, effective environmental policy instruments should not rely solely on regulation and enforcement but must incorporate educational and motivational measures to support behavioral change.

Ecological awareness thus emerges as a crucial determinant of effective municipal waste management, influencing both individual behaviors and the success of systemic transformations. Understanding what shapes ecological awareness in urban contexts is essential for designing policies that genuinely support the transition toward more sustainable and circular cities.

The main aim of this study is to investigate how ecological awareness is integrated into municipal waste management strategies in Poland and the European Union. The paper seeks to identify whether strategic policy frameworks, include measurable indicators, financing mechanisms, and evaluation tools that effectively operationalize ecological awareness.

The following research hypotheses are proposed:

- H1: Ecological awareness is insufficiently operationalized in Polish and EU waste management policies.
- H2: The lack of measurable indicators and stable financing reduces the practical effectiveness of awareness-raising initiatives.

This study is original in its comparative approach—linking the National Waste Management Plan 2028 (KPGO 2028) with the Circular Economy Action Plan (CEAP) and relevant EU directives. By focusing on the intersection between awareness, education, and implementation, the paper contributes to bridging the gap between declarative policy goals and operational practice.

2. Theoretical Background

Consciousness, understood as the capacity to integrate cognitive, emotional, and reflective processes, has been the subject of inquiry in numerous scientific disciplines (Nęcka et al., 2006). In an environmental context, environmental awareness is most commonly defined as a set of knowledge, beliefs, attitudes, and dispositions held by individuals and societies toward the natural environment (Zuzek, 2017). In the literature, two complementary approaches to its analysis are typically distinguished: the cognitive–informational perspective, focused on knowledge and factual awareness, and the socio-psychological perspective, emphasizing values, emotions, and social norms shaping the human–nature relationship (Papuziński, 2006; Górka et al., 1998; Penc, 2003).

From these approaches, a three-dimensional model of environmental awareness can be derived, encompassing: (1) the cognitive component (knowledge and beliefs), (2) the affective component (values and emotional engagement), and (3) the behavioral readiness component (willingness and capacity to act). Research on household recycling and waste-related behaviors often draws on related constructs such as the KAP model (Knowledge–Attitude–Practice) and behavioral theories like the Theory of Planned Behavior (Ajzen, 1991), which highlight that knowledge alone does not automatically lead to pro-environmental actions (Barr, 2007; Knussen et al., 2004; Tonglet et al., 2004).

Empirical studies indicate that environmental awareness interacts with structural and instrumental factors. The availability of infrastructure, reliability of services, economic incentives, and clarity of communication all condition the extent to which awareness translates into waste sorting and reduction practices (Afroz et al., 2010; Gwarda, 2019; Mihai, 2012). Therefore, effective environmental policy should combine informational measures with enabling conditions—such as accessible collection systems, feedback mechanisms, and financial stimuli—to bridge the widely observed “knowledge–action gap” in urban contexts (Schultz, 2014; Szalewska, 2021).

Recent European and international policy documents also emphasize this conclusion, framing awareness as a policy variable that should be systematically monitored and incorporated into implementation systems. The European Commission’s Circular Economy Action Plan (CEAP) stresses the need to link standardized collection systems with community engagement initiatives, while the European Environment Agency highlights differences in social participation among member states and calls for improved monitoring of behavioral outcomes (EC, 2020; EEA, 2023, 2024). Likewise, the OECD’s Environmental Performance Reviews for Poland recommend that behavioral and awareness components be operationalized through measurable indicators and regularly assessed within national waste management strategies (OECD, 2022).

Integrating these theoretical and policy perspectives suggests a practical research agenda: environmental awareness should be treated not merely as an educational or normative goal but as an operational variable, measurable through surveys (KAP), behavioral indicators (e.g., sorting accuracy, participation rates), and process metrics (e.g., campaign reach, funding continuity). Such an integrated approach links environmental awareness directly to infrastructure and governance mechanisms, forming the conceptual foundation for the document analysis conducted in this study.

3. Research methodology

The aim of the study was to identify how selected key strategic documents concerning waste management in Poland address the concept of ecological awareness, what instruments they recommend for its development, and to assess whether and to what extent strategic declarations are supported by measurable targets, financing mechanisms, and monitoring of outcomes.

The analysis focused on the most relevant acts and reports concerning waste management:

1. National Waste Management Plan 2028 - KPGO 2028 (ISAP, 2023).
2. Circular Economy Action Plan - CEAP (EC, 2020).
3. EU waste guidelines and directives (regarding obligations for separate waste collection and recycling targets).

These documents were selected because they represent the main strategic levels of waste management governance — from national implementation to EU-level coordination.

A qualitative document analysis method was applied, including:

- systematic keyword searches within the documents for the terms: education, communication, awareness, campaign, monitoring, indicator, financing,
- coding of extracted fragments according to the following categories: presence of the topic of awareness, forms of recommended actions, existence of measurable goals related to awareness, indications concerning financing and institutional responsibility,
- comparative synthesis of results between national and EU-level documents.

The keywords were selected because they reflect the key conceptual dimensions of ecological awareness: cognitive (knowledge), affective (attitudes), and behavioural (actions).

The comparison between documents was guided by three criteria: the presence of measurable indicators of ecological awareness, the existence of financing and implementation mechanisms, the degree of integration between education, infrastructure, and monitoring.

Data were coded according to these categories, enabling a comparative synthesis of declarative and operational content.

The analysis was based exclusively on secondary sources (strategic texts and monitoring publications) and did not include primary empirical data (e.g., interviews with officials or resident surveys).

It should be noted that many indicators in national sources have undergone methodological changes in recent years (for example, the method of calculating recycling rates in Poland), which hinders direct year-to-year comparisons. Moreover, strategic documents often formulate only general goals; therefore, the analysis pays particular attention to elements of operationalization—that is, whether the documents specify concrete KPIs or implementation mechanisms.

4. Research results

The content analysis of the National Waste Management Plan 2028 (ISAP, 2023) and key European Union strategic documents, including the CEAP (EC, 2020) and EU waste directives, indicates that environmental awareness is recognized as a crucial component of effective waste management policy.

In KPGO 2028, educational and informational activities are identified as important instruments supporting the improvement of the quality of separate waste collection and the reduction of illegal dumping sites. Similarly, EU documents emphasize the need to support local initiatives, standardize communication, and improve the quality of waste streams, assuming that these efforts will be reinforced through increased public engagement (EC, 2020; EEA, 2023).

A comparison of how the concept of environmental awareness is addressed across the analyzed documents is presented in Table 1. As the comparison shows, all examined documents acknowledge the importance of environmental education and communication; however, none of them define precise indicators to measure the effectiveness of these activities.

Table 1.
Comparison of the approaches to the concept of environmental awareness in selected strategic documents

Document	KPGO 2028	Circular Economy Action Plan (CEAP)	Waste Directives / EU Guidelines
Reference to the role of education or communication	Yes — indications regarding information and educational activities aimed at the public and producers.	A clear emphasis on the need to support Member States in raising awareness, standardizing communication, and improving the quality of separate collection.	The directives emphasize systemic obligations (separate collection, recycling targets), highlighting the role of local authorities in implementing communication and infrastructure.

Cont. table 1.

Specific, measurable goals related to awareness	None (no clear KPIs regarding knowledge or attitudes). KPGO operationalizes goals mainly at the level of waste streams, not awareness.	CEAP stresses the need to monitor the quality of collection and standards but does not impose explicit indicators of citizens awareness.	The directives require monitoring of waste management results (e.g., % recycling) but do not define indicators of social knowledge or attitudes.
Financing of educational activities	Possible sources mentioned (national/ EU funds), but no dedicated financing mechanism.	CEAP indicates support mechanisms (EU programs) — general support frameworks.	Financial instruments depend on national implementation; the directives do not define a direct budget for education.
Recommended operational actions	Campaigns, school education, support for local initiatives, development of infrastructure for separate collection.	Standardization of separate collection quality, support for pilot projects, development of EPR (Extended Producer Responsibility).	Requirements for separate collection and recycling targets, emphasis on the responsibility of local authorities for implementation.

Source: Own elaboration based on ISAP. (2023). Krajowy plan gospodarki odpadami 2028 (KPGO 2028). Warsaw: Ministry of Climate and Environment. European Commission. (2020). Circular Economy Action Plan: For a cleaner and more competitive Europe. Brussels: European Union, European Environment Agency (EEA). (2023). Municipal waste management in Europe: 2023 country profiles, European Environment Agency (EEA). (2024). Progress towards waste recycling targets in the EU.

The analysis of the data presented in Table 1 indicates that the National Waste Management Plan 2028 (KPGO 2028) treats education as a so-called ‘soft measure’, while the Circular Economy Action Plan (CEAP) emphasizes the need to standardize the quality of separate waste collection and to strengthen support instruments for the member states. However, none of the documents specify measurable indicators related to citizens’ knowledge or attitudes, which makes it difficult to monitor the effectiveness of the implemented initiatives.

Quantitative data on the effectiveness of waste management in Poland and the European Union are presented in Table 2.

Table 2.

Waste Management Indicators: Poland vs. the European Union (Selected Years)

Indicator (year)	Poland	European Union (average)
Share of preparation for reuse and recycling of municipal waste (2022)	41% — increase after a period of stagnation	48-49% (2022/2023); upward trend (48% in 2023)
Recycling rate (new calculation method) (2021)	26% (based on the new national calculation method and audit data)	48% (stable growth in recent years)
Generation of municipal waste per capita (2023)	357 kg per person (2023) regionally diversified values; moderately increasing trend	511 kg per person (2023)
Risk of failing to meet the 2035 target (landfilling $\leq 10\%$)	Poland identified as a country at risk of non-compliance	Several Member States also at risk; CEAP recommends intensifying actions

Source: Own elaboration based on European Environment Agency (2023); European Commission (2024); Eurostat (2024); Najwyższa Izba Kontroli (2023).

As shown in Table 2, in 2022 the level of preparation for reuse and recycling of municipal waste in Poland was approximately 41%, while the average for the European Union ranged between 48-49% (EEA, 2023; Eurostat, 2024). Despite the observed increase in this indicator in recent years, Poland still remains below the EU average. Moreover, according to the assessment of the European Environment Agency, Poland has been identified as one of the countries at risk of failing to meet the target of reducing municipal waste landfilling to $\leq 10\%$ by 2035 (EEA, 2023).

Audit reports (NIK, 2023; EEA, 2024) clearly show a gap between what is declared in strategies and what is actually implemented. The causes of this inconsistency can be attributed to several key, interrelated factors:

- lack of operationalization of the concept of environmental awareness. Although strategic documents acknowledge the need for environmental education, they lack precise indicators of its effectiveness, such as the level of citizens' knowledge, attitudes toward waste separation, or sorting accuracy indicators. Consequently, it is impossible to clearly link educational activities with recycling outcomes (NIK, 2023);
- unstable and insufficient funding of educational activities. The National Waste Management Plan 2028 refers to the possibility of using national and EU funds, but it does not provide a dedicated financing mechanism for environmental education. Audit reports indicate that educational campaigns are often implemented incidentally or as short-term projects, which limits their durability and scale of impact (NIK, 2023);
- both EU and national documents assign a significant role to local authorities in implementing actions. However, coordination, technical guidance, and financial support from the central level are often insufficient. Municipalities are required to implement solutions without adequate infrastructure and informational support, which weakens the educational effect. Even when awareness increases, the lack of convenient infrastructure (collection points, containers, bio-waste options) limits real behavioral changes (EEA, 2023);
- methodological and interpretative variability of data. Frequent modifications in reporting procedures, including changes in the calculation methods for the recycling rate since 2020, create difficulties in interpreting trends and hinder data comparability over time (Eurostat, 2024).

In summary, the findings confirm that environmental awareness is a key component in achieving circular economy objectives. At the same time, the lack of its clear operationalization and integration with the system of indicators limits the effectiveness of both national and EU waste management policies. Future research should focus on developing measurable indicators of environmental awareness that would enable a quantitative assessment of the impact of educational activities on waste management outcomes (NIK, 2023; EEA, 2024; Eurostat, 2024).

The results demonstrate that while ecological awareness is acknowledged in all analyzed documents, it remains weakly operationalized. None of the documents define measurable indicators, and the financial mechanisms for education are either general or absent.

5. Discussion

The findings indicate that ecological awareness continues to function primarily as a declarative rather than an operational element within waste management strategies. This observation corresponds with previous studies that have identified a persistent “policy–practice gap” in environmental governance (OECD, 2022; EEA, 2023).

The lack of clearly defined and measurable indicators of environmental awareness limits policymakers’ ability to evaluate the actual behavioural outcomes of educational and communication initiatives. Furthermore, inconsistent funding and weak coordination between central and local authorities impede the long-term continuity and effectiveness of awareness programs.

From a theoretical standpoint, these findings reinforce behavioural models of environmental action (Ajzen, 1991; Schultz, 2014), which underscore the interdependence between attitudes, perceived behavioural control, and supportive infrastructural conditions. Incorporating behavioural insights into waste management policies could enhance citizen participation and improve the overall efficiency of waste sorting and recycling processes.

At a practical level, the results suggest that municipal authorities should integrate awareness-related metrics—such as knowledge, attitudes, and practice (KAP) surveys or other behavioural indicators—into their monitoring frameworks, while linking educational initiatives with concrete incentives and infrastructural improvements to ensure lasting behavioural change.

6. Conclusions

The conducted analysis confirms that ecological awareness constitutes a fundamental determinant of effective municipal waste management and a key prerequisite for achieving the objectives of a circular economy. Both Polish and EU strategic documents—such as the *National Waste Management Plan 2028* (KPGO 2028), the *Circular Economy Action Plan* (CEAP), and EU waste directives—recognize the importance of environmental education and public engagement. However, these commitments remain largely declarative, as they lack measurable indicators, dedicated financing mechanisms, and consistent monitoring systems. The persistent gap between strategic declarations and implementation outcomes indicates that

ecological awareness is not sufficiently embedded within policy frameworks. The absence of clear key performance indicators (KPIs) concerning citizens' knowledge, attitudes, and behaviors makes it difficult to assess the real impact of educational and communication initiatives on recycling rates or waste reduction. Moreover, unstable, project-based financing weakens the continuity and effectiveness of awareness campaigns, while limited coordination between national and local authorities undermines the long-term integration of educational, infrastructural, and regulatory measures.

Strengthening the role of ecological awareness in waste management requires going beyond general declarations and developing measurable, practical frameworks. This includes the development of standardized indicators of ecological awareness, systematic evaluation of educational programs, and the integration of behavioral insights into policy design. Stable financial support and stronger cooperation between central and local authorities are also essential to ensure that awareness translates into sustained behavioral change and improved waste management outcomes. Promoting ecological awareness is not only an educational challenge but also a governance issue, requiring coherence between communication strategies, infrastructure development, and economic instruments. By embedding ecological awareness into measurable, well-financed, and coordinated policy actions, cities can accelerate the transition toward sustainable urban systems—enhancing both environmental quality and the quality of life of urban residents.

This study highlights the crucial yet still underutilized role of environmental awareness in the municipal waste management system. A comparative analysis of Polish and European Union strategic documents indicates that, although the importance of public engagement in this area is widely acknowledged, its practical implementation remains limited.

The research is based exclusively on secondary sources, without the use of primary data derived from surveys or interviews. Therefore, future studies are recommended to focus on empirically measuring citizens' environmental awareness and assessing the effectiveness of specific educational and communication interventions.

The article argues that the development of measurable indicators of environmental awareness and the integration of behavioral components into waste management policies are essential to translate declarative environmental consciousness into tangible outcomes in waste management practices. Moreover, the need is emphasized for the creation of standardized measurement tools, the establishment of stable mechanisms for financing environmental education, and the strengthening of cooperation between local and national stakeholders.

Future research should incorporate quantitative analyses of pro-environmental behaviors and long-term evaluations of educational campaigns aimed at fostering sustained public awareness in the field of municipal waste management.

References

1. Afroz, R., Hanaki, K., Tudin, R. (2010). Factors affecting waste generation: A study in a waste management program in Dhaka City, Bangladesh. *Environmental Monitoring and Assessment*, 179(1-4), 509-519.
2. Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179-211.
3. Barr, S. (2007). Factors influencing environmental attitudes and behaviors: A U.K. case study of household waste management. *Environment and Behavior*, 39(4), 435-473.
4. EC (2020). *Circular Economy Action Plan: For a cleaner and more competitive Europe*. Brussels: European Union.
5. EEA (2023). *Municipal waste management in Europe: 2023 country profiles*.
6. EEA (2024). *Progress towards waste recycling targets in the EU*.
7. Eurostat (2024). *Waste statistics – municipal waste*. Retrieved from: <https://ec.europa.eu/eurostat> 01.10.2025.
8. Górka, K., Poskrobko, B., Radecki, W. (1998). *Ochrona środowiska. Problemy społeczne, ekonomiczne i prawne*. Warszawa.
9. Gwarda, K. (2019). A study of residents' ecological awareness and behaviour in the context of the transformation of Gdynia towards a zero waste city. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 63(5), 123-135.
10. ISAP (2023). *Krajowy plan gospodarki odpadami 2028 (KPGO 2028)*. Ministry of Climate and Environment.
11. Knussen, C., Yule, F., MacKenzie, J., Wells, M. (2004). An analysis of intentions to recycle household waste: The roles of past behaviour, perceived habit, and perceived lack of facilities. *Journal of Environmental Psychology*, 24(2), 237-246.
12. Mihai, F. (2012). Waste management threats to the environment in Eastern Europe: Case study of Romania. *Romanian Review of Regional Studies*, 8(2), 95-110.
13. Nęcka, E., Orzechowski, J., Szymura, B. (2006). *Psychologia poznawcza*. Warszawa: PWN.
14. NIK (2023). *Realizacja zadań w zakresie gospodarki odpadami komunalnymi w Polsce*.
15. OECD (2022). *Environmental Performance Review: Poland 2022*. Paris: OECD Publishing.
16. Papuziński, A. (2006). Świadomość ekologiczna w świetle teorii i praktyki (Zarys politologicznego modelu świadomości ekologicznej. *Problemy Ekorozwoju*, 1(1), 34.
17. Penc, J. (2003). *Zarządzanie w warunkach globalizacji*. Warszawa: Difin.
18. Schultz, P. (2014). Strategies for promoting proenvironmental behavior: Lots of tools but few instructions. *European Psychologist*, 19(2), 107-117.

19. Szalewska, M. (2021). Edukacja ekologiczna w ujęciu prawnym. *Przegląd Prawa Ochrony Środowiska*, 1, 59-78.
20. Tonglet, M., Phillips, P. (2004). Using the Theory of Planned Behaviour to investigate the determinants of recycling behaviour: A case study from Brixworth, UK. *Resources, Conservation and Recycling*, 41(3), 191-214.
21. Zuzek D. (2017). Świadomość ekologiczna przedsiębiorców jako element zrównoważonego rozwoju. *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach*, 326, 164.

COMMUNICATION ERRORS IN LOCAL TOURISM MARKETING: EVIDENCE FROM FACEBOOK GROUP IN OKUNINKA

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Purpose: The purpose of the paper is to identify and analyze communication errors made by accommodation providers in Facebook groups related to local tourism, using the case of Okuninka at Lake Białe in Poland. The study aims to assess how these errors affect the effectiveness of online marketing, tourist engagement, and the overall image of the destination, with a particular focus on seasonality.

Design/methodology/approach: The research applied a mixed-methods approach combining quantitative and qualitative analysis. Data were collected from public posts and comments in a Facebook group dedicated to accommodation offers. The dataset comprised approximately 1200 posts (including both tourist inquiries and accommodation providers' promotional offers) and approximately 5000 responses from accommodation providers, collected over the period 2022-2025. Quantitative methods included descriptive statistics, χ^2 independence tests with Cramér's V, and a logistic regression model to measure the effect of selected variables. Qualitative content analysis was applied to classify types of communication errors and assess their contextual meaning.

Findings: The study found that 71% of responses contained at least one communication error, with the most frequent being the omission of price (42%) and redirecting to private messages (37%). Posts that included price and photos achieved significantly higher conversion rates, while reliance on private channels reduced effectiveness. Seasonal patterns were also observed, with distinct types of errors prevailing in different periods of the year. The multifactor model confirmed that price transparency, visual presentation, and personalized replies strongly increase communication effectiveness, while private-message redirection and phone-only contact negatively affect it.

Research limitations/implications: The study was limited to a single platform (Facebook) and one destination (Okuninka, Lake Białe), which restricts the generalizability of findings. Conversion was measured based on digital traces (further contact) rather than confirmed bookings. Future research should extend to other platforms (Instagram, Booking.com, TikTok), compare different types of tourist destinations, and integrate advanced analytical tools (AI, big data) to identify communication patterns more comprehensively.

Practical implications: The findings provide practical recommendations for accommodation providers and local tourism organizations. Transparent offers including price and photos should become standard practice, while public replies should be prioritized over private messages to ensure trust and visibility. Local DMOs could develop unified guidelines for online

communication. Such improvements could increase booking conversion, enhance customer satisfaction, and strengthen the competitive position of local tourism markets.

Social implications: The study highlights the role of online communities in shaping the image of local destinations. More transparent and personalized communication can foster trust, support social capital among tourists and residents, and contribute to sustainable tourism practices. By reducing communication gaps, tourism stakeholders may also improve perceptions of professionalism and hospitality, positively influencing the attractiveness of the region beyond the high season.

Originality/value: The paper provides new empirical evidence on the communication practices of small-scale accommodation providers in social media contexts. It demonstrates the synergistic effect of combining price transparency, photos, and personalization, and shows how seasonality influences the occurrence of communication errors. The study adds value to the literature on tourism marketing, destination management, and social media communication, offering insights relevant for academics, practitioners, and policymakers.

Keywords: tourism marketing; social media communication; seasonality; Facebook groups; accommodation providers.

Category of the paper: Research paper; Case study.

1. Introduction

The development of social media has radically changed the functioning of contemporary tourist and local communities. Platforms such as Facebook, Instagram, and TikTok have become not only tools for information exchange and recommendations but also spaces for shaping the image of places and tourist services. Facebook is particularly significant, as its thematic group functionality enables the creation of communities focused on specific destinations, attractions, or tourist needs. These groups simultaneously serve informational, integrative, and promotional functions, becoming an important communication channel between service providers and potential guests.

An example of such activity is Okuninka at Lake Białe – a popular holiday destination in eastern Poland, attracting thousands of tourists every year, especially during the summer season. The functioning of the group "Okuninka Jezioro Białe - noclegi (domki, pokoje, kwatery, pola namiotowe)" run by the profile "Okuninka Jezioro-Białe" allows for observing communication mechanisms on a micro-scale, encompassing both interactions between accommodation owners and tourists and the exchange of experiences among community members themselves. It is worth noting that this is one of several groups operating on Facebook related to this area, but due to its size and user activity, it remains the largest and most important discussion space. The literature emphasizes that social media activity can genuinely influence purchasing decisions, choice of vacation spot, and satisfaction levels with tourist services. In the context of Okuninka, it can be assumed that discussions and responses in the Facebook group serve as a substitute for traditional information sources – such as travel agencies, official municipal websites, or booking and review portals (e.g., Booking.com, Nocowanie.pl) – while

simultaneously providing a platform for tourists to exchange experiences. Thus, the group can function as a kind of "barometer" of tourist attractiveness and the quality of services provided.

Existing research indicates that social media activity influences purchasing decisions, choice of vacation spots, and satisfaction levels with services. However, the effectiveness of communication depends on many factors – the type of content published (interactive, visual), consistency of strategy, degree of local community engagement, or the presence of key elements such as price, contact details, or visual materials. The lack of such information can reduce the effectiveness of marketing activities, as can communication errors that appear in the responses of accommodation owners. An additional challenge is tourism seasonality – the intensity of online communication increases during the holiday period, while outside the season, it becomes necessary to seek alternative narratives and offers.

In this context, a particularly interesting research problem is the analysis of the quality and effectiveness of communication conducted in social media groups related to local destinations. This article focuses on the example of Okuninka at Lake Białe, juxtaposing an empirical analysis of activity in the group "Okuninka Jezioro Białe - noclegi (domki, pokoje, kwatery, pola namiotowe)" with findings from the literature on the role of social media in tourism and the specifics of seasonality. Particular emphasis is placed on the perspective of accommodation providers, for whom social media are an important tool for promoting their offer, acquiring customers, and responding to tourist opinions and expectations. The aim of the study is therefore to identify typical communication problems from the perspective of accommodation hosts, assess their consequences for regional promotion and the functioning of the local tourist services market, and indicate patterns that could support more effective destination image management.

This analysis fits into the broader context of transformations occurring in tourist destinations that have so far operated seasonally. Okuninka is an example of a region where the accommodation base has significantly increased over the last decade. This growth largely resulted from private investments, including both the expansion of existing facilities and the purchase of new properties intended for short-term rental. This phenomenon can be linked to the growing interest in investments generating passive income, which in recent years has become an attractive form of capital investment in the tourist real estate sector.

The development of the accommodation base in Okuninka, encompassing both an increase in the number of facilities and an improvement in their standard, creates complex conditions for property owners. On the one hand, growing competition in the segment of standard offers means that rental prices in this range have remained relatively stable for several years, limiting the possibility of increasing revenue in this segment. On the other hand, the increasing number of exclusive facilities, offering amenities such as jacuzzis, high-quality equipment, or attractive locations by the lake, allows owners to meet the expectations of wealthier tourists who are willing to pay higher rates for comfort and additional attractions. Such market segmentation enables more effective positioning of facilities, increased revenue in the premium segment,

and building a positive image on social media through recommendations and reviews from satisfied customers. As a result, owners can both maintain the competitiveness of standard offers and utilize the growing demand for exclusive accommodation to generate additional income.

Simultaneously, global trends are observed that influence the local structure of the tourist market. The growth of consumerism, the development of mobile and digital tourism, and the increasing importance of social media favor the intensification of short-term trips, which drives demand for accommodation and enables facility owners to flexibly adapt their offers to changing tourist preferences. At the same time, this process coexists with growing social stratification worldwide, where the increase in private investments in tourist real estate leads to changes in the availability and price structure of accommodation offers and may also affect residents' access to the local real estate market.

In the context of Okuninka, the dynamic development of the accommodation base and the growing commercialization of tourist space favor the emergence of phenomena typical for seasonal destinations with intensive tourism, such as infrastructure overload, the need to manage seasonal tourist influx, and the necessity for effective marketing strategies enabling the maintenance of destination attractiveness outside the main summer period. Simultaneously, this transformation creates challenges for spatial planning, sustainable tourism development, and local policy, requiring consideration of both the interests of tourists and the residents of the region.

2. Literature Review: Social Media, Tourism Marketing, and Seasonality

Social media play an increasingly important role in tourism marketing and in the process of building social bonds and social capital among users. Research shows that platforms like Facebook can be a key tool in promoting destinations, engaging tourists, and co-creating the image of a place. At the same time, insufficient utilization of the potential of social media groups by local tourism organizations and accommodation owners is indicated.

Research has shown that promotional posts generate the most "likes", but interactive posts elicit more comments, indicating deeper user engagement (Strzębicki, 2025). The literature also emphasizes that local tourism organizations in Poland often do not fully utilize Facebook's capabilities, and the lack of professionalization and a consistent strategy leads to insufficient communication effectiveness (Korbiel, 2021). Conversely, the potential of analyzing social media data for planning local tourism development is highlighted, enabling the monitoring of tourist preferences and behaviors (Zajadacz, Minkwitz, 2020).

The importance of building bonds and social capital by tourist communities has also been noted in research emphasizing that both online and offline networks support the exchange of experiences and sustainable tourism practices (Dickinson et al., 2017). Similar conclusions were presented in a study published in *Technology in Society*, analyzing tourist groups on Facebook in light of social facilitation theory, which demonstrated that an interactive content format (questions, answers, polls) increases engagement and maintains activity in groups (Camilleri, Kozak, 2022).

Another important issue is the co-creation of place branding by the local community. Research proves that the active involvement of residents and entrepreneurs in place promotion increases its authenticity and attractiveness in the eyes of tourists, but requires appropriate organizational and communication support (Leal et al., 2022). Similar conclusions emerge from analyses concerning tourism recovery after the COVID-19 pandemic, which indicate that social media became one of the key tools for communication and co-creating the destination narrative (Hysa et al., 2022).

It is also worth citing works directly analyzing Facebook as a destination marketing tool. Studies of Italian DMO organizations proved that elements such as photos, post length, and publication frequency significantly influence user engagement (Mariani et al., 2016). Conversely, a longitudinal analysis of European DMOs confirmed that consistent and regular communication activities yield the greatest effects in the long term, rather than short-term promotional campaigns (Gálvez-Rodríguez et al., 2020).

Seasonal tourism is a problem that significantly affects the functioning of destinations, especially those dependent on climatic conditions and summer-holiday activity. The literature on seasonality has analyzed both the causes and effects of this variability and strategies to counteract periods of low activity.

The study "Destination engagement on Facebook: Time and seasonality" indicates that the level of engagement on social media (reactions, comments) depends on the time of year: the authors observe better results in the months preceding summer and during the high tourism season (Villamediana et al., 2019). The work "Balancing Tourism Seasonality: The Role of Tourism Destination Image (TDI) and Spatial Levels (SLs)" emphasized that destination image and the level of spatial promotion can mitigate the effects of seasonality by building attractiveness also outside the peak season (Wang, Chen, 2025).

In the Polish context, Soldatke et al. (2023) studied the seaside resorts of Puck and Władysławowo, comparing the development of tourist services, planning solutions, and tourist offers between the summer and off-season periods. This study emphasized that the tourist offer outside the season is often limited, infrastructure is used less intensively, and residents perceive the inconveniences associated with tourist traffic differently, which also affects the acceptance of spatial development (Soldatke et al., 2023).

Also, the work "Tourism seasonality: the causes and effects" (Zvaigzne et al., 2022) constitutes a literature review, focusing on the causes of seasonality (e.g., natural, institutional, economic factors) and their effects – economic, social, but also environmental. It is a good reference point for analyzing the influence of season on the engagement and activity of online communities.

The work "Study of Seasonality Tourism in Simanindo Sub-district, Samosir Regency" (Zvaigzne et al., 2022) analyzes seasonal patterns of tourist arrivals in the Simanindo region; the author states that the peak season is related to holiday and festive periods, and that outside the season, promotional activities and alternative tourist offers can mitigate declines if well planned.

The case study example "How off-season tourism promotion affects seasonal destinations? A multi-stakeholder perspective in Tibet" (Senyao et al., 2021) shows that off-season promotion requires considering the perspective of multiple stakeholders – local entrepreneurs, residents, and authorities – and may encounter resistance stemming from tradition or seasonal expectations, but also create new opportunities for the destination.

In summary, the literature confirms that social media play a key role in tourism, serving not only as a tool for promoting offers but also as a platform for building bonds, exchanging experiences, and co-creating the tourist value of a destination. Research indicates several factors that increase the effectiveness of online communication, among which the most frequently mentioned are the presence of interactive content, consistency of communication strategy, active engagement of the local community, and appropriate use of visual elements such as photos and multimedia materials.

Simultaneously, the literature emphasizes the importance of the seasonality aspect, which significantly shapes tourist activity and the effectiveness of promotional activities. Research results prove that both the level of engagement on social media and the effectiveness of promotional campaigns depend on the phase of the tourist season – increased user activity occurs in the summer months and in periods preceding the summer peak, while outside the season, activities require different tools and communication narratives. The literature also stresses the need to expand the off-season offer and build the image of a destination attractive year-round, which requires the cooperation of many stakeholders and tailoring the message to the variable needs of the audience.

The entire literature review thus indicates that effective communication on social media in tourism cannot be analyzed in isolation from the cyclicity and dynamics of the season. Considering these two perspectives – communication and seasonal – allows for a better understanding of user engagement mechanisms and also provides a theoretical basis for analyzing the case of the Facebook group related to Okuninka at Lake Białe.

3. Metodologia badań

The aim of the study was to identify and analyze communication errors made by accommodation owners in responses to tourist inquiries on social media, and then assess their impact on the effectiveness of marketing activities. The analysis was conducted based on publicly available posts and comments published in thematic groups on the Facebook platform, focused on searching for and offering accommodation. The research sample included approximately 1200 posts, comprising both tourist inquiries and promotional content published by facility owners, as well as nearly 5000 responses provided by landlords between 2022 and 2025. For the purposes of the study, all empirical material was anonymized, and individual authors were assigned identification codes, ensuring methodological and ethical reliability in the analysis process.

A mixed-methods approach – quantitative and qualitative – was applied. Quantitative variables included the number of comments, reactions (e.g., 👍❤️😊), views, and conversion understood as the percentage of inquiries leading to further contact. Among qualitative variables, the presence of price and photos in the offer, the form of response (public, private message, phone, email), personalization of the response, and the type of communication error were analyzed. Errors were classified into five main categories: lack of price, redirecting to "priv" (private message), lack of photos, ignoring the content of the inquiry, and preferring only telephone contact. The adopted classification was based on several years of observation of discussions in the analyzed group.

The analytical tools used included content analysis (qualitative classification of posts and responses), descriptive statistics (average number of comments, reactions, conversion), χ^2 independence tests along with the Cramér's V measure of association strength, and seasonality analysis (winter, spring, summer, autumn). Furthermore, a multifactor model in the form of a simplified logistic regression was developed, allowing estimation of the impact of the presence of price, photo, personalization of response, and form of communication ("priv", phone) on interaction effectiveness. For all tests, a significance level of $\alpha = 0.05$ was adopted, enabling reliable statistical assessment of the data and limiting the risk of type I errors.

Based on the collected data, tabular summaries were prepared. The first presents the scale and consequences of communication errors, the second – the seasonality of error occurrence and their impact on conversion, the third – the significance of relationships between variables, and the fourth – the multifactor model illustrating the impact of individual factors on response effectiveness.

The study has certain limitations. The data come exclusively from Facebook, without comparison with other communication channels (e.g., Booking.com, Instagram). Conversion was determined based on digital traces (continuation of contact), not actual bookings. Additionally, the potential influence of seasonal advertising campaigns on the number of reactions and comments must be considered.

In light of the conducted analyses and identified communication problems, the following research hypotheses were formulated:

- H1: The lack of providing a price in accommodation offers significantly increases the number of comments (including questions "What's the price?"), but lowers the conversion of inquiries into actual reservation interest.
- H2: The presence of photos in the offer significantly increases the effectiveness of marketing communication, manifested by higher conversion and a greater number of positive reactions.
- H3: There are significant seasonal differences in the types of communication errors made by facility owners, with the practice of redirecting to private messages ("priv") dominating in summer, and the lack of price provision in winter.
- H4: Ignoring the content of tourist inquiries by accommodation owners (e.g., posting offers inadequate to the given criteria or omitting details contained in the post) significantly increases the percentage of comments that do not answer the question, indicating a serious problem of communication discrepancy between the parties.
- H5: There is a discrepancy between the communication channels preferred by accommodation owners (priv, phone) and tourist expectations (transparent public comments), which negatively affects the effectiveness of interactions.
- H6: The greatest positive impact on response effectiveness is exerted by providing the price, including a photo, and personalizing the message, while a negative impact is exerted by redirecting to "priv" and requiring telephone contact.

The above hypotheses summarize the assumed relationships between communication practices and their effectiveness. Their verification was carried out using both quantitative and qualitative methods described earlier. The following section presents the empirical results, allowing for a detailed assessment of the identified patterns and testing of the proposed hypotheses.

4. Research results

The analysis presented below covers both the frequency and nature of communication errors made by accommodation owners and their consequences for the effectiveness of interactions with tourists. The results are summarized in Tables 1-7, which illustrate the scale of the problem, the impact of the presence of key offer elements (price, photos), communication channel preferences, and identified statistical relationships. The chapter division allows first for an assessment of the scale and type of errors (4.1), and then an analysis of factors conditioning communication effectiveness on social media (4.2).

4.1. The scale and nature of communication errors

Analysis of accommodation owners' responses to tourist posts revealed a significant scale of communication errors (Table 1). The most frequent was the lack of price provision – in 210 cases, constituting 42% of all responses. An equally significant problem was directing the conversation to private messages ("priv, priv"), noted in 185 cases (37%). Subsequent error categories were: ignoring the content of the inquiry (155 cases; 31%) and lack of photos in the offer (140 cases; 28%). The requirement for only telephone contact appeared least frequently (75 cases; 15%). In total, at least one error occurred in 71% of the analyzed responses, indicating a systemic nature of the problem and a lack of consistent communication standards with tourists.

Table 1

Frequency of communication errors in responses to tourists' inquiries

Type of communication error	Number of cases (N)	% of all responses
No price provided	210	42
"Priv, priv" (redirect to private message)	185	37
No photos in the offer	140	28
Ignoring the content of the inquiry	155	31
Only telephone contact	75	15
Total (at least 1 error)	355	71

Source Authors' own elaboration based on Facebook group data analysis.

The data confirm that communication errors are widespread among accommodation providers, indicating a lack of consistent communication standards. This provides a foundation for analyzing how such mistakes affect marketing effectiveness in subsequent sections.

Table 2 presents the impact of the presence of key offer elements (price and photos) on user engagement and communication effectiveness. Posts by accommodation owners with the price provided generated an average of 12 comments, of which only 5% concerned additional questions about cost, and they achieved a 68% conversion rate in availability inquiries. In comparison, posts without a price had an average of 22 comments and a higher number of views (2400), but as many as 54% of comments concerned questions about the price, and conversion was significantly lower (21%). A similar pattern concerned the presence of photos: posts with photos achieved higher conversion (52%) than posts without photos (24%), even though the latter attracted a greater number of views (2700). The results indicate that transparency and visualization of the offer are crucial for the actual effectiveness of marketing communication.

Table 2*Frequency of communication errors in responses to tourists' inquiries*

Type of post	Average number of comments	% of comments asking "What's the price?"	Average number of views
Post with price	12	5	1,800
Post without price	22	54	2,400
Post with photo	18	12	2,100
Post without photo	20	41	2,700

Source: Authors' own elaboration based on Facebook group data analysis.

According to the data in Table 3, there is a clear discrepancy between the communication channels preferred by facility owners and tourist expectations. Owners most often redirected users to private messages (37%) or used the form of a public comment (28%), less frequently using email (20%) or phone (15%). Meanwhile, tourists decidedly preferred transparent responses in public comments (67%), and to a lesser extent private messages (54%). Phone contact (19%) and email (33%) were much less important to them. These data confirm a significant disconnect between the communication practices of owners and customer expectations, which can lead to the loss of potential reservations.

Table 3*Communication channels preferred by owners and tourists*

Form of contact	Share in owners' responses (N)	Tourists' preference (as declared in comments) (%)
Public comment with full offer	28	67
Private message (Messenger)	37	54
Telephone	15	19
E-mail / contact form	20	33
Only telephone contact	75	15
Total (at least 1 error)	355	71

Source: Authors' own elaboration based on Facebook group data analysis.

The observed discrepancies between preferred and expected communication channels highlight a clear asymmetry between hosts and tourists. This issue is further explored in the next subsection, which examines the determinants of communication effectiveness.

4.2. Dependencies and determinants of communication effectiveness

Table 4 presents the relationship between types of communication errors and user reactions in comments and emotional reactions. The highest percentage of responses burdened with an error concerned the lack of price (42%) and the "priv, priv" practice (37%). Lack of price generated an average of 22 comments and 6 positive reactions, but as many as 48% of owner comments did not directly answer the tourist's question. Ignoring the inquiry occurred in 31% of cases, resulting in 16 comments and 3 reactions, with 52% of responses being inadequate. The lowest indicators were recorded for offers limited only to telephone contact (15% of cases), which generated on average only 14 comments and 2 reactions.

Table 4*Matrix of communication errors vs. average number of reactions and comments*

Type of communication error	% of responses with error	Average number of comments	Average number of reactions (👍❤️)	% of comments not addressing the question
No price provided	42	22	6	44
"Priv, priv"	37	18	5	39
No photos	28	20	4	32
Ignoring the inquiry	31	16	3	51
Telephone only	15	14	2	26

Note. Owners' comments in response to tourists' posts inquiring about accommodation.

Source: Authors' own elaboration based on Facebook group data analysis.

Seasonal analysis of communication (Table 5) reveals variability in the number of inquiries and the nature of owner errors in different seasons. The most inquiries were recorded in the summer period (470), where the "priv, priv" error dominated (45%), and only 36% of posts contained a price. In spring (350 inquiries), a common problem was ignoring the content of the inquiry (38%), with a moderate level of price transparency (41%). In winter, when the number of inquiries was lower (310), the lack of price predominated (47%), while in autumn (190 inquiries), the characteristic error was the lack of photos (32%), even though the percentage of posts with a price was highest in this period (49%). Importantly, regardless of the season, the percentage of owner comments not answering the tourist's question remained high (19-29%).

Table 5*Seasonality of communication errors*

Season	Number of tourist inquiries	Most common owner error	% of posts with price provided	% of comments not addressing the question
Winter	190	No price provided (47%)	33	35
Spring	310	Ignoring the inquiry (38%)	41	42
Summer	570	"Priv, priv" (45%)	36	48
Autumn	150	No photos (32%)	49	27

Source: Authors' own elaboration based on Facebook group data analysis.

Table 6 presents the results of the χ^2 test, which allowed for examining the relationships between selected post features and user reactions. In all analyzed cases, statistically significant relationships were obtained. The analysis showed a statistically significant relationship between providing the price and the number of comments ($\chi^2 = 18.4$; $p < 0.001$; Cramér's $V = 0.34$), indicating a moderate effect size. An even stronger relationship was recorded in the case of photo presence and conversion ($\chi^2 = 22.7$; $p < 0.001$; Cramér's $V = 0.41$). The choice of contact channel also had a significant impact on the number of negative reactions ($\chi^2 = 12.9$; $p = 0.004$; Cramér's $V = 0.27$).

Table 6*Dependency analysis – χ^2 test*

Variable 1	Variable 2	χ^2 (chi-squared)	p-value	Cramér's V	Interpretation
Price provided (yes/no)*	Number of comments (<15 / ≥15)	18.4	0.0001	0.34	Significant relationship, moderate effect
Photo provided (yes/no)**	Conversion (yes/no)	22.7	0.0000	0.41	Significant relationship, medium effect
Contact channel (public/priv/phone)***	Number of negative reactions	12.9	0.004	0.27	Significant relationship, weak–moderate effect

Note. *if the seller provided the price, the post more often obtained ≥ 15 comments; **presence of a photo in the post clearly increased the probability of conversion (e.g., purchase, offer inquiry); ***the proposed contact method (public, priv, phone) had an impact on whether users reacted negatively.

Source: Authors' own elaboration based on Facebook group data analysis.

Table 7 illustrates the results of the multifactor model, which determines the impact of individual features of posts: accommodation advertisements in Okuninka on response effectiveness. The strongest positive impact was exerted by personalizing the response ($\beta = 0.45$; $p < 0.001$) and providing the price ($\beta = 0.42$; $p = 0.001$). Adding a photo was also significant ($\beta = 0.31$; $p = 0.008$). Factors with a negative impact were redirecting to a private message ($\beta = -0.38$; $p = 0.002$) and requiring telephone contact ($\beta = -0.29$; $p = 0.014$).

Table 7*Multifactor model – impact of post features on response effectiveness*

Factor	Direction of effect	Effect strength (β)	Significance (p-value)
Price provided (0 = no, 1 = yes)	+	0.42	0.001
Photo included (0/1)	+	0.31	0.008
Personalized reply (0/1)	+	0.45	0.000
"Priv" as a reply (0/1)	–	-0.38	0.002
Telephone contact (0/1)	–	-0.29	0.014

Note: A multifactor logistic regression model was adopted in the form of $\ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 \cdot X_{price} + \beta_2 \cdot X_{photo} + \beta_3 \cdot X_{personal} + \beta_4 \cdot X_{priv} + \beta_5 \cdot X_{phone} + \varepsilon$; where: p – probability of obtaining an effective response (reaction from the recipient), explanatory variables X were coded binarily (0/1): presence of price, photo, personalization of response, reference to "priv", and requirement of telephone contact. Variables with positive coefficients ($\beta > 0$) increased the probability of an effective response, while negative ones ($\beta < 0$) decreased it.

Source: Authors' own elaboration based on Facebook group data analysis.

4.3. Verification of hypotheses

The conducted quantitative and qualitative analysis allowed for the verification of the six research hypotheses (H1-H6). Verification was conducted using tabular data (Tables 2-7) and statistical tests (χ^2 , Cramér's V, logistic regression). Detailed results are presented below.

- H1: Data from Table 2 showed that posts without a price generated on average more comments (22 vs. 12), but as many as 54% of them concerned the question "What's the price?". Conversion in this case was significantly lower (21% vs. 68% for posts with a price). The χ^2 test results (Table 6; $\chi^2 = 18.4$; $p < 0.001$; Cramér's $V = 0.34$) confirm a significant relationship with a moderate effect size.
- H2: Data from Table 2 showed that posts with a photo achieved higher conversion (52%) than posts without a photo (24%). The χ^2 test (Table 6; $\chi^2 = 22.7$; $p < 0.001$; Cramér's $V = 0.41$) indicated a significant relationship with a medium effect size.
- H3: Analysis of Table 5 revealed clear differences between seasons: in summer, redirecting to private messages dominated (45%), in winter lack of price (47%), in spring ignoring inquiries (38%), and in autumn lack of photos (32%). The χ^2 test confirmed the significance of the differences ($p < 0.05$), indicating that seasonality significantly shapes the structure of errors.
- H4: As shown in Table 4, in the case of ignoring inquiries, as many as 51% of responses did not refer to the content of the question, which is the highest indicator among the analyzed error categories. This relationship persisted especially in spring and summer (Table 5). The χ^2 test confirmed the significance of the relationship ($p < 0.05$), and the Cramér's V value indicated a moderate effect.
- H5: As indicated by Table 3, owners most often redirected tourists to private messages (37%) or required telephone contact (15%), while tourists primarily preferred public comments (67%). The χ^2 test (Table 6; $\chi^2 = 12.9$; $p = 0.004$; Cramér's $V = 0.27$) confirmed a significant relationship between the communication channel and the number of negative reactions, indicating a weak–moderate effect.
- H6: The multifactor model (Table 7) showed that personalized response ($\beta = 0.45$; $p < 0.001$), providing the price ($\beta = 0.42$; $p = 0.001$), and adding a photo ($\beta = 0.31$; $p = 0.008$) had a significant positive impact on communication effectiveness. Conversely, negative impacts were exerted by: redirecting to private messages ($\beta = -0.38$; $p = 0.002$) and requiring telephone contact ($\beta = -0.29$; $p = 0.014$).

In summary, all research hypotheses (H1-H6) were confirmed, indicating a significant impact of both the form and content of online communication on the effectiveness of interactions between accommodation owners and tourists.

5. Discussion of the results

The obtained results confirm that the effectiveness of marketing communication on social media depends largely on the transparency of the message and the matching of responses to tourist expectations. The lack of providing a price or photo lowered conversion rates,

even though it increased the number of comments – which aligns with the conclusions of Strzębicki (2025), according to whom interactivity generates engagement but does not always lead to purchasing decisions. In the studied Facebook group, a contradiction between activity indicators (comments, reactions) and actual marketing effectiveness was therefore visible.

Reference to the literature indicates that this problem is not local. Studies by Mariani et al. (2016) and Gálvez-Rodríguez et al. (2020) on Italian and European DMO organizations show that systematicity and completeness of content are more important than the number of posts or their popularity. The results of our study strengthen these findings, emphasizing the importance of a transparent offer – especially including price and visualization – for the effective conversion of tourist inquiries.

Seasonality proved to be a factor differentiating both the number of inquiries and the nature of communication errors. In summer, redirecting to private messages dominated, while in winter the lack of price in the offer was most common. Convergent observations were presented by Villamediana et al. (2019), indicating that the intensity and form of activity on social media change throughout the annual cycle, reaching a maximum before and during the season. These results also correspond with the findings of Soldatke et al. (2023) for seaside resorts in Poland, where seasonality affects the limited off-season offer.

It is worth emphasizing that a discrepancy between tourist preferences and owner practices appeared in the analyzed group. While guests expected primarily responses in public comments, owners preferred "priv" or telephone contact. This communication asymmetry finds confirmation in the research of Camilleri and Kozak (2022), who point out that engaging content in an open online space builds lasting bonds and strengthens the sense of community. Our results suggest that moving conversations to private channels may limit the social capital of the group and reduce the potential for recommendations.

The identified communication errors can be interpreted in the context of the theory of social facilitation (Camilleri, Kozak, 2022) and the concept of social capital (Dickinson et al., 2017). The lack of price and photos, redirecting to "priv", or ignoring the content of the inquiry may result from the desire to control the message or avoid price comparisons. However, such behavior reduces the transparency of the offer and may lead to a loss of trust, which in the long run weakens the image of the destination.

A novel element introduced by this study is the empirical confirmation that the greatest positive impact on communication effectiveness comes from the simultaneous occurrence of three factors: providing the price, including a photo, and personalizing the response. In the literature, these have typically been analyzed separately (e.g., Leal et al., 2022 in the context of co-creating an authentic message, or Hysa et al., 2022 in studies on tourism recovery post-COVID-19). The results of our multifactor model indicate that the synergistic combination of these elements is crucial for translating online activity into actual tourist decisions.

The latest research emphasizes the growing importance of artificial intelligence in analyzing tourist data from social media. AI-based tools allow for the automatic detection of patterns in user behavior and can support local communities in adapting their communication. The integration of such solutions could help avoid the recurring communication errors identified in this study (Bulchand-Gidumal et al., 2024; To, Yu, 2025; Żyminkowska, Zachurzok-Srebrny, 2025).

The practical implications of the study are clear: accommodation owners should strive for transparent and personalized communication, providing key information (price, photos) already in the first contact. Local tourism organizations could develop communication standards and promote good practices, such as responding publicly to inquiries and using multimedia content. This would increase conversion, build trust, and strengthen the brand of the destination.

6. Conclusions

The conducted study enabled the identification of typical communication errors made by accommodation owners in Facebook groups dedicated to local tourism and an assessment of their impact on marketing effectiveness. The results confirmed that offer transparency and completeness—specifically, providing the price, including a photo, and personalizing the response—significantly enhance communication effectiveness and inquiry conversion. Conversely, strategies that involve moving conversations to private messages or insisting on exclusive telephone contact reduce interaction efficiency and provoke negative tourist reactions.

The study has several limitations. The analysis was confined to data from Facebook, excluding other platforms such as Booking.com, Instagram, and TikTok. Furthermore, conversion was measured based on digital traces (i.e., further contact initiated) rather than confirmed bookings. The study's focus on a single destination (Okuninka at Lake Białe) also limits the generalizability of the findings. Additionally, seasonal patterns may have been influenced by external factors like advertising campaigns, local events, weather conditions, or unpredictable incidents related to the town's border location. Despite these limitations, the study is entirely original in its scope and geographical focus.

The analysis revealed that 71% of owner responses contained at least one communication error. The most prevalent errors were omitting the price (42%) and redirecting users to private messages (37%). The presence of a price and photos in an offer significantly increased conversion rates, whereas redirecting to private messages or requiring telephone contact had a negative effect. Seasonal variations in the prevalence of different error types were also observed. All six research hypotheses were confirmed, indicating that communication errors represent a systemic issue that adversely affects interaction effectiveness with tourists.

These findings align with existing literature on social media in tourism, which emphasizes the importance of transparency, interactivity, and audience-tailored messaging.

Future research could extend this analysis in several directions: (1) comparing communication effectiveness across different social media platforms; (2) incorporating tangible economic metrics, such as the number of bookings and length of stay; (3) employing artificial intelligence and big data analytics to automate the detection of communication errors and patterns; (4) conducting comparative studies across various types of tourist destinations (e.g., coastal, mountain, and urban resorts); and (5) performing in-depth qualitative analyses that incorporate the sociodemographic perspectives of both tourists and facility owners.

This article contributes several novel elements to the literature. Firstly, it provides empirical confirmation that the synergistic combination of three factors, price transparency, visual content (photos), and response personalization, most substantially boosts communication effectiveness. Secondly, it demonstrates that seasonality influences not only inquiry volume but also the nature of the most common communication errors. Thirdly, it identifies a communication asymmetry between tourist preferences (for transparent public comments) and owner practices (favoring private channels). Lastly, it offers quantitative and qualitative insights from a local market previously unrepresented in social media tourism research.

Based on these results, several practical recommendations can be proposed. Accommodation owners should prioritize offer transparency by clearly stating prices and showcasing photos. Personalizing responses within public comment threads is advisable over mass redirection to private messages. Local tourism organizations could develop online communication standards to promote consistent and professional promotional practices. To maintain engagement during the off-season, alternative narratives—such as promoting weekend getaways, local events, and natural or cultural assets—should be leveraged. Finally, adopting analytical tools, including those powered by artificial intelligence, could facilitate the continuous identification of communication errors and help tailor content to better meet tourist expectations.

References

1. Bulchand-Gidumal, J., William Secin, E., O'Connor, P., Buhalis, D. (2024). Artificial intelligence's impact on hospitality and tourism marketing: Exploring key themes and addressing challenges. *Current Issues in Tourism*, 27(14), 2345-2362. <https://doi.org/10.1080/13683500.2023.2229480>
2. Camilleri, M.A., Kozak, M. (2022). Interactive engagement through travel and tourism social media groups: A social facilitation theory perspective. *Technology in Society*, 71, 102098. <https://doi.org/10.1016/j.techsoc.2022.102098>

3. Dickinson, J.E., Filimonau, V., Hibbert, J.F., Cherrett, T., Davies, N., Norgate, S., Speed, C., Winstanley, C. (2017). Tourism communities and social ties: The role of online and offline tourist social networks in building social capital and sustainable practice. *Journal of Sustainable Tourism*, 25(2), 163-180. <https://doi.org/10.1080/09669582.2016.1182538>
4. Dwi Debora Sitanggang (2021). Study of Seasonality Tourism in Simanindo Sub-district, Samosir Regency. *International Journal of Architecture and Urbanism*, 5(1), 49-57. <https://doi.org/10.32734/ijau.v5i1.6031>
5. Gálvez-Rodríguez, M.D.M., Alonso-Cañadas, J., Haro-de-Rosario, A., Caba-Pérez, C. (2020). Exploring best practices for online engagement via Facebook with local destination management organisations (DMOs) in Europe: A longitudinal analysis. *Tourism Management Perspectives*, 34, 100636. <https://doi.org/10.1016/j.tmp.2020.100636>
6. Hysa, B., Zdonek, I., Karasek, A. (2022). Social Media in Sustainable Tourism Recovery. *Sustainability*, 14(2), 760. <https://doi.org/10.3390/su14020760>
7. Korbiel, K. (2021). The use of Facebook in marketing communication by local tourist organizations in Poland. *Turyzm/Tourism*, 31(2), 25-37. <https://doi.org/10.18778/0867-5856.31.2.02>
8. Leal, M.M., Casais, B., Proença, J.F. (2022). Tourism co-creation in place branding: The role of local community. *Tourism Review*, 77(5), 1322-1332. <https://doi.org/10.1108/TR-12-2021-0542>
9. Mariani, M.M., Di Felice, M., Mura, M. (2016). Facebook as a destination marketing tool: Evidence from Italian regional Destination Management Organizations. *Tourism Management*, 54, 321-343. <https://doi.org/10.1016/j.tourman.2015.12.008>
10. Senyao, S., Wei, H., Ma, N. (2021). How off-season tourism promotion affects seasonal destinations? A multi-stakeholder perspective in Tibet. *Tourism Review*, 76(1), 229-240. <https://doi.org/10.1108/TR-04-2019-0123>
11. Soldatke, N., Żukowska, S., Połom, M. (2023). Seasonality of seaside towns on the example of spatial planning solutions in Poland. *Acta Scientiarum Polonorum Administratio Locorum*, 22(2), 241-261. <https://doi.org/10.31648/aspal.8672>
12. Strzębicki, D. (2025). Consumer Engagement on Facebook: The Role of Comments in Travel Agency Brand Interactions in Poland. *Marketing of Scientific and Research Organizations*, 55(1), 56-68. <https://doi.org/10.2478/minib-2025-0004>
13. To, W.M., Yu, B.T.W. (2025). Artificial Intelligence Research in Tourism and Hospitality Journals: Trends, Emerging Themes, and the Rise of Generative AI. *Tourism and Hospitality*, 6(2), 63. <https://doi.org/10.3390/tourhosp6020063>
14. Villamediana, J., Küster, I., Vila, N. (2019). Destination engagement on Facebook: Time and seasonality. *Annals of Tourism Research*, 79, 102747. <https://doi.org/10.1016/j.annals.2019.102747>

15. Wang, J., Chen, X. (2025). Balancing Tourism Seasonality: The Role of Tourism Destination Image (TDI) and Spatial Levels (SLs). *Sustainability*, 17(6), 2569. <https://doi.org/10.3390/su17062569>
16. Zajadacz, A., Minkwitz, A. (2020). Using Social Media Data to Plan for Tourism. *Quaestiones Geographicae*, 39(3), 125-138. <https://doi.org/10.2478/quageo-2020-0027>
17. Zvaigzne, A., Litavniece, L., Dembovska, I. (2022). Tourism seasonality: The causes and effects. *Worldwide Hospitality and Tourism Themes*, 14(5), 421-430. <https://doi.org/10.1108/WHATT-07-2022-0080>
18. Żyminkowska, K., Zachurzok-Srebrny, E. (2025). The Role of Artificial Intelligence in Customer Engagement and Social Media Marketing—Implications from a Systematic Review for the Tourism and Hospitality Sectors. *Journal of Theoretical and Applied Electronic Commerce Research*, 20(3), 184. <https://doi.org/10.3390/jtaer20030184>

STRUCTURAL CHANGES IN THE DYNAMICS OF TAX ARREARS – EVIDENCE FROM POLAND (2003-2024)

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Purpose: The aim of the paper is to conduct a quantitative analysis of trends, turning points, and the impact of global crises on the scale and structure of tax arrears in Poland in the years 2003-2024. The study fills a gap in literature, where in-depth analyses based on long-term time series and econometric tools are still scarce.

Design/methodology/approach: The research employed statistical and econometric methods, including linear regression models and structural stability tests (e.g., Chow test). Annual time-series data covering the number of entities in arrears, the value of overdue tax liabilities, and the value of interest on arrears were analyzed. Special attention was paid to crisis periods: the global financial crisis (2008-2009), the COVID-19 pandemic (2020-2021), and geopolitical disruptions after 2022.

Findings: The analysis confirmed strong and statistically significant relationships between the number of entities, the value of liabilities, and the interest on tax arrears in the long run. However, structural stability tests revealed that crises significantly modified the mechanisms of fiscal debt accumulation – during the pandemic, extended repayment periods played a key role, while after 2022 both liabilities and interest increased simultaneously, reflecting intensifying fiscal pressure. Most of the research hypotheses (H1, H2, H3, H5) were confirmed.

Research limitations/implications: The main limitation is the relatively short time horizon of crisis subperiods (2-3 years), which constrains the power of structural stability tests. Moreover, the analysis relied solely on aggregated data, without incorporating broader macroeconomic variables. Future research should expand the models with additional determinants (e.g., GDP, inflation, energy prices) and include cross-country comparative studies.

Practical implications: The results indicate that during crises the risk of accumulating tax arrears increases significantly, requiring tax administrations to apply flexible tools such as relief programs, restructuring mechanisms, or liquidity support schemes. Identifying turning points helps design more effective preventive and intervention measures, thereby improving the efficiency of the tax system.

Social implications: Tax arrears negatively affect the financial condition of enterprises and households, and on a larger scale, undermine the fiscal stability of the state. The findings may inform public policy aimed at reducing the risk of tax debt accumulation and mitigating its social consequences, including financial exclusion and a decline in quality of life.

Originality/value: The paper contributes to the literature by providing a comprehensive quantitative analysis of long-term tax arrears trends in Poland using structural stability tests. It offers new insights into the mechanisms of tax debt formation under crisis conditions and may serve as a reference point for comparative research and fiscal policy practice in other countries.

Keywords: tax arrears, fiscal policy, economic crises, regression analysis, structural stability.

Category of the paper: Research paper.

1. Introduction

In recent years, the problem of tax arrears has gained significance both in public debate and in analyses concerning the public finance system. This phenomenon is particularly evident in the context of increased macroeconomic volatility, frequent legislative changes, and crises such as the COVID-19 pandemic or the currently observed systematic rise in defense expenditures. The scale and pace of the accumulation of tax arrears constitute an important indicator of the condition of the public revenue collection system as well as the effectiveness of the state's enforcement apparatus.

Tax indebtedness is a complex phenomenon, the causes of which stem from the interaction of multiple interconnected economic, legal, and social factors. At the macroeconomic level, key determinants include business cycle fluctuations, GDP (gross domestic product) growth rates, inflation, and labor market conditions. Periods of recession or economic slowdown typically result in deteriorating financial liquidity of enterprises and declining household incomes, which foster the emergence of tax arrears. High inflation further reduces the real value of taxpayers' incomes, making it more difficult to meet obligations to tax authorities on time.

Legal and institutional factors also play a crucial role. The design of the tax system, its transparency, and legislative stability significantly condition the level of voluntary tax compliance. Frequent amendments, excessive complexity, or a lack of clear interpretations may lead to unintentional breaches of tax obligations or payment delays. Moreover, the effectiveness of tax administration in monitoring and enforcing liabilities, the degree of digitalization of processes, and the availability of taxpayer support tools directly affect the scale of arrears. Social factors are also important, including the level of tax awareness, trust in public institutions, and attitudes toward compliance with tax law.

The problem of increasing tax indebtedness is not limited to Poland. Many OECD countries report a high level of tax arrears, which continue to rise despite the introduction of new enforcement mechanisms (OECD, 2019, 2020). In FTA countries, tax arrears reached approximately EUR 820 billion in 2019. OECD (2019) emphasizes that effective debt management requires both preventive measures and more advanced enforcement methods, as shown by international comparisons. Despite the implementation of innovative analytical

tools and digital control systems, the effectiveness of arrears collection remains limited in many states (OECD, 2024).

Quantitative analyses of taxation in various perspectives and dimensions are particularly important in shaping public policies, assessing the efficiency of state institutions, and creating conditions conducive to entrepreneurship. Tax costs and the high and uneven distribution of tax arrears across business forms, sectors, and industries are of particular importance. The sources of these problems lie both in non-compliance with tax regulations and in inefficient tax payment systems. An additional risk factor is the existence of tax havens and the specific characteristics of countries of the Global South, where weak fiscal institutions contribute to persistent arrears accumulation (Beck, 2021).

At the macroeconomic level, factors such as inflation, increases in minimum wages, and changes in the number of active business entities significantly affect tax indebtedness. Despite the growing importance of this problem, the scientific literature remains limited – there is a lack of in-depth theoretical studies in economics and finance as well as quantitative research based on long-term time series.

The aim of this article is to fill this gap by conducting a quantitative analysis of trends, turning points, and the impact of global crises on the scale and structure of tax arrears in Poland in the years 2003-2024, using statistical and econometric methods, including structural stability tests. The analysis is based on time-series data covering:

1. the total nominal value of tax arrears, and
2. the value of interest on arrears.

The scope of the study includes the identification of trends, turning points, potential structural changes, and the development of forecasting models. A quantitative approach – based on statistical and econometric methods – is not only appropriate but also necessary to draw objective and practically useful conclusions. The results may provide a foundation for further research, both quantitative and qualitative, as well as guidance for fiscal and treasury policy makers.

Tax indebtedness remains a global fiscal problem, requiring not only national but also international solutions. Therefore, a quantitative analysis – even when focused on Poland – can provide insights of broader significance, useful in the context of international comparisons.

2. Tax Debt, Compliance Mechanisms, and Socio-Economic Implications: A Literature Review

The issue of tax indebtedness among citizens and enterprises in Poland over the past two decades has become the subject of growing interest within the academic community. This increase stems from a variety of factors, among which the most significant are: legislative

changes in the tax system, global economic crises, persistent inflationary pressures, the effects of the COVID-19 pandemic, and payment backlogs (Jeżewski, 2021; Kobylski, 2024; Kraska, 2022; Nakonieczny, Nesterowicz, 2021; Sierpińska-Sawicz, 2023). Equally important are rising public expenditures, particularly in defense. A crucial backdrop for these phenomena is the steady growth of public debt and its consequences for the stability and security of public finances (Bożek, 2021; Ciak, 2024; Górniewicz, 2023; Kielin, 2023; Skwarek, 2024). The organization and efficient functioning of the state depend on access to capital, the primary source of which remains tax revenues.

The research presented in this article is not original in terms of the dataset analyzed. Rather, it supplements the limited body of quantitative studies that have attempted to examine the scale, dynamics, and determinants of tax indebtedness in sectoral, temporal, regional, and structural dimensions (Hybka, 2025; Poniatowicz, Jastrzębska, 2021; Walczak et al., 2011).

Debates over the level and distribution of taxation have long been present in the economic, legal, and political literature. However, they remain in the form of discourse without reaching consensus in either theoretical or practical terms. Among the key issues highlighted are: fiscal stability, the organization of tax administrations in terms of operating costs, efficiency in the collection of due levies, as well as protective and preferential systems (Braunerhjelm et al., 2021; Caporale et al., 2024; Djankov et al., 2010; Filipiak, Wyszowska, 2022; Iwin-Garzyńska, 2022; Mantzaris, Fošner, 2024; Radzikowski, 2021a, 2021b, 2022; Wojciechowski, 2021), advancing internationalization (Felis, 2008; Garcia-Bernardo, Janský, 2023), tax havens (Pawlak, 2022), tax crimes (Szymczyk, Szymański, 2022), debt spirals embedded in the behavior of enterprises and individuals not engaged in business activity (Talar, 2019) and finally, the costs of indebtedness (Iwin-Garzyńska, 2016).

2.1. International Evidence on Tax Arrears and Compliance Mechanisms

The analysis of tax debt in Poland gains a fuller dimension when placed in an international context. In many advanced economies, such as Germany, France, and the United Kingdom, mechanisms for monitoring and enforcing tax liabilities are strongly integrated with financial information systems and rely on intensive data exchange between tax administrations, financial institutions, and judicial authorities. Studies show that the digitalization of processes, the use of predictive analytics tools, and early preventive measures are crucial for reducing the scale of tax arrears. Solutions based on automatic information exchange and centralized taxpayer registers make it possible to identify insolvency risks more quickly and respond to them in real time (Bott et al., 2020; Dwenger et al., 2016; Hallsworth et al., 2017; Kleven et al., 2011; Kobylski, 2024; Perez-Truglia, Troiano, 2018; Pomeranz, 2015; Trescher, 2025).

In lower-income countries, including some emerging economies, challenges remain in the form of low levels of voluntary tax compliance, limited digitalization of processes, and insufficient human resources in tax administrations. Research by the World Bank (Hoy et al., 2021) and the International Monetary Fund (Beer, 2022), indicates that the effectiveness

of tax debt management largely depends on the gradual introduction of digital solutions, increased procedural transparency, enhanced data openness, and educational programs directed at taxpayers. OECD analyses (OECD, 2017, 2019, 2022b, 2022a, 2023, 2023, 2024) confirm that combining effective enforcement tools with measures facilitating timely payments—such as installment programs, simplified online payment procedures, and early-warning mechanisms—can significantly reduce the level of arrears and improve the efficiency of tax collection systems.

2.2. Socio-economic effects of excessive tax indebtedness and instruments for its mitigation

Excessive tax debt exerts a significant impact both on the microeconomic condition of individual entities and on the macroeconomic stability of the state. For enterprises, tax arrears often lead to reduced financial liquidity, which in turn results in lower investment expenditures, suspension of development plans, and in some cases the need for restructuring or even liquidation (Janský, Palanský, 2019). At the household level, tax debt may generate increasing financial difficulties, reduce creditworthiness, and heighten the risk of economic exclusion (Perez-Truglia, Troiano, 2018). Negative effects are also observed in the psychological sphere, where tax debt correlates with a decline in well-being and a reduced sense of financial security (Kettle et al., 2016).

At the macroeconomic level, the accumulation of uncollectible tax liabilities weakens the state's ability to finance public expenditures, deepens the budget deficit, and may force either higher tax burdens or borrowing on financial markets. Prolonged persistence of this phenomenon therefore poses a threat to fiscal stability and may undermine the country's creditworthiness in the international arena. A partial aspect of the problem is the statute of limitations on tax obligations, which reduces the effectiveness of tax enforcement and perpetuates arrears. In international literature, the OECD (2020) emphasizes the importance of preventive and intervention tools in managing tax debt, while studies by Bott et al. (2020) and Dwenger et al. (2016) demonstrate that early information campaigns and digital monitoring tools can significantly reduce the scale of indebtedness. It should be noted that the debt spiral amplifies the risk of a self-reinforcing mechanism of fiscal deterioration, particularly when ineffective enforcement instruments coincide with low voluntary tax compliance (Talar, 2019).

The literature identifies a range of solutions aimed at reducing the scale of tax arrears. Legal instruments include simplifying collection procedures, shortening enforcement times, and expanding the scope of asset seizure. Economic tools cover interest relief for prompt repayment, automated reminder systems, and the possibility of renegotiating payment schedules. Increasingly important are interventions based on behavioral economics, such as so-called “nudges” – subtle informational prompts encouraging timely payment. Examples from Australia, Canada, and Scandinavian countries demonstrate that combining traditional enforcement methods with educational initiatives and digitalized taxpayer communication can

substantially reduce tax debt levels and improve the overall efficiency of tax collection systems (Andersson et al., 2024; Biddle et al., 2017; Canada Revenue Agency, 2022; OECD, 2021).

3. Regression Analysis and Structural Stability Tests

The analysis was based on annual data from 2003-2024, covering: the number of entities with outstanding tax liabilities, the total value of overdue obligations (tax debt) and interest on overdue obligations (tax arrears), as well as the average value of liabilities and interest per entity.

The study was conducted in several stages. In the first step, descriptive and index analysis was applied, including year-on-year dynamics, long-term growth rates, and the relationships between the number of entities and liabilities, as well as between liabilities and interest, as a measure of the intensity of arrears. Next, the relationships between variables were examined using correlation coefficients and simple regression models. This made it possible to identify the links between the number of entities and the values of liabilities and interest.

In addition, the analysis accounted for the impact of external crisis events—the global financial crisis (2008-2009), the COVID-19 pandemic (2020-2021), and geopolitical tensions and energy price fluctuations after 2022. For this purpose, structural stability tests (including the Chow test) were applied to verify whether significant changes occurred in the nature of the relationships between variables during these periods.

Based on the literature review and quantitative data observations, the following research questions were formulated:

- 1) How did the dynamics of the number of entities with tax liabilities and the value of liabilities and interest evolve in 2003-2024?
- 2) What relationships exist between the number of entities and the size of tax liabilities and interest on tax arrears?
- 3) Did crisis periods (2008-2009, 2020-2021, post-2022) result in significant structural changes in the relationships between the studied variables?

The following research hypotheses were formulated:

- H1: There is a significant relationship between the value of tax arrears and the number of entities with such arrears.
- H2: During economic crises (e.g., the 2008 financial crisis, the COVID-19 pandemic, the post-2022 energy crisis), tax arrears grow faster than in periods of macroeconomic stability.
- H3: Interest on arrears remains strongly correlated with the total value of tax arrears; however, the nature of this relationship changes during periods of economic disruption.

H4: Legislative changes and increased tax burdens contribute to the growth of tax debt, regardless of economic conditions.

H5: Econometric models based on long-term time series can effectively identify turning points and structural changes in the mechanisms of tax debt formation.

The dependency analysis was carried out using a linear regression model, where in the first case the explanatory variable was the value of liabilities and the dependent variable was interest on overdue obligations, and in the second case the explanatory variable was the number of entities, and the dependent variable was the value of liabilities.

To assess the stability of these relationships over time, the Chow test was applied, which made it possible to verify whether statistically significant changes occurred in the structure of the regression model at selected breakpoints (2009 – financial crisis, 2019 – pre-pandemic period, 2020 – COVID-19 pandemic, 2022 – geopolitical disruptions).

Based on the statistical data analysis for the years 2003-2024, clear long-term trends and strong interdependencies between the studied variables can be identified. During the analyzed period, the number of entities increased more than fourfold—from 3370 in 2003 to 15,202 in 2024. The compound annual growth rate (CAGR) of the number of entities was approximately 7.64%. The value of tax liabilities grew even faster, rising from PLN 7.0 billion to PLN 93.1 billion (CAGR $\approx$ 13.93%). A similar dynamic was observed for interest on arrears, which increased from PLN 8.1 billion to PLN 85.6 billion (CAGR $\approx$ 12.23%). This indicates that both liabilities and the costs associated with late payments grew faster than the number of entities, resulting in an increasing per-entity burden.

The analysis of average values per entity confirms this trend. The average liability per entity rose from PLN 2.08 thousand in 2003 to PLN 6.13 thousand in 2024, while the average interest per entity increased from PLN 2.40 thousand to PLN 5.63 thousand over the same period. This demonstrates that the fiscal burden grew not only in macroeconomic but also in individual terms. This phenomenon can be interpreted as the effect of growing difficulties in settling obligations, which, combined with the rising number of economic entities, led to an increase in both aggregate and per-entity arrears.

Complementing the analysis are correlation results between variables across the entire period. A very strong positive relationship was found between the number of entities and the value of liabilities ($r = 0.994$; $p < 0.001$), and between the number of entities and the value of interest ($r = 0.935$; $p < 0.001$). An equally strong correlation was observed between the values of liabilities and interest ($r = 0.933$; $p < 0.001$), confirming that these phenomena are closely interconnected. The analysis of unit values (liabilities per entity and interest per entity), however, revealed a moderate correlation ($r = 0.700$; $p < 0.001$), suggesting that the intensity of the burden did not always change proportionally. This may indicate that at certain points—particularly during periods of macroeconomic disruption—the structure of relationships between the analyzed variables underwent significant transformations.

3.1. Liabilities–Interest Relationship

The linear regression analysis, in which the dependent variable was interest on tax arrears, and the independent variable was the level of liabilities, revealed very high statistical significance of the model in most of the analyzed subperiods (Tab. 1). The values of the coefficient of determination R^2 indicate that in the stable period 2010-2019, nearly 98% of the variability in interest could be explained by the level of tax liabilities, whereas during the financial crisis of 2003-2009 R^2 reached 0.88. The estimated regression parameters for these years were positive (0.44 and 0.73, respectively) and significant, confirming a strong and stable relationship between the two phenomena under conditions of macroeconomic equilibrium.

Further examination of the stability of this relationship over time, conducted using the Chow test, revealed significant changes during the most recent crises. For the sample split including the year 2009, the F-statistic value was 0.30 ($p = 0.745$), which indicates no significant structural differences in the relationship between interest and liabilities during the global financial crisis. A different picture emerges for the COVID-19 pandemic years (2020-2021), when the R^2 value reached 1.00 and the regression parameter took a negative value (-1.35). This suggests that despite the decline in the nominal level of liabilities, interest continued to rise, and the mechanism of the relationship was distorted by the extension of repayment periods for previously accumulated arrears. In this period, the F-statistics were 41.72 ($p < 0.001$), indicating a significant structural change.

An even more pronounced deviation from previous trends appeared in 2022-2024, under conditions of energy and geopolitical shocks. The average level of liabilities remained high (PLN 95.2 billion), while interest increased even more sharply (PLN 77.2 billion). The coefficient of determination fell to 0.32, and the regression parameter (-2.81) indicated a reversal of the nature of the relationship—interest accumulated independently of changes in the level of liabilities. Although the Chow test could not be formally carried out due to the very small number of observations, qualitative analysis suggests a cumulation of arrears and an intensification of the mechanism of their accumulation.

Table 1.
Analysis of the relationship: liabilities $\rightarrow$ interest

Period of analysis	Econometric results: regression and structural stability tests						
	Average level of liabilities (billion PLN)	Average level of interest (billion PLN)	R^2 of regression*	Regression coefficient (β)**	Chow test (F)	p-value (Chow test)	Significance of structural change
2003-2009 (financial crisis)	10.17	10.58	0.884	0.725	0.300	0.745	Not significant
2010-2019 (stable period)	48.03	26.43	0.979	0.023	25.503	0.000	Significant

Cont. table 1.

2020-2021 (COVID-19 pandemic)	96.44	57.80	1.00	-1.354	41.716	0.000	Significant
2022-2024 (geopolitical disruptions)	95.24	77.20	0.316	-2.814	n.d.	n.d.	n.d.

Note. * Extent to which variability of liabilities explains variability of interest, ** increase in liabilities translated into increase in interest. It is important to emphasize the methodological limitations associated with short time series for the periods 2020-2021 (2 years) and 2022-2024 (3 years). Such a small number of observations may lead to artificially high R^2 values, limited power of the Chow test, and—in the case of 2022-2024—the impossibility of formally performing the test (n.d.). Therefore, the results for these subperiods are exploratory in nature and should be interpreted mainly in the light of the macroeconomic context (COVID-19 pandemic, energy crisis, geopolitical tensions), whereas conclusions drawn from longer periods (2003-2009, 2010-2019) are methodologically more reliable.

Source: own study.

The obtained results show that although in the long run the relationship between liabilities and interest was strong and stable, during contemporary economic crises this dependency underwent profound modifications. During the COVID-19 pandemic, the extension of repayment periods for earlier liabilities played a key role, while after 2022 this mechanism intensified, as the scale of new arrears increased alongside the persistence of existing ones. The stability tests thus confirm that external shocks (the pandemic, the energy crisis, geopolitical uncertainty) contributed to a more rapid increase in both liabilities and the costs of servicing them.

3.2. Entities–Liabilities Relationship

The linear regression analysis, in which the dependent variable was the level of tax liabilities, and the independent variable was the number of entities in arrears, revealed a strong and stable relationship in the long run (Tab. 2). The coefficients of determination R^2 in the stable subperiods were very high, reaching 0.98 in 2010-2019, which means that almost all variability in liabilities could be explained by changes in the number of entities. The regression parameters ($\beta = 0.009$ in the stable period) were positive and statistically significant, indicating a predictable mechanism of liability growth as the number of debtors increased.

The Chow test analysis showed that for the sample split including the year 2009, the F-statistic took the value of 6.82 ($p = 0.006$), confirming a significant structural change in the relationship between the number of entities and liabilities during the global financial crisis. This change suggests that the mechanism of liability accumulation became less proportional—individual entities generated relatively higher arrears than in stable periods.

During the COVID-19 pandemic (2020-2021), the coefficient of determination reached 1.00, and the regression parameter was 0.008. Formally, the model indicates an almost perfect fit; however, due to the very small number of observations, these results should be interpreted with caution. The Chow test did not confirm a significant structural change in this period

($F = 0.45$; $p = 0.644$), although qualitative analysis suggests some deviations in the behavior of the relationship mechanism.

A different picture emerges in the years 2022–2024, when the number of entities in arrears reached the highest levels in the entire time series (an average of 15.2 thousand), while the value of the coefficient of determination dropped to only 0.03. The regression parameter took a very low value (0.001), indicating that in this period the number of entities ceased to be a good predictor of the scale of liabilities. Formal stability tests could not be performed due to the insufficient number of observations; however, empirical observations confirm that the mechanism of tax arrears accumulation weakened significantly and underwent modification during this time.

Table 2.

Analysis of the relationship: number of entities $\rightarrow$ liabilities

Period of analysis	Econometric results: regression and structural stability tests						
	Average level of liabilities (billion PLN)	Average number of entities (thousands)	R ² of regression*	Regression coefficient (β)**	Chow test (F)	p-value (Chow test)	Significance of structural change
2003-2009 (financial crisis)	10.17	3,909	0.914	4.844	6.820	0.006	Significant
2010-2019 (stable period)	48.03	9,287	0.983	8.715	1.111	0.351	Not Significant
2020-2021 (COVID-19 pandemic)	96.44	14,616	1.000	8.305	0.452	0,644	Not Significant
2022-2024 (geopolitical disruptions)	95.24	15,171	0.027	1.318	n.d.	n.d.	n.d.

Note. * Extent to which variability of liabilities explains variability of interest, ** The coefficient (β) represents the change in the total value of liabilities (in million PLN) associated with a unit increase in the number of entities.

Source: own study.

In summary, the obtained results show that in the long run the number of entities in arrears strongly explains the level of liabilities; however, during crisis periods this mechanism underwent transformations. In the global financial crisis, this relationship became more intensive, whereas under the conditions of the pandemic and geopolitical disruption the number of entities ceased to fully determine the value of liabilities. This indicates a differentiated impact of crisis factors on the scale and dynamics of tax arrears accumulation.

3.3. Empirical validation of tax indebtedness mechanisms

The conducted analysis confirmed the existence of a strong relationship between the value of tax liabilities and the amount of interest on arrears, which was reflected in the high level of the determination coefficient of the regression model. However, this relationship proved to be variable over time, as revealed by stability tests performed for crisis periods. The results of the

Chow test indicated no significant structural changes during the global financial crisis of 2008–2009, while in the case of the COVID-19 pandemic (2020–2021) and in the period of geopolitical disruptions after 2022, significant instability of the relationship was demonstrated.

During the pandemic years, a decline in the nominal value of liabilities was observed, accompanied by an increase in interest on arrears and a rise in the number of indebted entities. This phenomenon indicates that under conditions of reduced economic activity and macroeconomic uncertainty, the key factor was not the accumulation of new liabilities per entity, but rather the extension of repayment periods for existing obligations. Interest thus became an indicator of the intensification of liquidity problems, while the growing number of debtors signaled an expansion of the problem's scale.

A different pattern of change occurred after 2022, when a significant increase in interest, the persistence of high levels of liabilities, and the stabilization of the number of entities at record levels were simultaneously recorded. These results indicate that under shocks related to the geopolitical situation and rising energy prices, the relationship between the analyzed categories intensified interest grew faster than could be explained by nominal liabilities, while the high number of entities reinforced the effect of accumulation. It can thus be concluded that the most recent crises were characterized by deeper destabilization of fiscal mechanisms than in previous decades.

The analysis of the relationship between the number of entities and the value of tax liabilities revealed a similarly strong association, especially in longer subperiods. The coefficients of determination reached very high levels ($R^2 > 0.9$), which indicates that the number of debtors largely explained the scale of arrears. The stability of this relationship was confirmed in the years 2003–2009 and 2010–2019, although the Chow test for the financial crisis revealed a significant structural change, suggesting that at that time individual arrears accumulated faster than the number of entities.

During the COVID-19 pandemic (2020–2021), the model formally indicated an almost perfect fit, but with only two observations this result must be treated with caution. Nevertheless, the fact that liabilities remained high while the number of entities increased significantly suggests the spread of debt problems across the economy.

An even clearer departure from earlier trends emerged after 2022. In this period, the number of entities reached the highest values in the series analyzed, while the coefficient determination of the regression dropped sharply. This means that the number of debtors ceased to be a good predictor of the sum of liabilities—besides the quantitative factor, qualitative aspects such as the heterogeneity of arrears and deepening liquidity problems of specific groups of enterprises became increasingly important. This relationship indicates that in the context of contemporary crises, the number of entities did not always reflect the real burden of fiscal debt.

Taken together, the results demonstrate that both the liabilities–interest relationship and the entities–liabilities relationship are characterized by strong and statistically significant links in the long run, yet their mechanisms underwent substantial modifications in times of crisis.

This highlights the need for analyses that simultaneously consider the number of debtors, the volume of arrears, and the costs of servicing them in order to capture the full picture of fiscal system destabilization under external shocks. The conducted study does not address the causes, including the motivations for tax debt, but focuses solely on the scale of the phenomenon. Nevertheless, it constitutes an important contribution to literature, as an accurate diagnosis of the scale of tax arrears is a prerequisite for designing effective preventive and intervention measures. Defining the size of the problem makes it possible to better assess its fiscal consequences, identify the groups most at risk of debt accumulation, and indicate areas requiring more in-depth research into taxpayer motivations. In this way, the study creates a foundation for further qualitative and quantitative analyses that may in the future explain the sources of debt and shape appropriate fiscal policy.

In summary, most of the research hypotheses (H1, H2, H3, H5) were confirmed, which demonstrates the strong influence of macroeconomic and crisis-related factors on the scale and dynamics of tax debt. Only the hypothesis concerning the impact of legislative changes (H4) was not unequivocally confirmed—although the literature points to the important role of tax law stability, in the analyzed period it was difficult to distinguish the effects of legal changes from the influence of economic factors, which prevented full verification of this relationship. Thus, the obtained results suggest that macroeconomic factors and external crises have a more direct and measurable impact on tax debt than legislative changes themselves, which require further, in-depth qualitative research. Furthermore, our inability to isolate the distinct effect of legislative changes (H4) underscores the complexity of tax debt dynamics and suggests that future policy evaluations require more nuanced, qualitative approaches to disentangle the impact of legal reforms from concurrent economic shocks.

4. Discussion of results

Tax burdens reduce the incomes of enterprises, limiting their ability to satisfy needs, pursue development, and remain competitive, and in extreme cases leading to the erosion of assets. It is therefore not surprising that taxpayers attempt to counteract them (Klonowska, 2008). The phenomenon of non-payment of taxes includes both actions contrary to the law and situations arising from internal problems of enterprises, which are often the consequence of external macroeconomic or even global factors. The first category includes deliberate tax avoidance, income concealment, or operating in the shadow economy. The second category involves cases where failure to fulfill tax obligations results from loss of liquidity, declining demand, exchange rate fluctuations, rising input costs, or disruptions in supply chains. According to many studies, global economic crises and geopolitical tensions have a significant impact on the emergence of tax arrears (Alm et al., 2014; Brondolo, 2009; Caldara, Iacoviello,

2022; Haque et al., 2023) and in recent years also energy price volatility (Mousavi et al., 2024) and the COVID-19 pandemic (Athira, Ramesh, 2023; European Parliament. Directorate General for Internal Policies of the Union., 2023; Hartmann et al., 2022; Kobbi-Fakhfakh, Bougacha, 2023; Țibulcă, 2022; Zhu et al., 2023), which directly affected market stability and the capacity to settle fiscal liabilities on time.

The empirical analysis confirmed the existence of strong relationships between overdue tax liabilities, interest on arrears, and the number of entities in arrears. However, these relationships were not stable over time, as evidenced by structural stability tests. In the long-term perspective, regression models showed high explanatory power, with R^2 values exceeding 0.9 in stable periods. Nevertheless, crisis episodes such as the global financial crisis, the COVID-19 pandemic, and post-2022 geopolitical disruptions revealed significant modifications in these mechanisms.

During the COVID-19 pandemic, liabilities decreased while interest levels increased, suggesting that the key mechanism was not the accumulation of new arrears but the extension of repayment periods for existing ones. This finding aligns with international studies (e.g., OECD reports, IMF working papers) that highlight liquidity constraints and payment delays during pandemic-related restrictions. Conversely, after 2022, both liabilities and interest rose simultaneously, reflecting cumulative effects of geopolitical instability and rising energy prices. This observation corresponds with broader literature emphasizing fiscal stress during external shocks.

The relationship between the number of entities and total liabilities was also strong but more sensitive to crisis periods. In stable times, the number of entities was a reliable predictor of total arrears. However, in the most recent crises this link weakened, as liabilities grew faster or slower than the number of entities, indicating a decoupling between the scale of debtors and the value of arrears. This is consistent with empirical evidence from other economies, where shocks altered both the extent and intensity of fiscal burdens. Importantly, the results confirm theoretical findings that arrears should not be seen solely as intentional non-compliance but also as systemic shocks that constrain taxpayers' financial capacity.

From a policy perspective, these findings imply that effective countermeasures should go beyond stricter enforcement and address systemic vulnerabilities—such as liquidity shortages, energy price volatility, or disrupted supply chains—that directly affect taxpayers' ability to meet obligations. Structural breaks identified in the models clearly show that crises not only increase the scale of arrears but also alter the very mechanisms that link liabilities, interest, and the number of indebted entities. As highlighted by comparative studies (Alm et al., 2014; Hartmann et al., 2022), the resilience of the tax system depends not only on enforcement capacity but also on the flexibility of instruments that mitigate the impact of crises on taxpayers. Designing adaptive fiscal tools, including temporary tax reliefs, restructuring schemes, or targeted support measures, could therefore reduce the risk of long-term arrears accumulation and protect both public revenues and enterprise viability. An equally important element is the

early monitoring of liquidity indicators and fiscal pressures in the business sector, enabling authorities to react quickly to emerging risks. Finally, experiences such as the COVID-19 relief packages demonstrate that temporary, targeted interventions at the national and EU levels can play a crucial role in sustaining both compliance and economic stability during systemic shocks.

This study provides insights into the dynamics of tax arrears in Poland, but its limitations should be acknowledged. The analysis relies on aggregated national data, which masks sectoral, regional, and firm-size heterogeneity. Furthermore, the models do not incorporate broader macroeconomic variables (e.g., GDP growth, unemployment, inflation), limiting the ability to fully explain the drivers behind the observed structural changes. Finally, the short time span of the recent crisis sub-periods (2020-2021 and 2022-2024) constrains the statistical power of the stability tests, making these results more indicative.

These limitations suggest fruitful directions for future research. Studies utilizing disaggregated data could identify high-risk sectors and regions. Expanding the models to include macroeconomic determinants would offer a more robust explanation of arrears formation. Finally, comparative cross-country analyses could determine whether the observed structural changes are specific to Poland or part of a broader regional pattern.

5. Conclusions

The results demonstrate that in the long run, relationships between overdue liabilities, interest on arrears, and the number of entities in arrears are strong and statistically significant. However, economic crises trigger structural changes that reshape these dependencies. During the pandemic, the persistence of arrears rather than their volume became the main driver of interest accumulation. After 2022, the simultaneous rise in liabilities and interest revealed intensified fiscal stress.

Research limitations should be emphasized. Short subperiods (2020-2021, 2022-2024) reduce the reliability of statistical inference, particularly in structural stability tests (Chow test). Moreover, the analysis is based solely on aggregated data, without incorporating broader macroeconomic determinants. These constraints suggest that findings for the most recent years should be treated as exploratory.

Practical implications arise for fiscal authorities, who should account for the heightened risk of arrears accumulation during crises, especially due to extended repayment periods and increased unit burdens. Scientific implications include the need to integrate crisis-sensitive factors into models of tax arrears and to test structural stability more systematically.

Future research directions should include expanding the model by introducing additional macroeconomic variables such as GDP dynamics, unemployment, or energy prices. Comparative studies across countries would also allow verification of whether the observed structural changes are specific to Poland or represent a broader pattern of fiscal dynamics under external shocks.

References

1. Alm, J., Hodge, T.R., Sands, G., Skidmore, M. (2014). Detroit Property Tax Delinquency: Social Contract in Crisis. *Public Finance and Management*, 14(3), 280-305. <https://doi.org/10.1177/152397211401400302>
2. Andersson, H., Engström, P., Nordblom, K., Wanander, S. (2024). Nudges and threats: Soft versus hard incentives for tax compliance. *Economic Policy*, 38(116), 771-819. <https://doi.org/10.1093/epolic/eiad017>
3. Athira, A., Ramesh, V.K. (2023). COVID-19 and corporate tax avoidance: International evidence. *International Business Review*, 32(4), 102143. <https://doi.org/10.1016/j.ibusrev.2023.102143>
4. Beck, G. (2021). *The severe problem of tax arrears in Mediterranean countries*. https://www.europarl.europa.eu/doceo/document/E-9-2021-003183_EN.html
5. Beer, S. (2022). How to Evaluate Tax Expenditures. *IMF How To Notes*, 5, 1. <https://doi.org/10.5089/9798400221507.061>
6. Biddle, N., Fels, K., Sinning, M. (2017). Behavioral Insights and Business Taxation: Evidence from Two Randomized Controlled Trials. *Journal of Behavioral and Experimental Finance*, 18, 30-49.
7. Bott, K.M., Cappelen, A. W., Sørensen, E.Ø., Tungodden, B. (2020). You've Got Mail: A Randomized Field Experiment on Tax Evasion. *Management Science*, 66(7), 2801-2819. <https://doi.org/10.1287/mnsc.2019.3390>
8. Bożek, W. (2021). „Stabilność sektora finansów publicznych” w warunkach pandemii COVID-19. *Prawo Budżetowe Państwa i Samorządu*, 9(4), 69-85. <https://doi.org/10.12775/PBPS.2021.022>
9. Braunerhjelm, P., Eklund, J.E., Thulin, P. (2021). Taxes, the tax administrative burden and the entrepreneurial life cycle. *Small Business Economics*, 56(2), 681-694. <https://doi.org/10.1007/s11187-019-00195-0>
10. Brondolo, J. (2009). Collecting Taxes During an Economic Crisis: Challenges and Policy Options. *IMF Staff Position Notes*, 17, 2. <https://doi.org/10.5089/9781462339440.004>
11. Caldara, D., Iacoviello, M. (2022). Measuring Geopolitical Risk. *American Economic Review*, 112(4), 1194-1225. <https://doi.org/10.1257/aer.20191823>

12. Canada Revenue Agency (2022). *Evaluation: CRA management of small business nudge. Government of Canada*. <https://www.canada.ca/en/revenue-agency/corporate/about-canada-revenue-agency-cra/evaluation-reports/evaluation-cra-management-small-business-nudge.html>
13. Caporale, G.M., Tapia, S.G., Gil-Alana, L.A. (2024). Persistence in Tax Revenues: Evidence from Some OECD Countries. *Journal of Quantitative Economics*, 22(2), 475-491. <https://doi.org/10.1007/s40953-024-00386-x>
14. Ciak, J.M. (2024). Konsekwencje zadłużenia publicznego dla bezpieczeństwa finansów publicznych. *Studia i Prace Kolegium Zarządzania i Finansów*, 193, 9-30. <https://doi.org/10.33119/SIP.2023.193.1>
15. Djankov, S., Ganser, T., McLiesh, C., Ramalho, R., Shleifer, A. (2010). The Effect of Corporate Taxes on Investment and Entrepreneurship. *American Economic Journal: Macroeconomics*, 2(3), 31-64. <https://doi.org/10.1257/mac.2.3.31>
16. Dwenger, N., Kleven, H., Rasul, I., Rincke, J. (2016). Extrinsic and Intrinsic Motivations for Tax Compliance: Evidence from a Field Experiment in Germany. *American Economic Journal: Economic Policy*, 8(3), 203-232. <https://doi.org/10.1257/pol.20150083>
17. European Parliament. Directorate General for Internal Policies of the Union (2023). *National tax measures in response to the COVID-19 crisis: Assessment of their impact and results lessons to be learned for future crises*. Publications Office. <https://data.europa.eu/doi/10.2861/46353>
18. Felis, P. (2008). Ryzyko podatkowe podmiotów powiązanych w konstrukcji podatków dochodowych. *Zeszyt Naukowy*, 90. Szkoła Główna Handlowa, 26-44.
19. Filipiak, B.Z., Wyszowska, D. (2022). Fiscal stability in EU countries. *Wiadomości Statystyczne. The Polish Statistician*, 67(8), 17-40. <https://doi.org/10.5604/01.3001.0015.9703>
20. Garcia-Bernardo, J., Janský, P. (2023). *Profit Shifting of Multinational Corporations Worldwide* (Nr arXiv:2201.08444). arXiv. <https://doi.org/10.48550/arXiv.2201.08444>
21. Górniewicz, G. (2023). Dług publiczny krajów Unii Europejskiej w okresie pandemii COVID-19. *Nierówności Społeczne a Wzrost Gospodarczy*, 73, 21-38. <https://doi.org/10.15584/nsawg.2023.1.2>
22. Hallsworth, M., List, J.A., Metcalfe, R.D., Vlaev, I. (2017). The behavioralist as tax collector: Using natural field experiments to enhance tax compliance. *Journal of Public Economics*, 148, 14-31. <https://doi.org/10.1016/j.jpubeco.2017.02.003>
23. Haque, T., Pham, T.P., Yang, J. (2023). Geopolitical risk, financial constraints, and tax avoidance. *Journal of International Financial Markets, Institutions and Money*, 88, 101858. <https://doi.org/10.1016/j.intfin.2023.101858>
24. Hartmann, A.J., Gangl, K., Kasper, M., Kirchler, E., Kocher, M.G., Mueller, M., Sonntag, A. (2022). The economic crisis during the COVID-19 pandemic has a negative effect on

- tax compliance: Results from a scenario study in Austria. *Journal of Economic Psychology*, 93, 102572. <https://doi.org/10.1016/j.joep.2022.102572>
25. Hoy, C., McKenzie, L., Sinning, M. (2021). *Improving Tax Compliance without Increasing Revenue: Evidence from Population-Wide Randomized Controlled Trials in Papua New Guinea*. Washington, DC: World Bank, <https://doi.org/10.1596/1813-9450-9539>
26. Hybka, M.M. (2025). Collecting and Managing Tax Debt in Poland. *Prace Naukowe Uniwersytetu Ekonomicznego We Wrocławiu*, 69(1), 46-58. <https://doi.org/10.15611/pn.2025.1.04>
27. Iwin-Garzyńska, J. (2016). Tax Aspects of Debt in the Enterprise. *Zeszyty Naukowe Uniwersytetu Szczecińskiego Finanse Rynki Finansowe Ubezpieczenia*, 80, 53-61. <https://doi.org/10.18276/frfu.2016.2.80/1-06>
28. Iwin-Garzyńska, J. (2022). Tax shield depreciation and inflation. *Doradztwo Podatkowe - Biuletyn Instytutu Studiów Podatkowych*, 11(315), 10-12. <https://doi.org/10.5604/01.3001.0016.1217>
29. Janský, P., Palanský, M. (2019). Estimating the scale of profit shifting and tax revenue losses related to foreign direct investment. *International Tax and Public Finance*, 26(5), 1048-1103. <https://doi.org/10.1007/s10797-019-09547-8>
30. Jeżewski, R. (2021). Wpływ koronawirusa SARS-CoV-2 (jako wystąpienie siły wyższej) na zadłużenie Polaków/The impact of the SARS-CoV-2 coronavirus (as an occurrence of force majeure) on the debt of Poles. *The Scientific Journal of the Polish Economic Society*, 8(14), 50-64. <https://doi.org/10.26366/PTE.ZG.2021.191>
31. Kettle, S., Hernandez, M., Ruda, S., Sanders, M. (2016). *Behavioral Interventions in Tax Compliance: Evidence from Guatemala*. Washington, DC: World Bank, <https://doi.org/10.1596/1813-9450-7690>
32. Kielin, Ł. (2023). Limit zadłużenia z art. 216 ust. 5 Konstytucji RP w dobie pandemii wirusa COVID-19 oraz w obliczu agresji Rosji na Ukrainę. *Przegląd Prawa Konstytucyjnego*, 72(2), 39-50. <https://doi.org/10.15804/ppk.2023.02.03>
33. Kleven, H.J., Knudsen, M.B., Kreiner, C.T., Pedersen, S., Saez, E. (2011). Unwilling or Unable to Cheat? Evidence From a Tax Audit Experiment in Denmark. *Econometrica*, 79(3), 651-692. <https://doi.org/10.3982/ECTA9113>
34. Klonowska, A. (2008). Ekonomiczne skutki ucieczki przed podatkiem. *Zeszyty Naukowe / Uniwersytet Ekonomiczny w Krakowie*, 778, 211-244.
35. Kobbi-Fakhfakh, S., Bougacha, F. (2023). The impact of the COVID-19 pandemic on corporate tax avoidance: Evidence from S&P 500 firms. *Journal of Financial Reporting and Accounting*, 21(4), 847-866. <https://doi.org/10.1108/JFRA-06-2022-0216>
36. Kobylski, P. (2024). Zagrożenia i kierunki zmian Polskiego Ładu. *Zeszyty Prawnicze*, 24(3), 71-89. <https://doi.org/10.21697/zp.2024.24.3.04>
37. Kraska, E.M. (2022). Wpływ pandemii COVID-19 na kondycję finansową przedsiębiorstw w Polsce. *Przegląd Prawno-Ekonomiczny*, 2, 79-96. <https://doi.org/10.31743/ppe.13241>

38. Mantzaris, C., Fošner, A. (2024). *Germany's Tax Revenue and its Total Administrative Cost* (Nr arXiv:2411.12543). arXiv. <https://doi.org/10.48550/arXiv.2411.12543>
39. Mousavi, M.M., Gozgor, G., Acheampong, A. (2024). Do oil market shocks affect financial distress? Evidence from firm-level global data. *Journal of Commodity Markets*, 36, 100436. <https://doi.org/10.1016/j.jcomm.2024.100436>
40. Nakonieczny, J., Nesterowicz, R. (2021). Ocena systemu podatkowego w opinii przedsiębiorców z województwa podkarpackiego. *Przedsiębiorczość - Edukacja*, 17(2), 9-26. <https://doi.org/10.24917/20833296.172.1>
41. OECD (2017). *The Changing Tax Compliance Environment and the Role of Audit*. OECD. <https://doi.org/10.1787/9789264282186-en>
42. OECD (2019). *Successful Tax Debt Management: Measuring Maturity And Supporting Change*. OECD Publishing. <https://doi.org/10.1787/e8fdb816-en>
43. OECD (2021). *Behavioural Insights for Better Tax Administration: A Brief Guide*. OECD Publishing. <https://doi.org/10.1787/582c283e-en>
44. OECD (2022a). *Tax Administration 2022: Comparative Information on OECD and other Advanced and Emerging Economies*. OECD Publishing. <https://doi.org/10.1787/1e797131-en>
45. OECD (2022b). *Tax Policy Reforms 2022: OECD and Selected Partner Economies*. OECD Publishing. <https://doi.org/10.1787/067c593d-en>
46. OECD (2023). *Tax Administration 2023: Comparative Information on OECD and other Advanced and Emerging Economies*. OECD Publishing. <https://doi.org/10.1787/900b6382-en>
47. OECD (2024). *Tax Administration 2024: Comparative Information on OECD and other Advanced and Emerging Economies*. OECD. <https://doi.org/10.1787/2d5fba9c-en>
48. Pawlak, M. (2022). Raje podatkowe i ich wykorzystanie przez zagraniczne korporacje działające na terenie Polski. *Nowe Tendencje w Zarządzaniu*, 2, 21-49. <https://doi.org/10.31743/ntz.13961>
49. Perez-Truglia, R., Troiano, U. (2018). Shaming tax delinquents. *Journal of Public Economics*, 167, 120-137. <https://doi.org/10.1016/j.jpubeco.2018.09.008>
50. Pomeranz, D. (2015). No Taxation without Information: Deterrence and Self-Enforcement in the Value Added Tax. *American Economic Review*, 105(8), 2539-2569. <https://doi.org/10.1257/aer.20130393>
51. Poniatowicz, M., Jastrzębska, M. (2021). Zadłużenie jednostek samorządu terytorialnego i jego determinanty. *Studia BAS*, 68(4). <https://doi.org/10.31268/StudiaBAS.2021.40>
52. Radzikowski, K. (2021a). The modern dilemmas of equality and fairness in taxation (Part 3). *Doradztwo Podatkowe - Biuletyn Instytutu Studiów Podatkowych*, 2(294), 36-38. <https://doi.org/10.5604/01.3001.0014.7762>

53. Radzikowski, K. (2021b). Współczesne dylematy równości i sprawiedliwości opodatkowania (cz. 2). *Doradztwo Podatkowe - Biuletyn Instytutu Studiów Podatkowych*, 1(293), 20-23. <https://doi.org/10.5604/01.3001.0014.7017>
54. Radzikowski, K. (2022). Prawo podatkowe w cieniu populizmu (na przykładzie Polskiego Ładu). *Studia Iuridica*, 91, 334-350. <https://doi.org/10.31338/2544-3135.si.2022-91.19>
55. Sierpińska-Sawicz, A. (2023). Przyczyny i skutki zatorów płatniczych w przedsiębiorstwach w sektorze B2B w Polsce i krajach europejskich. in: C. Kochalski (ed.), *Analiza ekonomiczna przedsiębiorstw w warunkach niepewności* (pp. 135-155). Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu. <https://doi.org/10.18559/978-83-8211-195-8/8>
56. Skwarek, A. (2024). Public debt and Poland's financial security. *Studia Administracji i Bezpieczeństwa*, 16(16), 184-193. <https://doi.org/10.5604/01.3001.0054.6833>
57. Szymczyk, P., Szymański, W. (2022). Analiza i ocena regulacji uszczelniających w zakresie podatku od towarów i usług wdrożonych na przestrzeni ostatnich lat. *Doradztwo Podatkowe - Biuletyn Instytutu Studiów Podatkowych*, 3(307), 4-26. <https://doi.org/10.5604/01.3001.0015.8111>
58. Talar, T. (2019). Tax debt spiral. *Journal of Modern Science*, 39(4), 293-307. <https://doi.org/10.13166/jms/96312>
59. Țibulcă, I.-L. (2022). The impact of the COVID-19 pandemic on tax revenues in the EU. *Economic Research-Ekonomska Istraživanja*, 35(1), 2442-2459. <https://doi.org/10.1080/1331677X.2021.1954967>
60. Trescher, B. (2025). L'appréhension de l'intelligence artificielle par la fiscalité française. *Studi Tributari Europei*, 14(1). <https://doi.org/10.6092/ISSN.2036-3583/21289>
61. Walczak, D., Kołosowska, B., Krupa, D. (2011). Dopuszczalny poziom zadłużenia jednostek samorządu terytorialnego w świetle nowej ustawy o finansach publicznych. *Prace Naukowe Uniwersytetu Ekonomicznego We Wrocławiu*, 173, 692-699.
62. Wojciechowski, K. (2021). Prawo podatkowe w poglądach i polityce Andrew Mellona. *Studia Prawno-Ekonomiczne*, 119. <https://doi.org/10.26485/SPE/2021/119/7>
63. Zhu, J., Ho, K.-C., Luo, S., Peng, L. (2023). Pandemic and tax avoidance: Cross-country evidence. *Economic Modelling*, 124, 106300. <https://doi.org/10.1016/j.econmod.2023.106300>

THE EVOLUTION OF TOURIST PREFERENCES IN POLAND IN 2022-2025: A CASE STUDY OF OKUNINKA AT LAKE BIAŁE

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Purpose: The purpose of this paper is to analyze the evolution of tourist preferences in Poland between 2022 and 2025, using the case of Okuninka at Lake Białe. The research seeks to identify key trends such as the shortening of stays, the growing role of social media in decision-making, the demand for premium amenities, and demographic differences in leisure expectations.

Design/methodology/approach: The study is based on a mixed-methods design combining qualitative and quantitative techniques. The empirical data were collected through (1) content analysis of social media posts and comments, (2) in-depth interviews with accommodation providers, and (3) participant observation conducted on-site during the tourist seasons of 2022-2025. Triangulation of methods increased the robustness of findings. Statistical analyses (t-tests, χ^2 tests) were used to identify significant patterns, while thematic analysis provided deeper insights into motivations and perceptions.

Findings: The results reveal a clear shift from week-long vacations to short-term, weekend-oriented stays, often booked less than a week in advance. Premium amenities such as jacuzzis, saunas, and wellness zones have become decisive competitive factors. Tourist expectations are strongly differentiated by age and gender: younger visitors seek entertainment and social interaction, older groups prioritize peace and comfort, women emphasize aesthetics and amenities, while men focus on price–location balance. Observations highlight the contrast between families and younger tourists, as well as the popularity of cottages that enable private gatherings and barbecues. Rising perceptions of an unfavorable price-to-quality ratio indicate increasing consumer sensitivity to costs.

Research limitations/implications: The study is limited to one seasonal destination and to the period of 2022–2025, which may restrict generalizability. Data from social media capture public discourse but not necessarily private motivations. Future research could broaden the scope by including comparative analyses of other Polish tourist regions, longitudinal studies beyond 2025, and deeper exploration of the environmental and cultural impacts of short-term tourism.

Practical implications: The findings suggest that accommodation providers must adapt to a new consumption model by offering short-stay packages, investing in premium amenities, and adopting flexible pricing strategies. Effective use of social media for last-minute marketing becomes crucial. For regional policymakers, the results indicate a need to support

diversification of tourism products and year-round attractions to mitigate the risks of seasonality.

Social implications: The growing popularity of short, intensive leisure trips affects local communities by concentrating noise, traffic, and crowding in peak periods. Families staying close to the entertainment center often face conflicts between accessibility and the need for quiet. The rising number of tourists traveling with pets highlights new challenges for infrastructure and service design. Findings may inform community discussions on sustainable tourism, public space management, and coexistence of diverse tourist groups.

Originality/value: (The paper provides one of the first comprehensive analyses of post-pandemic tourist behavior in a Polish seasonal resort, combining social media analytics with interviews and field observations. It offers both theoretical insights into changing patterns of tourism consumption and practical recommendations for local businesses and policymakers.

Keywords: tourist preferences; short-term tourism; social media; Okuninka; Lake Białe.

Category of the paper: Research paper; Case study.

1. Introduction

Changes in tourist preferences represent one of the key challenges for the contemporary tourism economy. Dynamic social, economic, and technological processes significantly affect the way destinations are chosen, trips are planned, and expectations regarding stays are defined. Short-term trips, often organized spontaneously, are gaining increasing importance, while consumer decisions are more frequently based on information available in social media and reviews shared by other Internet users.

In Poland, this phenomenon is particularly evident in seasonal destinations that have long attracted visitors from both the region and beyond. Okuninka, located at Lake Białe, provides an example of a microregion where tourist traffic is concentrated mainly during the summer season. Along with the growing popularity of this location, visitors' expectations are also changing: in addition to basic accommodation services, there is a growing demand for higher standards and premium amenities, such as hot tubs, jacuzzis, or saunas.

The analysis of tourist preferences also reveals clear generational and gender-based differences in approaches to leisure. Younger tourists primarily seek entertainment, a dynamic lifestyle, and opportunities for social integration, whereas older groups attach greater importance to peace, quiet, and comfort. Women tend to emphasize the aesthetics of the place and additional amenities more often, while men are more focused on the price–quality ratio and convenient location.

Tourist decisions are increasingly shaped by economic factors, including inflation and rising living costs. Visitors expect high-quality services while simultaneously optimizing expenditures, which forces accommodation providers to flexibly adapt their offerings—both in terms of the length of stay (e.g., weekend packages) and the diversity of additional services.

The dynamic transformations in tourist behavior in Poland after 2020 give rise to new research challenges related to adapting traditional models of tourism consumption to socio-economic and technological realities. Phenomena such as the shortening of stays, the growing importance of last-minute bookings, the influence of social media on decision-making, and the rising demand for premium amenities indicate the emergence of a new paradigm of domestic tourism. The research problem of this study focuses on the question of how tourist preferences in Poland evolved between 2022 and 2025 using the example of Okuninka at Lake Białe, and what social, economic, and cultural factors determine these changes. This case study makes it possible to capture both the local specificity of the phenomenon and the broader processes of transformation in short-term tourism in Poland.

The aim of this article is to provide an in-depth analysis of changes in tourist preferences in the years 2022-2025, based on the case of Okuninka and Lake Białe. The empirical basis of the study consists of social media posts, interviews with accommodation providers, and field observations. The results make it possible not only to capture the specificity of local tendencies but also to indicate broader directions of change in domestic tourism.

2. Contemporary Changes in Tourist Preferences – A Literature Review

Changes in tourist preferences are the subject of intensive research in the international literature. Particular attention is paid to the growing popularity of short-term weekend trips, which in many regions are beginning to dominate over traditional, longer forms of leisure. An example is research conducted among tourists from Budapest visiting waterside destinations, where the predominance of short-term travel was clearly confirmed, resulting, among other things, from time and economic constraints, as well as studies carried out in Barcelona (Kádár, Gede, 2022; Suriñach et al., 2019). These findings correspond with trends observed in Poland, where recreational trips lasting only a few days, often organized spontaneously, are increasingly chosen.

A second important area of research is the role of social media in the process of selecting tourist destinations. As scientific analyses indicate, the impact of content published online is particularly strong in the case of new and unfamiliar places, whereas for well-established destinations this influence may be weaker (Johan Andersson, 2024; Tham et al., 2020; Wang, Yan, 2022). In the Polish context, this issue has also been studied, and researchers emphasize that although influencers and user-generated content are important sources of inspiration, they are not always treated as fully reliable decision-making tools (Zawadka, Liwińska, 2022). Similar conclusions are presented by Barbu and co-authors, who highlight the key role of social media marketing activities in shaping tourist choices, especially among young audiences (Barbu et al., 2024).

The importance of younger age groups in shaping new patterns of tourism consumption is also emphasized in Asian studies. Researchers point out that among young tourists in Malaysia, social media plays a crucial role in trip planning, selecting attractions, and ways of spending leisure time (Siti Yuliandi Ahmad, Nur Qasdina Asyura Pg Idris, 2024). These findings are consistent with observations concerning young Polish tourists, who prefer active forms of leisure and attach great importance to integration and entertainment aspects.

Another widely discussed element in the literature is the growing role of premium and luxury amenities in the accommodation sector. Available analyses show that the attractiveness of such services is strongly linked to tourists' emotional attachment to a destination brand ("Destination Brand Love"), which enhances their loyalty and willingness to incur higher expenditures (Morando, Platania, 2022; Swanson, 2017; Tang et al., 2023). Premium amenities thus become not only a factor of competitiveness but also a means of building lasting relationships between visitors and the place of stay.

The problem of seasonality in tourist traffic, which is one of the key challenges for summer holiday destinations, is also of great importance. According to scientific analyses, seasonality is a global phenomenon generating both opportunities and threats for local tourism economies (Duro, Turrión-Prats, 2019). Researchers point out that it is associated with difficulties in managing tourism infrastructure and providing stable employment, making local economies particularly sensitive to fluctuations in demand (Butler, 1998). The literature also emphasizes that seasonality affects not only economic but also social and environmental aspects—it leads to overuse of resources in peak season and their underutilization outside of it (Zvaigzne et al., 2022). Empirical analyses further indicate that in rural tourism, the intensity of seasonality is determined by both natural factors and the structure of the local service offer (Li, 2023). Other studies show that the development of cultural tourism can reduce seasonal fluctuations, attracting visitors even outside the summer period (Zhang et al., 2022). Practical recommendations, in turn, focus on the need to apply seasonality management tools, such as diversification of tourism products or organizing events outside the high season, which can stabilize demand and increase the attractiveness of a destination throughout the year (Hutsal, Stoliar, 2023). Researchers also point out that seasonality is rooted not only in economic and natural factors but also in cultural and institutional conditions, as confirmed by historical-anthropological analyses highlighting the role of demand distribution policies in shaping tourist flows (Rudihartmann, 1986). In destinations such as Okuninka, dependence on the summer season determines accommodation strategies and forces the adaptation of offers to a short period of intense demand, while at the same time creating a need to develop year-round products and implement measures to mitigate the effects of seasonality.

Polish studies on tourist preferences have examined leisure forms, accommodation choices, sources of information, and destination selection factors. Research indicates that price, user reviews, word-of-mouth marketing, and social media are increasingly decisive in shaping tourist behavior in Poland (Herbik, 2024). Other analyses show that tourists seek peace, contact

with nature, and cultural assets, with agritourism and “emotion tourism” (e.g. thematic villages) becoming more popular (Wojciechowska-Solis et al., 2022). In the context of sustainable development, studies highlight the extent to which Polish lodging facilities adopt low-emission practices and communicate these efforts to tourists (Rutecka et al., 2023). However, there are relatively few works covering the period 2022–2025 that focus on short-term weekend stays, premium amenities (e.g. jacuzzis, wellness zones), and demographic segmentation of preferences. The Okuninka case study therefore fills an important gap in the national tourism literature.

In summary, the literature clearly indicates three dominant trends in contemporary tourism: (1) the shortening of stays and the growing popularity of short-term travel, (2) the increasing role of social media in destination choice, and (3) the growing importance of premium amenities as a competitive differentiator. All these phenomena are reflected in the case of Okuninka at Lake Białe, which makes it an interesting case study for analyzing changes in tourist preferences in Poland.

3. Research Methodology

The research was conducted between 2022 and 2025 and employed three complementary data collection techniques: content analysis of social media, in-depth interviews, and participant observation. The application of methodological triangulation made it possible to obtain a comprehensive picture of the phenomenon, while the combination of qualitative and quantitative data increased the reliability of the findings.

The first technique was a content analysis of social media, focused on the Facebook group titled “Okuninka Jezioro Białe – noclegi (domki, pokoje, kwatery, pola namiotowe)”, which at the time of the last data collection had nearly 40,000 members. This group served as one of the main online forums for the exchange of information, opinions, and offers related to tourism in the Lake Białe region of Okuninka. The analysis covered both accommodation advertisements and tourists’ reactions in the form of questions, comments, and opinions, as well as interactions (likes, shares). A qualitative content analysis was applied, aimed at identifying dominant themes, communication patterns, and ways of presenting the tourism offer and participants’ experiences. The material was purposefully selected and included posts published during the peak tourist season (June–August), when activity was the highest, and outside the season (November–February), to capture differences in the intensity and character of discussions. In total, 1250 posts and 4860 comments were analyzed. The analysis was conducted in line with the principles of internet research ethics—data were collected from the public domain, without interfering with the content of the publications and without disclosing any personal information.

The second technique consisted of in-depth interviews conducted with 25 owners of accommodation facilities (holiday cottages, guest rooms, boarding houses). The conversations focused primarily on changes in customer behavior, length of stay, expectations regarding amenities, and booking methods.

The third element comprised participant observations, carried out on-site in Okuninka during the summer seasons of 2022–2025. They concerned tourist behavior and the use of tourism infrastructure, which made it possible to capture the dynamics of social interactions and recreational practices in the tourist space.

The collected empirical material was subjected to statistical analysis. The analysis covered the following quantitative data: length of stay, timing of reservations, and the importance of amenities in relation to tourists' demographic characteristics. Student's t-test for independent samples was applied to compare the average length of stay in 2022 and 2025, and χ^2 tests were used for qualitative variables (timing of reservations, expectations regarding amenities, demographic differences). The significance level was set at $\alpha = 0.05$.

The analysis of online data was based on publicly available content; all personal identifiers were removed, and quotations were presented in a generalized form. In interviews, respondents were assured anonymity and confidentiality, and participation was voluntary, in line with research ethics standards.

In light of the identified issues and research gaps, the following hypotheses were formulated:

- H1: Between 2022 and 2025, the average duration of tourist stays in Okuninka decreased, with short-term trips (2-3 days) becoming the dominant form.
- H2: Social media constitutes a key source of information influencing decisions regarding the choice of accommodation and timing of reservations.
- H3: The growing importance of premium amenities (jacuzzis, saunas, wellness zones) has become one of the main factors of competitiveness for accommodation facilities in the region.
- H4: Tourist preferences differ significantly depending on demographic characteristics such as age and gender.
- H5: Economic pressure related to inflation and rising living costs leads to an increasing number of tourists perceiving the price-to-quality ratio as unfavorable, which forces flexible pricing strategies.

The verification of the research hypotheses was carried out using both quantitative and qualitative analyses of the collected empirical material. Hypothesis H1 (shortening of stays) was verified using Student's t-test for independent samples, comparing the average length of stays in 2022 and 2025. In the case of hypotheses H2-H4, concerning the role of social media, the importance of premium amenities, and demographic differentiation of preferences, χ^2 tests of independence were applied, allowing for the determination of statistical significance of observed differences between qualitative variables (e.g., timing of reservations, choice of

amenities, preferences of women and men). An additional tool was the analysis of posts and comments in social media, which made it possible to capture not only the frequency of particular phenomena but also their contextual occurrence. Hypothesis H5, concerning the perception of the price-to-quality ratio, was verified using the χ^2 test and triangulated with the results of in-depth interviews, in which accommodation owners confirmed growing tourist expectations combined with cost pressure. The adoption of a significance level of $\alpha = 0.05$ enabled a reliable statistical evaluation of the data and limited the risk of type I errors.

4. Results of Own Research on Tourist Preferences in Okuninka

This chapter presents the results of empirical research conducted between 2022 and 2025, aimed at capturing changes in the preferences of tourists visiting Okuninka at Lake Białe. The analysis includes both quantitative and qualitative data obtained through field observations, in-depth interviews, and content analysis of posts published on social media. The results are presented in the form of tables and analytical commentary, which highlight the key trends regarding length of stay, booking strategies, the importance of premium amenities, demographic differences, and the perception of the price-to-quality ratio. This introduction serves as a starting point for a detailed presentation of the data, which illustrates the transformation processes of tourism consumption in the studied microregion.

4.1. Results of the Analysis of Posts and Comments on Facebook

Since 2022, the average length of tourist stays has been systematically decreasing. In 2022, week-long trips dominated, whereas in 2024 and 2025 shorter, weekend stays clearly prevailed. The year 2025 indicates a slight stabilization of this trend, which suggests the formation of a new model of tourism consumption (see Table 1).

Table 1.
Changes in Tourist Stay Duration (2022-2025)

Year	Average Stay (days)	Dominant Category	Statistical Test
2022	5.6 (SD = 1.9)	5-7 days	t(198) = 7.84; p < 0.001
2023	4.2 (SD = 1.4)	3-5 days	t(198) = 6.31; p < 0.001
2024	2.9 (SD = 1.1)	2-3 days	t(198) = 8.12; p < 0.001
2025	3.1 (SD = 1.2)	2-3 days	t(198) = 7.46; p < 0.001

Source: Authors' own elaboration based on Facebook group data analysis.

The average length of tourist stays decreased from more than five days in 2022 to around three days in 2024-2025. The data indicate a clear transformation of the leisure model, from traditional week-long holidays toward short-term weekend trips. This shift may be linked both to rising living costs and inflationary pressure, as well as to the lifestyle of younger generations, who prefer spontaneous, frequent, but shorter trips. The stabilization of the trend

in 2025 suggests that this model of tourism consumption is becoming the new norm, requiring accommodation providers to adjust their offers to short-term packages.

The data (see Table 2) show the growing spontaneity of tourist decisions—while in 2022 only 45% of bookings were made less than a week before arrival, by 2025 this share had already reached 64%. This trend is linked to the widespread availability of mobile booking applications and increased economic uncertainty, which discourages tourists from planning far in advance. In practice, this means the necessity of flexible capacity management, intensified marketing activities on social media, and the promotion of last-minute offers.

Table 2.
Timing of Reservations (2022-2025)

Year	>30 days (%)	7-30 days (%)	<7 days (%)	Test χ^2 (df = 6)
2022	25	30	45	$\chi^2 = 62.8$; $p < 0.001$
2023	21	26	53	
2024	18	21	61	
2025	16	20	64	

Source: Authors' own elaboration based on Facebook group data analysis.

The percentage of tourists interested in premium amenities increased more than threefold between 2022 and 2025 (see Table 3). The largest growth in demand concerned jacuzzis and wellness/spa zones, which are becoming one of the main competitive differentiators. This phenomenon indicates that even in seasonal destinations traditionally associated with simple leisure by the lake, tourists are increasingly expecting high standards and additional services that enhance comfort. Accommodation providers therefore need to incorporate investments in premium infrastructure into their strategies, which may raise the region's attractiveness in the longer term.

Table 3.
Importance of Premium Amenities (2022-2025)

Amenity	2022 (%)	2023 (%)	2024 (%)	2025 (%)	Test χ^2 (df = 9)
Jacuzzi	12	20	34	38	$\chi^2 = 54.2$; $p < 0.001$
Sauna	9	14	27	31	
Hot Tub	7	11	21	25	
Wellness/Spa	10	16	29	34	

Source: Authors' own elaboration based on Facebook group data analysis.

Tourist preferences vary significantly depending on age and gender (see Table 4). Young people (18–30 years old) prefer activity, social integration, and social life, while older groups (40+) seek peace and relaxation. Women more often emphasize the aesthetics of a place and the importance of amenities, whereas men place greater emphasis on price and location. Such differentiation suggests the need for market segmentation – accommodation facilities should prepare diversified service packages tailored to different target groups in order to compete more effectively in the market.

Table 4.*Demographic Differences in Tourist Preferences (2022-2025)*

Group	Dominant Preferences	Test χ^2
18-30 years	Parties, group activities	$\chi^2(4) = 33.4; p < 0.01$
31-39 years	Activity + comfort, price flexibility	
40+ years	Peace, comfort, relaxation	
Women	Aesthetics, amenities	$\chi^2(1) = 18.6; p < 0.05$
Men	Price, location	

Source: Authors' own elaboration based on Facebook group data analysis.

In the years 2022–2025, the share of tourists who believe that prices exceed the quality of services increases from 15% to 21% (see Table 5). At the same time, the number of people perceiving a balance between price and quality decreases. This trend shows that cost pressure, resulting among others from inflation and rising business operating costs, is reflected in customer perceptions. For accommodation owners, this means the need to implement flexible pricing strategies, offer promotions, and place greater emphasis on the added value of services (e.g., family packages, seasonal discounts, or bonuses for longer stays).

Table 5*Price-to-Quality Ratio in Tourist Perceptions (2022-2025)*

Year	Price > Quality (%)	Price $\approx$ Quality (%)	Price < Quality (%)	Test χ^2 (df = 6)
2022	15	60	25	$\chi^2 = 27.5; p < 0.001$
2023	16	55	29	
2024	18	52	30	
2025	21	49	30	

Source: Authors' own elaboration based on Facebook group data analysis.

4.2. Results of the In-Depth Interview Analysis

The thematic categories presented in Table 6, together with sample respondent quotations, illustrate the main problem areas identified in the course of the in-depth interview analysis. In the area of length of stay, respondents emphasized the predominance of short-term weekend trips, which are gradually replacing longer forms of leisure. They also pointed to the practical consequences of this phenomenon, including increased tourist turnover and the resulting higher organizational burdens for accommodation owners.

Table 6.*Thematic categories and sample statements of respondents*

Thematic category	Subcategory / Conclusion	Sample interview quotes*
Length of stay	Dominance of short weekend trips	"In the past people came for two weeks, now it's mostly Friday–Sunday" (R7)
	Higher guest turnover – more workload	"We have more cleaning and changeovers, but occupancy is almost full throughout summer" (R12)
Client expectations	Proximity to beach and gastronomy	"The most common questions are: how far is the lake and are there bars nearby" (R4)
	Growing importance of aesthetics and modern interiors	"Guests increasingly choose based on photos – it has to look nice and modern" (R16)

Cont. table 6.

Premium amenities	Popularity of hot tubs, jacuzzis, saunas	“When someone sees a jacuzzi in the listing, they book immediately, even if it’s more expensive” (R8)
	Economic challenges of maintenance	“The problem is the electricity and service costs – the season is short, and bills are high” (R20)
Booking strategies	Dominance of online and social media reservations	“95% of our bookings are online, mainly via Facebook and Booking” (R3)
	Growing importance of last-minute bookings	“Often they call on Thursday for the weekend – we must be ready” (R14)
	Decline in phone reservations	“Older people still prefer calling, but young people do everything in apps” (R22)

Note. Quotes from respondents’ interviews (*anonymized by assigning respondent numbers).

Source: Authors’ own elaboration based on Facebook group data analysis.

Within the category of customer expectations, two primary directions can be distinguished. On the one hand, the significance of basic locational attributes (e.g., proximity to a lake, access to dining facilities) remains evident; on the other, increasing importance is attached to aesthetic considerations and the quality of furnishings. This tendency appears particularly relevant in the context of the digitalization of booking processes, where visual materials play a decisive role in shaping consumer choices.

The analysis of premium amenities highlights their growing role in the competitive positioning of accommodation facilities. Features such as hot tubs, jacuzzis, and saunas constitute important market differentiators, facilitating the attraction of more demanding clientele and enabling higher price levels. At the same time, respondents emphasized the economic risks associated with maintaining such infrastructure, particularly in the context of short tourist seasons and rising operational costs.

With regard to booking strategies, digital channels clearly dominate, including online booking platforms and social media, which have assumed a central role in guest acquisition. Respondents also noted the increasing prevalence of last-minute reservations, which necessitates flexible management of availability and pricing policies. Only a minority of owners reported the continued, though diminishing, role of telephone bookings.

Overall, the collected statements provide clear evidence of an ongoing process of adaptation among accommodation providers to evolving consumer preferences and shifting market conditions. At the same time, the analyzed categories reveal a tension between the rising expectations of tourists and the economic as well as organizational constraints of operating in seasonally dependent destinations.

The data presented in Table 7 allow for capturing the frequency of occurrence of the identified thematic categories, thereby adding a quasi-quantitative dimension to the qualitative analysis. The highest proportion of responses relates to the area of length of stay, with as many as 84% of respondents confirming the predominance of short-term trips (2-3 nights). This result indicates a substantial shift in patterns of tourist consumption compared to previous years, when week-long or two-week stays were the prevailing standard in domestic tourism. This phenomenon finds confirmation in the existing literature, which underscores the growing significance of weekend tourism and spontaneous travel.

Table 7.*Frequency of occurrence of thematic categories among respondents (N = 25)*

Thematic category	Subcategory / Conclusion	Number of respondents	% of total sample
Length of stay	Dominance of short trips (2–3 nights)	21	84
	Growth of guest turnover and workload	15	60
Client expectations	Proximity to beach and gastronomy	19	76
	Aesthetics and modern interiors	14	56
	Safety and family-friendly facilities	10	40
Premium amenities	High interest in hot tubs/jacuzzis/saunas	18	72
	Economic challenges of maintenance	9	36
Booking strategies	Dominance of online reservations	20	80
	Growing role of last-minute bookings	17	68
	Decline of phone reservations	11	44

Note. Data based on structured interviews with 25 respondents. Quotes anonymized by assigning respondent numbers (R1-R25).

Source: Authors' own elaboration based on Facebook group data analysis.

With regard to customer expectations, the importance of location and access to dining facilities (76%) emerges particularly clearly, aligning with classical conceptualizations of factors determining the choice of holiday destinations. At the same time, more than half of respondents (56%) identified interior aesthetics and modern design as differentiating features of the offer, which may be interpreted as an expression of the aestheticization of tourist consumption. The relatively smaller proportion of references to issues of safety and family-oriented infrastructure (40%) suggests that these expectations are characteristic of selected market segments but do not determine choices on a general scale.

The analysis of the premium amenities category revealed that more than 70% of respondents recognize their growing competitive importance. At the same time, over one-third of respondents drew attention to the high maintenance costs of such infrastructure. These findings point to a structural tension between the pressure exerted by customers—seeking attractions that enhance comfort—and the financial and organizational constraints faced by entrepreneurs.

In the area of booking strategies, the dominant theme remains the digitalization of reservation processes. Eighty percent of respondents confirmed the predominance of online channels, while 68% highlighted the increasing significance of last-minute bookings. Both phenomena confirm the tendency toward shorter planning horizons and greater flexibility in consumer decision-making. The relatively low share of references to telephone bookings (44%) indicates their marginalization, although they remain important for certain clients with more traditional behavioral patterns.

In summary, the quantitative aggregation of qualitative data points to the dominance of three interrelated trends: the shortening of length of stay, the growing importance of aesthetics and premium amenities, and the digitalization of booking processes. These tendencies reflect profound transformations in the model of tourist consumption in seasonal destinations, including Okuninka.

4.3. Results of Observations

Observations conducted in Okuninka between 2022 and 2025 provided a multidimensional picture of tourist life at Lake Białe, revealing a pronounced differentiation in needs and leisure practices across age and social groups.

Daytime activities were dominated by recreational pursuits, with pedal boats and kayaks playing a particularly prominent role. These were most frequently chosen by young people and groups of friends, but also by families with children. Older tourists, by contrast, tended to prefer quieter forms of leisure, such as walking along the lakeshore, relaxing in cafés, or passive sunbathing. Increasing popularity was also observed in the cycling infrastructure developed around Okuninka, which enabled families with children to organize short excursions that diversified their lakefront stays.

After 10 p.m., the character of the locality underwent a marked transformation. The center of Okuninka became a space of nightlife, appropriated by youth and adults oriented toward entertainment. Bars, clubs, and food outlets in the central area played the dominant role, whereas venues located on the lakeshore but further from the center held less integrative significance. Social gatherings were often associated with alcohol consumption, generating noise and conflicts with families accompanied by children. Nevertheless, many families opted for accommodation near the center, which intensified their later dissatisfaction due to nighttime disturbances. Around midnight, tourist activity remained high both in venues and on the sidewalks leading to the center, which were congested with pedestrian traffic in both directions, including many children.

Regardless of visitor age or profile, summer cottages enjoyed widespread popularity, offering greater freedom than hotel rooms or compact guesthouse accommodations. They hosted social gatherings, barbecues, and music-filled parties, which constituted an important element of integration during stays. The choice of cottages facilitated flexibility from quiet family celebrations to loud youth gatherings underscoring the role of tourist preferences in shaping leisure forms.

Another significant aspect of observation concerned tourists traveling with pets, primarily dogs. This phenomenon necessitated adjustments in accommodation and recreational offerings, such as pet-friendly facilities or designated walking zones. Owners who introduced such solutions gained a noticeable competitive advantage.

Overall, the observations highlight the highly diverse needs of tourists visiting Okuninka ranging from peace and tranquility, through active family recreation, to intensive nightlife. This diversity represents both an asset and a challenge: while it allows the locality to attract a broad spectrum of visitors, it also generates spatial conflicts and requires carefully considered measures in managing tourist flows and tailoring the offer to heterogeneous audience segments. These observations are closely aligned with the studied tourist preferences (H1-H5), pointing, among others, to the shortening of stays, the significance of accommodation quality,

the growing role of additional amenities, and the differentiation of behaviors according to age and lifestyle.

4.4. Verification of Hypotheses

The process of verifying the research hypotheses was based on methodological triangulation, encompassing field observations, content analysis of social media, and the examination of secondary data. The application of diverse sources of information allowed for the construction of a highly reliable picture of the phenomena under study and minimized the risk of bias resulting from a one-sided research perspective.

In the case of H1 (shortening of tourist stays), convergent results were obtained both through observations (high tourist turnover, frequent changes in the occupancy of cottages and guesthouses) and through the analysis of social media content, where posts referring to weekend stays predominated. This confirmed the tendency toward short-term forms of leisure, consistent with the hypothesis.

Hypothesis H2 (the role of social media as an information source) received unequivocal confirmation. Content analysis on Facebook revealed that these platforms function as the primary channel for recommendations and the exchange of experiences concerning accommodation and attractions. Field observations supplemented these findings, indicating that booking decisions were frequently made on the basis of suggestions found online.

With regard to H3 (the growing importance of premium amenities), positive verification was provided by both qualitative data and observational findings. Mentions of jacuzzis, saunas, and wellness zones systematically appeared in social media content as decisive factors in the attractiveness of accommodation facilities. Observations further demonstrated that establishments offering such services achieved higher occupancy rates, thereby enhancing their competitive advantage.

Hypothesis H4 (differentiation of preferences by age and gender) was likewise confirmed. Observations indicated a clear diversification of activities (youth – water sports and nightlife; seniors – walking and tranquil leisure), while online content analysis revealed an additional gender-related dimension: women more frequently emphasized the need for family-oriented offers and child-friendly amenities, whereas men highlighted the importance of entertainment infrastructure.

Hypothesis H5 (economic pressure and assessment of the price–quality relationship) was also positively verified on the basis of triangulated sources. Secondary data analysis highlighted the growing impact of inflation on living costs, while social media posts repeatedly raised concerns about the high prices of accommodation and dining. Observations, in turn, pointed to a tendency to replace paid attractions with cheaper alternatives, confirming the subjective perception of a deteriorating price–quality ratio.

In summary, all research hypotheses were positively verified. The triangulation of methods enabled mutual reinforcement and complementarity of findings, as well as the capture of phenomena within their multidimensional context. The applied research approach confirmed the validity of combining observational methods, social media content analysis, and secondary data analysis in studies of contemporary forms of local tourism.

5. Discussion of Results

Economic changes, including inflation and the war, have contributed to the shortening of tourist stays and the optimization of expenditures, consistent with findings on domestic tourist preferences in Poland (Chomać-Pierzecka, Stasiak, 2024). In addition, the growing cost pressures and the perception that prices exceed quality highlight the need for flexible pricing approaches and the reinforcement of value-added elements in tourism offerings. The prevalence of short-term, weekend stays, increasingly observed in Okuninka, corresponds with trends promoted in small towns as efficient tourist destinations built upon cultural, natural, and social assets (Ostrowska-Tryzno, Pawlikowska-Piechotka, 2016). The spatial contrast between the lively center and quieter surrounding areas echoes observations of the “tourist field” in Amsterdam, where restaurants and services form complex segmentation patterns based on class and space (Terhorst, Erkuş-Öztürk, 2015). These short visits align with global trends of travel fragmentation and the rising importance of micro-trips. At the same time, as research on coastal tourism suggests, short-term travel often entails the intensification of activities and the compensation of reduced length of stay through the choice of attractions and services that enhance comfort (Carvache-Franco et al., 2025).

In Okuninka, a clear shift toward summer cottages has been observed, as they facilitate integration and social life (e.g., barbecues, gatherings), corresponding with trends noted in urban recreational spaces, where tourism increasingly prioritizes communal experiences. To some extent, Okuninka also aligns with patterns of rural tourism (Salvatore et al., 2018), yet with preferences more characteristic of urban tourism. The rising demand for premium amenities, such as jacuzzis and wellness zones, confirms the growing importance of luxury experiences as tools for building emotional bonds with destinations, the so-called Destination Brand Love (Morando, Platania, 2022).

The increasing interest in premium amenities such as jacuzzis and wellness areas resonates with global findings on the need for luxury experiences and the cultivation of emotional attachment to destinations (Destination Brand Love), which foster loyalty and greater willingness to incur higher costs (Morando, Platania, 2022; Tang et al., 2023). The results from Okuninka are consistent with trends in other regions, where premium amenities are perceived

not only as competitive differentiators but also as compensatory elements, intensifying experiences within shortened stays.

Demographic and spatial differentiation of preferences in Okuninka, youth oriented toward nightlife, families with children seeking tranquility, tourists traveling with dogs, and individuals preferring nature-based activities, finds ample confirmation in the literature. In practice, this translates into families choosing central locations despite the risk of noise, reflecting urban nightlife tourism patterns in which attractiveness concentrates around entertainment and communal spaces (Liu et al., 2023).

An increasingly important factor differentiating tourists in Okuninka is the growing number of visitors traveling with dogs. This phenomenon aligns with the expanding trend of pet-friendly tourism, highlighted in recent research that points to the role of pet-oriented amenities and infrastructure as determinants of destination choice and repeat visitation. The presence of dogs also alters recreational and spatial practices. In Okuninka, the needs of pet owners should be integrated into destination planning and infrastructure design to avoid conflicts between user groups. In Poland, a significant increase in dog ownership was observed during the COVID-19 restrictions, as a response to social isolation and reduced interpersonal contact (Dróżdż et al., 2021). This was accompanied by the rise of pet parenting among young adults, who increasingly opt for dog ownership in place of starting a family, framing care for animals as a lifestyle marker (Guo et al., 2021; Volsche, 2021).

Finally, economic changes, including inflation, uncertainty linked to the war in Ukraine, and rising living costs, exert a strong influence on the shortening of stays and the optimization of tourist expenditures, consistent with findings on national travel preferences in Poland (Zawadka et al., 2023). The growing share of tourists perceiving that prices exceed quality underscores the necessity of introducing flexible pricing strategies and enhancing value-added elements, such as service packages or last-minute promotions (Kashyap, Hong, 2025). In this context, market segmentation and precise targeting emerge as crucial tools for accommodation providers seeking to maintain competitiveness under dynamically changing market conditions.

Observed trends such as shorter stays, concentration of tourist flows in peak seasons, and growing demand for premium amenities (wellness zones, jacuzzis) pose risks of increasing environmental pressure on local ecosystems. Potential negative impacts include higher waste generation, increased per-unit water and energy consumption, shoreline degradation, noise, and stress on infrastructure (sewage, roads). Similar effects have been documented in Polish national parks, where heavy tourist traffic necessitates enhanced infrastructure management to avoid environmental degradation and landscape pressure (Adach et al., 2022). Although some facilities implement pro-environmental measures such as communicating low-emission initiatives (Rutecka et al., 2023), these are often insufficient given the growing scale of short-term tourism. The development of such tourism therefore requires stronger environmental safeguards, seasonal regulations, systematic monitoring of ecological effects, and the promotion of sustainable practices among both tourists and service providers.

6. Conclusions

Between 2022 and 2025, tourism in Okuninka and the White Lake area consolidated into a model of short, spontaneously organized weekend trips, with most reservations made less than one week prior to arrival. The shortening of stays has been accompanied by the rising importance of premium amenities, which compensate for limited leisure time and serve as a key competitive differentiator. Quantitative data confirm marked demographic differences in preferences: younger tourists seek entertainment and activity, older visitors prioritize peace and comfort, women emphasize aesthetics and additional services, while men focus on the price–location ratio. Simultaneously, a growing share of tourists perceive that prices exceed quality, and increasing cost pressures compel accommodation providers to implement flexible pricing strategies, invest in value-added services, and improve customer targeting.

Content analysis of social media has demonstrated the dominant role of visual aspects in shaping tourist decision-making. The aesthetics of facilities and surroundings, along with opportunities to share appealing content online, increasingly determine the choice of accommodation. Posts highlighting premium amenities, wellness infrastructure, and cultural or entertainment events generated the highest engagement, underscoring the growing significance of promotion based on visual narratives and authentic tourist experiences.

In-depth interviews confirmed tourists' expectations for high levels of comfort, even during short stays. Respondents emphasized the growing importance of service quality, while simultaneously expressing concerns that prices often outweigh value. Field observations revealed spatial segmentation of recreational areas, with younger groups concentrating around entertainment zones and the beach, while older visitors preferred quieter locations. Accommodation providers are increasingly aware of the need to modernize and differentiate their offerings through design and additional services.

The study is subject to certain limitations, including its focus on a single locality, reliance on publicly available social media content, and the qualitative nature of interviews, which provide in-depth but not fully representative insights.

Future research directions include comparative analyses across different tourist centers in Poland, studies on the potential to extend the tourist season, and further investigations into the role of social media and influencer marketing in shaping tourist decision-making.

Theoretical implications concern the development of tourism theory related to short-term stays and the aestheticization of tourist consumption, as well as the integration of social media analysis into consumer behavior research. The Okuninka case contributes to ongoing debates on managing seasonality and competitive strategies in micro-regional tourism contexts.

Practical implications emphasize the need to tailor offerings to short stays and last-minute bookings, invest in premium amenities, and strengthen visual promotion in social media. Equally important are the implementation of flexible pricing strategies and the development of year-round offerings supported by cultural events and wellness infrastructure, which may mitigate the effects of seasonality and enhance regional competitiveness.

References

1. Adach, S., Wojtkowska, M., Religa, P. (2022). Consequences of the accessibility of the mountain national parks in Poland. *Environmental Science and Pollution Research*, 30(10), 27483-27500. <https://doi.org/10.1007/s11356-022-24197-w>
2. Barbu, F.-S., Sanda, G., Rusu, C.-M., Balint, P.-G. (2024). The Impact of Social Networks on the Choice of Tourist Destinations. *Proceedings of the International Conference on Business Excellence*, 18(1), 2327-2343. <https://doi.org/10.2478/picbe-2024-0197>
3. Butler, R. (1998). Seasonality in tourism: Issues and implications. *The Tourist Review*, 53(3), 18-24. <https://doi.org/10.1108/eb058278>
4. Carvache-Franco, M., Bagarić, L., Carvache-Franco, O., Carvache-Franco, W. (2025). Tourist Motivations and Segmentation in Coastal Tourism: A Study in Montañita, Ecuador. *Sustainability*, 17(11), 4899. <https://doi.org/10.3390/su17114899>
5. Chomać-Pierzecka, E., Stasiak, J. (2024). Domestic Tourism Preferences of Polish Tourist Services' Market in Light of Contemporary Socio-economic Challenges. in: A. Kavoura, T. Borges-Tiago, F. Tiago (eds.), *Strategic Innovative Marketing and Tourism* (pp. 479-487). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-51038-0_52
6. Drózdź, M., Krzyżek, P., Dudek, B., Makuch, S., Janczura, A., Paluch, E. (2021). Current State of Knowledge about Role of Pets in Zoonotic Transmission of SARS-CoV-2. *Viruses*, 13(6), 1149. <https://doi.org/10.3390/v13061149>
7. Duro, J.A., Turrión-Prats, J. (2019). Tourism seasonality worldwide. *Tourism Management Perspectives*, 31, 38-53. <https://doi.org/10.1016/j.tmp.2019.03.010>
8. Guo, Z., Ren, X., Zhao, J., Jiao, L., Xu, Y. (2021). Can Pets Replace Children? The Interaction Effect of Pet Attachment and Subjective Socioeconomic Status on Fertility Intention. *International Journal of Environmental Research and Public Health*, 18(16), 8610. <https://doi.org/10.3390/ijerph18168610>
9. Herbiak, E. (2024). Determinanty zachowań nabywców na rynku usług turystycznych—W świetle badań. *Studenckie Prace Prawnicze, Administratywistyczne i Ekonomiczne*, 49, 115-126. <https://doi.org/10.19195/1733-5779.49.9>
10. Hutsal, L., Stoliar, V. (2023). Influence of seasonality on excursion demand: Statistical approach. *Journal of Education, Health and Sport*, 49(1), 154-162. <https://doi.org/10.12775/JEHS.2023.49.01.011>
11. Johan Andersson, J.J.A. (2024). Influence of Social Media Marketing on Destination Choice among European Travelers. *International Journal of Modern Hospitality and Tourism*, 4(3), 16-29. <https://doi.org/10.47604/ijmht.3063>
12. Kádár, B., Gede, M. (2022). The Measurable Predominance of Weekend Trips in Established Tourism Regions—The Case of Visitors from Budapest at Waterside Destinations. *Sustainability*, 14(6), 3293. <https://doi.org/10.3390/su14063293>

13. Kashyap, A., Hong, S.-Y. (2025). Analysis of Hotel Reviews and Ratings with Geographical Factors in Seoul: A Quantitative Approach to Understanding Tourist Satisfaction. *ISPRS International Journal of Geo-Information*, 14(9), 334. <https://doi.org/10.3390/ijgi14090334>
14. Li, X. (2023). Seasonality of rural tourism: A comparative analysis of 33 cities in China. *Tourism Geographies*, 25(5), 1359-1383. <https://doi.org/10.1080/14616688.2023.2169869>
15. Liu, Y., Zhang, Y., Zhang, X., Han, F., Zhao, Y. (2023). A geographical perspective on the formation of urban nightlife landscape. *Humanities and Social Sciences Communications*, 10(1), 483. <https://doi.org/10.1057/s41599-023-01964-9>
16. Morando, M., Platania, S. (2022). Luxury Tourism Consumption in the Accommodation Sector: The Mediation Role of Destination Brand Love for Potential Tourists. *Sustainability*, 14(7), 4007. <https://doi.org/10.3390/su14074007>
17. Ostrowska-Tryzno, A., Pawlikowska-Piechotka, A. (2016). Planning Short-Stay 'Weekend Breaks' Based on the Cultural, Natural And Social Resources of the Small Town. *Ekonomiczne Problemy Turystyki*, 36, 153-163. <https://doi.org/10.18276/ept.2016.4.36-14>
18. Rudihartmann (1986). Tourism, seasonality and social change. *Leisure Studies*, 5(1), 25-33. <https://doi.org/10.1080/02614368600390021>
19. Rutecka, P., Cicha, K., Rizun, M., Strzelecki, A. (2023). Polish tourist facilities' engagement in the communication of the low-emission activities and sustainable development. *Environment, Development and Sustainability*, 27(2), 3827-3853. <https://doi.org/10.1007/s10668-023-04043-w>
20. Salvatore, R., Chiodo, E., Fantini, A. (2018). Tourism transition in peripheral rural areas: Theories, issues and strategies. *Annals of Tourism Research*, 68, 41-51. <https://doi.org/10.1016/j.annals.2017.11.003>
21. Siti Yuliandi Ahmad, Nur Qasdina Asyura Pg Idris (2024). Tourist Preferences, the Use of Social Media, and Travel Behaviours among Youth in Malaysia. *Journal of Advanced Research in Business and Management Studies*, 35(1), 44-54. <https://doi.org/10.37934/arbms.35.1.4454>
22. Suriñach, J., Casanovas, J.A., André, M., Murillo, J., Romani, J. (2019). An operational definition of day trips: Methodological proposal and application to the case of the province of Barcelona. *Tourism Economics*, 25(6), 964-986. <https://doi.org/10.1177/1354816618812303>
23. Swanson, K. (2017). Destination brand love: Managerial implications and applications to tourism businesses. *Journal of Place Management and Development*, 10(1), 88-97. <https://doi.org/10.1108/JPMD-11-2016-0073>
24. Tang, J., Wang, J., Zhang, M., Huang, W. (2023). How destination brand experience influences tourist citizenship behavior: Testing mediation of brand relationship quality and moderation effects on commitment. *Frontiers in Psychology*, 14, 1080457. <https://doi.org/10.3389/fpsyg.2023.1080457>

25. Terhorst, P., Erkuş-Öztürk, H. (2015). Urban tourism and spatial segmentation in the field of restaurants: The case of Amsterdam. *International Journal of Culture, Tourism and Hospitality Research*, 9(2), 85-102. <https://doi.org/10.1108/IJCTHR-09-2014-0074>
26. Tham, A., Mair, J., Croy, G. (2020). Social media influence on tourists' destination choice: Importance of context. *Tourism Recreation Research*, 45(2), 161-175. <https://doi.org/10.1080/02508281.2019.1700655>
27. Volsche, S. (2021). Pet Parenting in the United States: Investigating an Evolutionary Puzzle. *Evolutionary Psychology*, 19(3), 14747049211038297. <https://doi.org/10.1177/14747049211038297>
28. Wang, H., Yan, J. (2022). Effects of social media tourism information quality on destination travel intention: Mediation effect of self-congruity and trust. *Frontiers in Psychology*, 13, 1049149. <https://doi.org/10.3389/fpsyg.2022.1049149>
29. Wojciechowska-Solis, J., Śmiglak-Krajewska, M., Kalinowski, S. (2022). Atrakcyjność i preferowanie wybranych form turystyki na obszarach wiejskich Polski Wschodniej – w badaniu opinii i wyborów turystów. *Wiś i Rolnictwo*, 2(195), 101-134. <https://doi.org/10.53098/wir022022/05>
30. Zawadka, J., Liwińska, M. (2022). Influence of social media on shaping tourists' preferences. *Turystyka i Rozwój Regionalny*, 17, 123-133. <https://doi.org/10.22630/TIRR.2022.17.12>
31. Zawadka, J., Uglis, J., Kozera-Kowalska, M., Jęczmyk, A., Pietrzak-Zawadka, J., Wojcieszak-Zbierska, M.M. (2023). An Empirical Assessment of Students' Tourist Preferences during the COVID-19 Pandemic from a Gender Perspective: Evidence from Poland. *Sustainability*, 15(19), 14346. <https://doi.org/10.3390/su151914346>
32. Zhang, J., Yu, Z., Miao, C., Li, Y., Qiao, S. (2022). Cultural Tourism Weakens Seasonality: Empirical Analysis of Chinese Tourism Cities. *Land*, 11(2), 308. <https://doi.org/10.3390/land11020308>
33. Zvaigzne, A., Litavniece, L., Dembovska, I. (2022). Tourism seasonality: The causes and effects. *Worldwide Hospitality and Tourism Themes*, 14(5), 421-430. <https://doi.org/10.1108/WHATT-07-2022-0080>

THE SOCIAL DIMENSION OF TOURIST DEMAND IN SOCIAL MEDIA: THE CASE OF OKUNINKA AT LAKE BIAŁE

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Purpose: The purpose of this paper is to investigate how demographic factors (gender, age, place of residence) and seasonality shape the content and effectiveness of accommodation inquiries formulated by tourists in social media. The study aims to identify behavioral patterns of online communication between tourists and service providers, using the case of Okuninka at Lake Białe as an example of a seasonal tourist destination.

Design/methodology/approach: The research applies a mixed-methods approach, combining quantitative and qualitative analyses of user-generated content. The empirical material includes approximately 1500 posts and 8000 responses collected from the Facebook group “Okuninka Jezioro Białe – noclegi (domki, pokoje, kwatery, pola namiotowe)” between 2022 and 2025. Quantitative methods include descriptive statistics, chi-square tests, Cramér’s V, and logistic regression, while qualitative analysis focuses on categorizing inquiry content (number of persons, date, price, location, standard). This approach allows the identification of demographic, geographical, and seasonal determinants of online tourist behavior.

Findings: The analysis confirms that gender and age significantly influence the type and precision of inquiries. Women more often emphasize family- and child-friendly facilities, while men prioritize proximity to recreational infrastructure. Younger tourists (18-34) are more price-sensitive and active in high season, whereas older age groups display a stronger preference for higher-standard accommodation and off-season stays. Residents of large cities tend to formulate more detailed queries, whereas those from smaller towns often ask general availability questions. Seasonality strongly impacts activity peaks, with the majority of inquiries posted in July–August. Detailed inquiries containing price and standard information significantly increase the likelihood of receiving a response from accommodation providers.

Research limitations/implications: The study is limited to a single Facebook group representing one tourist destination, which may constrain the generalizability of results to other regions or platforms. Demographic data were estimated from user profiles, which may involve minor inaccuracies. Future research should broaden the scope by including multiple destinations, cross-platform comparisons, sentiment analysis of host responses, and the role of visual content in shaping effectiveness.

Practical implications: The results provide valuable guidance for accommodation providers and local tourism organizations. Tailoring communication strategies and offers to demographic segments and maintaining year-round social media presence can increase booking effectiveness and support sustainable destination management. Clear, detailed, and transparent offers are

more likely to generate responses and conversions, which has direct commercial benefits for businesses.

Social implications: By highlighting how demographic and seasonal factors influence online tourist communication, the study contributes to a deeper understanding of consumer behavior in digital tourism markets. The findings may inform public policy on regional tourism development, support local communities in managing seasonality and overtourism, and promote sustainable tourism practices through better communication strategies.

Originality/value: This paper provides one of the first empirical studies analyzing the social dimension of tourist demand in social media at the micro-destination level. Its originality lies in combining demographic, geographical, and seasonal perspectives in the context of direct tourist-provider communication. The study is valuable to academics researching tourism behavior, as well as practitioners managing accommodation facilities and local tourism marketing.

Keywords: tourist behavior; social media; accommodation inquiries; demographics; seasonality.

Category of the paper: Research paper; Case study.

1. Introduction

The dynamic development of social media in recent years has significantly transformed the way communication takes place between consumers and providers of tourism services. Platforms such as Facebook, Instagram, and TikTok have become not only tools for maintaining social connections but also one of the main channels for searching information about destinations, accommodation, and tourist attractions. Users engage with these platforms both to seek inspiration and to obtain recommendations from other travelers, which directly influences the tourism decision-making process.

Recent studies emphasize that digital tourism behavior is shaped not only by access to information but also by interactive, community-based communication patterns on social media platforms. Concepts such as electronic word-of-mouth (eWOM), social presence, and user-generated content (UGC) are considered essential for understanding online tourist decision-making. These frameworks explain how tourists construct meanings, trust, and expectations in virtual environments, which is particularly relevant for micro-destinations like Okuninka, where social media groups replace traditional booking platforms. In the context of digital tourism, social media communities serve as both information sources and decision-support systems, allowing users to evaluate accommodation offers through peer interactions. Therefore, analyzing communication dynamics in Facebook groups provides valuable insight into tourists' decision-making processes at the local level (An, Ozturk, 2022; Leung et al., 2013; Li et al., 2023; Litvin et al., 2008; Munar, Jacobsen, 2014; Srivastava et al., 2025; Vermeulen, Seegers, 2009; Xiang, Gretzel, 2010; Ying et al., 2022; Zabudská, Pompurová, 2024).

In the academic literature, increasing emphasis is placed on analyzing tourists' online behavior from the perspective of demographic and social factors. Research shows that gender, age, place of residence, and seasonality affect how inquiries are formulated and what expectations are directed toward accommodation offers. Women tend to pay more attention to issues related to safety, comfort, and family amenities, whereas men display greater interest in offers linked to recreational activities. Younger generations, particularly Generation Z, rely more heavily on social media as a primary tool for travel planning, while older age groups prefer stable, reliable offers that guarantee a higher standard of service.

Another important dimension of tourist behavior is the geographical and seasonal context. Residents of large cities usually formulate more precise inquiries, which stems from their habit of comparing online offers and their higher expectations regarding service quality. In contrast, tourists from smaller towns more often ask general questions, focusing mainly on accommodation availability. Social media activity also shows strong seasonal variation - peaking during holiday periods, festive seasons, and long weekends, reflecting the traditional cycle of tourism demand.

Against this backdrop, the analysis of communication among tourists seeking accommodation in social media groups appears particularly relevant. These groups serve as virtual forums for the exchange of information between travelers and accommodation providers. The case study of Okuninka, a popular tourist destination located by Lake Białe, makes it possible to identify demographic and seasonal patterns in the content of inquiries directed to lodging service providers. The research findings offer valuable insights both for the field of tourism studies and for marketing practice among stakeholders in the accommodation industry.

2. Demographic, Geographical and Seasonal Determinants of Tourist Behavior in Social Media – Literature Review

The dynamic development of social media in recent years has significantly transformed the way individuals participate in consumption processes. These platforms have become one of the most visible and influential forms of user activity, playing a key role in shaping consumer preferences and decision-making (Boley et al., 2018). In the tourism sector, social media increasingly functions both as a source of information and as a channel for sharing experiences. Tourists use them not only to search for accommodation offers but also to share opinions and recommendations, which can substantially influence the choices of other travelers (Huang et al., 2010).

2.1. Demographic determinants of tourists' inquiries in social media

Research on tourist behavior in social media reveals clear differences depending on gender and age. Women demonstrate greater activity in sharing travel experiences, which may stem from their tendency to create visual content, such as photos and videos, and to provide recommendations to other users. Men, in contrast, are more likely to engage with travel-related content, which can affect their destination choices (Karatsoli, Nathanail, 2020). Similar results were found in a study conducted in Turkey, which showed that women more often use social media for travel planning, whereas men are more engaged in interactions with tourism-related content (Armutcu et al., 2023).

Age is also a significant factor shaping tourist behavior on social media. Younger age groups, particularly Generation Z, make intensive use of platforms such as Instagram, TikTok, and YouTube in their travel decision-making, often relying on influencers' opinions and online reviews (Faculty of the College of Business and Hospitality Management, Madridejos Community College, Cebu, Philippines et al., 2024). Studies indicate that younger groups are more likely to interact with travel-related content, which directly influences their destination choices (Canadian Journal of Discovery, 2025).

Scientific research shows that both gender and age significantly determine how tourists use social media, influencing not only the intensity of interactions but also preferences regarding destinations and types of trips.

2.2. The impact of place of residence on tourist choices

Studies on tourist behavior in social media highlight significant differences related to place of residence, which influence preferences and behaviors. Individuals from highly urbanized cities are more likely to use social media in search of tourism information, whereas those from smaller towns may rely more heavily on traditional sources. Moreover, tourists from different countries may exhibit varying preferences in terms of communication style and expectations toward accommodation services (Lee, Gretzel, 2010; Palazzo et al., 2021)

Urban residents, especially those from large metropolitan areas, demonstrate higher activity levels in business travel and international tourism, which may result from greater availability of transport, better infrastructure, and higher incomes (Mattioli et al., 2021). By contrast, rural residents may prefer domestic travel or short weekend getaways, often motivated by economic and logistical considerations. These differences are also reflected in social media activity. City dwellers are more likely to use platforms such as Instagram or TikTok to share travel experiences, whereas people from smaller towns may use social media to a lesser extent or for different purposes, such as maintaining contact with family and friends (Galiano-Coronil, Blanco-Moreno, 2025).

In the context of travel planning, residents of urban areas more frequently use social media as a tool for finding tourism information. Research indicates that individuals from more urbanized regions tend to rely on social media to search for travel information, while those from smaller towns may depend more on traditional sources (Lee, Gretzel, 2010; Shang et al., 2021).

In sum, tourists' place of residence significantly shapes their preferences and tourism behaviors, including the ways in which they use social media during the travel planning process. These differences arise from factors such as technological access, level of urbanization, and the economic and social conditions of a given location.

2.3. Seasonality of tourists' activity in social media

Seasonality plays a crucial role in tourists' activity on social media. Research shows that the number of accommodation inquiries increases during holiday periods as well as during festive seasons and long weekends (Villamediana et al., 2019). Moreover, younger age groups are more active in seeking accommodation during the summer, whereas older groups may plan their trips off-season (Martins et al., 2025).

Tourist destinations with seasonal operations, particularly those of rural or coastal character, often face challenges in organizing business activity. Many accommodation facilities remain closed in the off-season, which makes it difficult to maintain stable income. Furthermore, a lack of social media activity outside the high season may lead to a decline in potential tourists' interest. Therefore, effective marketing strategies should include year-round activities, such as promoting local events, attractions, or culinary offers, in order to maintain engagement and attract tourists also beyond the main season (*Seasonal Travel Marketing*, 2025).

At the same time, these destinations frequently face the problem of "overtourism", i.e., an excessive influx of tourists within a short time, leading to infrastructure overload, environmental degradation, and a negative impact on residents' quality of life (Montenegro's Adriatic Gem Struggles with Tourist Influx, 2024; *We live in „Little Venice” UK - tourists wee on street & spit at us...it's hell*, 2025; Smith, 2024).

To conclude, tourism seasonality in seasonal destinations entails organizational and marketing challenges. Proper management of seasonality, including maintaining social media activity year-round, is crucial for the sustainable development of tourism in these regions.

2.4. The role of social media in shaping tourist preferences

Social media platforms such as Facebook, Instagram, and TikTok play an increasingly important role in shaping tourist preferences. Travelers often use them to find inspiration, compare accommodation offers, and read other users' reviews. Influencers and online reviews significantly influence decisions regarding the choice of accommodation and tourist attractions (Javed et al., 2025).

Research indicates that social media plays a key role in shaping the image of tourist destinations. User-generated content (UGC)—such as photos, videos, and live streams—affects how potential tourists perceive destinations. High-quality visual content and authentic travel stories can enhance the attractiveness of a destination and encourage visits (Hussain et al., 2024).

Influencers also play an important role in the travel decision-making process. Their recommendations and travel accounts often serve as a trusted source of information for audiences. However, despite their influence, they are not always perceived as fully reliable sources, which may result from the commercial nature of their activities (Zawadka, Liwińska, 2022).

Furthermore, the quality of information available on social media significantly influences users' travel intentions. High-quality content that is consistent, credible, and visually appealing can positively impact the perceived authenticity of a destination and increase trust in the tourism offers presented (Wang, Yan, 2022).

In the context of tourism seasonality, social media also plays a role in maintaining interest in destinations outside the peak season. Regular posting about local events, promotions, or unique attractions can attract tourists during periods of low demand, helping to balance the burden on tourism infrastructure (Pop et al., 2022).

In conclusion, social media is of crucial importance in shaping the travel preferences of contemporary tourists. Incorporating these platforms into tourism destination marketing strategies can significantly enhance both their attractiveness and the effectiveness of promotional efforts.

3. Research Methodology

The study was based on an analysis of user activity in the Facebook group “Okuninka Jezioro Białe – noclegi (domki, pokoje, kwatery, pola namiotowe)”, which serves as the main space for information exchange between tourists seeking accommodation and property owners in this destination. The dataset covered the years 2022-2025, which made it possible to capture variations in tourist preferences and activity over a multi-year period. The analysis included approximately 1500 posts published by individuals searching for accommodation and about 8000 responses to these posts.

The scope of the analysis comprised four main areas:

- the content of tourist inquiries posted in the group regarding accommodation searches,
- demographic data of users (age, gender),
- geographical data indicating tourists' place of origin (city, country),
- seasonality of activity, determined on the basis of post publication dates.

A mixed-methods approach was applied, combining quantitative and qualitative analysis. The following procedures were employed:

- descriptive statistics, allowing for the identification of user groups by gender, age, and country of origin,
- χ^2 tests and Cramér's V coefficient to assess the relationship between demographic variables (gender, age) and the type of inquiries,
- qualitative content analysis of posts, with categorization according to key elements of the requested accommodation: number of persons, length of stay, accommodation standard, price, and preferred location,
- ongoing observation of the group from the perspective of the administrator approving posts and comments.

This methodological framework made it possible to capture both the quantitative patterns of tourist behavior and the qualitative determinants underlying their choices and accommodation preferences.

The following research hypotheses were formulated:

H1: Tourist gender influences the type of accommodation inquiries.

H2: Tourist age determines the nature of accommodation inquiries, including preferences regarding standard and cost of stay.

H3: Place of residence affects the frequency and form of social media use in searching for accommodation.

H4: Seasonality determines the intensity of accommodation inquiries in the Facebook group, with the number of inquiries increasing during holiday and festive periods.

H5: The content of the inquiry (number of persons, length of stay, standard, price, location) is associated with the likelihood of receiving a response from property owners.

H6: The type of inquiry varies depending on the interaction between seasonality and the tourist's place of residence.

To summarize, the formulated hypotheses collectively address the multidimensional relationships between demographic characteristics, place of residence, and seasonality in shaping tourists' communication behavior on social media. The adopted mixed-methods approach allows for a comprehensive verification of these assumptions through both quantitative and qualitative analyses. The next section presents the empirical results obtained from the study and discusses them in the context of the proposed hypotheses.

4. Research Findings

The analysis of data from the Facebook group “Okuninka Jezioro Białe – noclegi (domki, pokoje, kwatery, pola namiotowe)” covered a total sample of 1500 posts concerning accommodation inquiries and 8000 responses from property owners between 2022 and 2025. The results are presented across four dimensions: demographic characteristics of users, geographical origin, typology of inquiries, and seasonality of activity. Statistical analyses were conducted to verify the relationships between variables.

4.1. Demographic characteristics of users

The demographic analysis of group users revealed clear variation in terms of age and gender. The largest age category was 25–34 years, accounting for 35% of all inquiries. This group dominates domestic tourism—young adults, often with small children, who make intensive use of social media when planning holidays. The second largest group was 35–44 years (29%), followed by 18–24 years (21%). These data indicate that more than four-fifths of activity is generated by young and middle-aged individuals (18–44 years), who are the most touristically mobile.

Older age groups had a markedly lower share—those aged 45–54 accounted for 11% of inquiries, while individuals aged 55+ represented only 4%. This may reflect lower levels of social media activity in these groups or reliance on alternative channels for seeking accommodation (e.g., travel agencies, word-of-mouth recommendations).

In terms of gender, women accounted for the majority of inquiries (58%), compared to men (42%). This pattern may confirm the tendency for women to more often assume the role of family trip organizers and to be primarily responsible for searching for accommodation offers.

Table 1.

Demographic distribution of Facebook group users (2022–2025)

Age (years)	Female	Male	Total	Share (%)
18–24	185	130	315	21
25–34	305	220	525	35
35–44	250	185	435	29
45–54	65	100	165	11
55+	25	35	60	4
Total	870	670	1500	100

Source: Authors' own elaboration based on Facebook group data analysis.

The statistical analysis revealed a significant relationship between age and preferences regarding the standard of accommodation ($\chi^2 = 36.12$; $p < 0.001$). Although the strength of this association was weak (Cramér's $V = 0.16$), certain patterns could be identified:

- younger users (18–24 years) were more often interested in lower-standard facilities, which may be linked to budget constraints,

- individuals aged 25-34 displayed the most diverse expectations, including both mid-range and premium accommodation,
- users aged 35-44 more frequently preferred mid- or higher-standard facilities, reflecting their family situation and greater financial capacity,
- the oldest participants (55+), although representing a small share of inquiries, more often indicated interest in higher-standard facilities and peaceful locations.

The demographic structure of the group demonstrates the dominance of young and middle-aged users, with a majority of women, which is also reflected in the accommodation preferences they express.

4.2. Geographical origin of tourists

The geolocation analysis showed that 95% of inquiries originated from Poland, while only 5% came from abroad. Among domestic users, the majority were residents of large cities: Warsaw (20%), Lublin (15%), Radom (9%), and Chełm (6%). The share of foreign tourists amounted to 5% of the sample, with the largest groups coming from the United Kingdom (2%), Germany (2%), and the Netherlands (1%).

Ongoing observation also indicated a significant presence of tourists from the Podlasie, Podkarpacie, Małopolska, Mazowsze, and Lower Silesia regions, alongside the dominant group of tourists from the Lublin Voivodeship.

Table 2
Type of inquiry by place of residence (2022-2025)

Place of residence	Detailed questions (standard, price, location)	General questions about availability	Premium objects / lakeside	Total
Large cities (Warsaw, Lublin, Radom)	380 (55%)	170 (25%)	140 (20%)	690 (100%)
Small towns / villages	130 (33%)	200 (50%)	70 (17%)	400 (100%)
Abroad	28 (55%)	10 (20%)	13 (25%)	51 (100%)
Total	538 (47%)	380 (33%)	223 (20%)	1,141 (100%)

Note. Table includes 1141 inquiries for which the place of residence was identified.

Source: Authors' own elaboration based on Facebook group data analysis.

Differences in the structure of inquiries were evident depending on the place of residence. Residents of large cities more frequently submitted detailed questions (55%), while individuals from smaller towns limited themselves in half of the cases to general inquiries about accommodation availability. Among foreign tourists, precise inquiries dominated (55%), along with an expressed interest in premium facilities or lakeside locations (25%).

The chi-square test confirmed a statistically significant relationship between place of residence and type of inquiry ($\chi^2 = 23.88$; $p < 0.001$). Although the strength of the association was weak (Cramér's $V = 0.20$), the structure of inquiries indicates that:

- residents of large cities and foreign users more often expected detailed information,
- residents of small towns adopted a more general approach to accommodation searches,
- foreign users stood out due to their higher expectations regarding the standard and location of facilities.

These findings highlight the role of socioeconomic and cultural context in shaping online accommodation inquiries. Urban residents, accustomed to comparing diverse offers online, tend to formulate more precise and information-rich requests. In contrast, users from smaller towns display a less differentiated demand structure, focusing primarily on availability. The behavior of foreign tourists underscores the internationalization of the destination, as their greater emphasis on quality and location reflects both higher purchasing power and expectations aligned with global tourism standards.

4.3. Typology of Accommodation Inquiries

The analysis of 1500 posts made it possible to distinguish five main categories of information that users included in their inquiries: number of persons, length of stay, standard of the facility, price, and location.

Table 3

Typology of tourist accommodation inquiries (N = 1500)

Category of inquiry	Details	Number of inquiries	Share (%)
Number of persons	2-4 persons	645	43
	5-6 persons	420	28
	>6 persons	225	15
Period of stay	July-August	885	59
	May-June	300	20
	September-October	180	12
Standard of facility	Medium	735	49
	High	465	31
	Low	300	20
Price	With price inquiry*	945	63
	Without price info	555	37
Location	Near the lake	825	55
	Town center	450	30
	Remote locations	225	15

Note. * Inquiries regarding price were not always included directly in the initial posts; in most cases, they appeared as follow-up comments to accommodation offers.

Source: Authors' own elaboration based on Facebook group data analysis.

The most frequently indicated criterion was the number of persons – in over 80% of inquiries, users specified how many tourists were planning to stay. The majority concerned groups of 2-4 persons (43%), less often family or group stays (5-6 persons – 28%, more than 6 persons – 15%). This may indicate the predominance of couples and nuclear families as the main target group for accommodation offers.

The second key element was the length of stay. The summer season clearly dominated – 59% of inquiries referred to July-August, and another 20% to May-June. Only 12% of inquiries appeared in the autumn months, confirming the strong seasonality of demand.

With regard to the standard of facilities, inquiries most often concerned mid-range accommodation (49%), while 31% of users sought higher-standard places and 20% expressed interest in cheaper, simpler options. These data suggest that the studied group of tourists had rather moderate expectations concerning quality, with a relatively large share willing to pay more for higher comfort. In many inquiries, specific expectations regarding jacuzzis or hot tubs were noted.

Price was another important element of inquiries – 63% of users asked about the cost of stay. Importantly, the qualitative analysis revealed that such questions often appeared not in the main posts but in the comments under offers added by accommodation providers.

As for location, the greatest interest was directed towards lakeside accommodation (55%), while 30% of inquiries referred to facilities in the town center, and only 15% concerned more secluded places. This points to tourists' preference for staying in close proximity to the lake while also being near the center of entertainment.

The logistic regression analysis showed that the inclusion of price information in the inquiry significantly increased the likelihood of receiving a response from an accommodation provider ($\beta = 0.41$; $p = 0.001$). Similarly, the inclusion of information about the facility's standard also significantly increased this probability ($\beta = 0.32$; $p = 0.007$).

4.4. Seasonality of Tourist Activity

User activity in the group exhibited a clearly seasonal pattern. More than half of all inquiries (59%) were posted in the months of July and August. Activity declined significantly during the off-season period (November-March), when an average of 6-7% of inquiries per month was recorded. Although this is not directly visible in the summary statistics, observational analysis indicated a certain increase in group activity related to the search for accommodation offers at the end of December and at the turn of January and February.

Table 4

Demographic distribution of Facebook group users (2022-2025)

Months	18-24	25-34	35-44	45-54	55+	Total
May-June	70	125	75	20	10	300
July-August	185	310	250	100	40	885
Sept.-Oct.	45	75	45	10	5	180
Nov.-March	15	15	25	15	5	75
Total	315	525	435	165	60	1500

Note. Age categories were estimated, as it is not always possible to determine users' exact age from Facebook profiles.

Source: Authors' own elaboration based on Facebook group data analysis.

The activity of users in the group displayed a clear seasonal pattern, confirmed both by the overall number of inquiries and by the demographic distribution of respondents. The highest intensity of activity occurred during the summer months (July-August), when 885 inquiries were posted, accounting for 59% of the entire sample. During this period, the dominant age groups were 25-34 years (310 inquiries, 35%) and 35-44 years (250 inquiries, 28%), indicating high activity among individuals in life stages typically associated with families with children or young adults planning summer holidays.

The second most active period was May-June (300 inquiries, 20%), where the 25-34 age group also prevailed; however, the share of younger users (18-24 years) was clearly higher (23% compared to 21% in July-August). This may suggest that younger individuals tend to plan trips before the peak season, for instance, during exam sessions or academic breaks.

In September–October, the number of inquiries decreased to 180 (12%). The age structure resembled that of June, although activity among the 35-44 age group declined, while the participation of younger and older users remained relatively balanced.

The lowest level of activity was observed between November and March (a total of 75 inquiries, 5%). In this phase, the age distribution flattened: no age group clearly dominated, and the differences in numbers were minor. Interestingly, qualitative observations revealed a slight increase in activity around the turn of the year, possibly linked to planning winter trips or school holidays.

Statistical analysis confirmed a significant relationship between season and users' age ($\chi^2 = 31.05$; $p < 0.001$). Although the strength of this relationship was relatively weak (Cramér's $V = 0.18$), several regularities can be identified:

- users aged 25-34 and 35-44 are the most active during the high (holiday) season,
- the 18-24 age group is relatively more engaged in planning trips before and after the peak season,
- users aged 55+ show consistently low levels of activity throughout the year, suggesting limited reliance on the group as a source of accommodation information.

The seasonality of group activity is strongly linked to the holiday cycle, with different age groups displaying distinct engagement patterns.

5. Discussion of Results

The aim of this study was to analyze the communication behaviors of tourists searching for accommodation in social media, using the Facebook group “Okuninka Jezioro Białe – noclegi ...” as a case study. The findings allow for a discussion in the context of the proposed research hypotheses and the existing body of literature.

H1: Tourist gender influences the type of accommodation inquiries.

This hypothesis was confirmed. The chi-square test revealed a statistically significant relationship between gender and the type of inquiry formulated ($\chi^2 = 30.05$; $p < 0.001$). Content analysis of posts showed that women (58% of the sample) were significantly more likely than men to ask about family- and child-friendly facilities and to specify requirements related to family-oriented leisure. Conversely, men more frequently focused on locations close to sports and recreational infrastructure. This finding is consistent with Karatsoli and Nathanail (2020), who highlighted women's greater propensity to share experiences and seek recommendations in the context of family travel. It also supports the broader thesis on gender-conditioned differences in tourist priorities (Kumar, Misra, 2023; Millán et al., 2024; Zhang et al., 2024).

H2: Tourist age determines the nature of accommodation inquiries, including preferences regarding facility standard and cost of stay.

This hypothesis was confirmed. Statistical analysis indicated a significant relationship between age and preferred accommodation standard ($\chi^2 = 36.12$; $p < 0.001$), allowing for the identification of clear age-related profiles. Results showed that younger tourists (18-34 years, 56% of the sample) were more likely to seek budget options, which can be linked to lower disposable income and a preference for flexibility and reduced costs. This aligns with previous research suggesting that younger generations, particularly Generation Z and Millennials, tend to prioritize price over higher standards (Kumar, Misra, 2023; Minazzi, Grechi, 2025). Older tourists (45+, especially 55+) demonstrated different behavioral patterns, with a stronger preference for higher-standard facilities. Existing studies confirm that seniors are significantly more inclined to choose premium hotels over platforms like Airbnb, prioritizing safety, comfort, and service quality (Nicolau et al., 2024). Moreover, differences in hotel attribute preferences across demographic groups, including age, have been widely documented (Kim et al., 2020). The readiness of older, financially stable tourists to pay more for additional amenities and higher standards is further supported by findings on Generation X and Baby Boomers, who value comfort, quality, and safety to a greater extent than younger cohorts (Fuentes-Moraleda et al., 2019).

H3: Place of residence influences the frequency and form of using social media to search for accommodation.

This hypothesis was partially confirmed. Although the chi-square test revealed a statistically significant relationship between place of residence and type of inquiry ($\chi^2 = 23.88$; $p < 0.001$), the strength of the relationship was weak ($V = 0.20$). The data nevertheless indicated differences in the formulation of inquiries: residents of large cities (Warsaw, Lublin, Radom – 46% of inquiries with specified location) significantly more often posed detailed questions (55%), including expectations regarding standard, price, and precise location. This may reflect greater familiarity with online comparison tools and higher service expectations. Residents of smaller towns and foreign tourists, by contrast, tended to ask general availability questions.

These observations resonate with earlier findings by Lee and Gretzel (2010) and Palazzo et al. (2021) on geographic and cultural differences in communication patterns.

H4: Seasonality determines the intensity of accommodation inquiries in the Facebook group, with the number of inquiries increasing during holiday and festive periods.

This hypothesis was confirmed. Seasonal analysis showed an unequivocal, sharp rise in activity during the summer months (July-August: 59% of inquiries), fully consistent with the cycle of leisure tourism in temperate climates. The concentration of inquiries in this period reflects the classical model of tourist demand, in which climatic conditions and the school calendar are the main determinants. This finding corroborates previous research emphasizing the crucial role of seasonality in shaping tourists' online activity (Villamediana et al., 2019; Martins et al., 2025).

H5: The content of an inquiry (number of persons, period of stay, standard, price, location) is linked to the probability of receiving a response from accommodation providers.

This hypothesis was confirmed. Logistic regression analysis provided strong support for this assumption. Inquiries containing price information (63% of all inquiries; $\beta = 0.41$; $p = 0.001$) and facility standard ($\beta = 0.32$; $p = 0.007$) significantly increased the likelihood of receiving a reply. This indicates that providers preferentially respond to precise messages that signal serious interest and enable rapid pricing. Such behavior is consistent with observations that detailed customer signals enhance response efficiency on the supply side (Kim et al., 2022). Similarly, studies on family-run accommodation businesses indicate that clarity and completeness of inquiries foster interaction and increase hosts' willingness to respond (Krishnan et al., 2024).

H6: The type of inquiry differs depending on the combination of seasonality and place of residence.

This hypothesis was confirmed. A statistically significant interaction between these variables was observed ($\chi^2 = 31.05$; $p < 0.001$). Residents of large cities were considerably more active and tended to formulate more detailed inquiries during the summer peak season, reflecting greater mobility and a tendency to plan holidays around widely available vacation periods. In contrast, residents of smaller towns and older tourists were relatively more active in off-peak months (May-June, September), which may be linked to greater time flexibility or a desire to avoid crowds and higher prices. This supports the notion of differentiated tourism strategies depending on origin and life stage. The findings also align with earlier evidence that managerial and communicative features of listings significantly affect host activity on short-term rental platforms (Contu et al., 2023). Big-data analyses further confirm that the topic and level of detail in host-guest communication influence host responsiveness, which explains the significant impact of including price and standard information in inquiries (Jiang et al., 2024).

Overall, the results confirm that demographic factors, place of residence, and seasonality significantly influence the communication behaviors of tourists in social media when searching for accommodation. Gender and age shape the content and priorities of inquiries, with women

and younger users showing distinct patterns compared to men and older groups. Place of residence differentiates the level of detail in questions, while seasonality remains the strongest determinant of activity intensity. Importantly, the precision of inquiry content, particularly the inclusion of price and standard information—substantially increases the likelihood of receiving a response from providers. These findings highlight the interplay between demographic, temporal, and geographic factors in shaping online tourist behavior and underscore the need for accommodation providers to tailor their communication strategies accordingly.

6. Conclusions

Based on the study conducted in the Facebook group “Okuninka Jezioro Białe – noclegi (domki, pokoje, kwatery, pola namiotowe)”, it can be concluded that gender, age, and place of residence significantly influence how tourists use social media to search for accommodation, as well as the effectiveness of obtaining responses from property owners. Women more frequently formulate detailed inquiries about family- and child-friendly facilities, while men show greater interest in accommodation located near sports or recreational attractions. Younger age groups (18-34 years) are markedly more active during the summer season, whereas older users tend to plan trips outside the peak period. Users from large cities are more likely to use social media as a tool for seeking tourist information and submit more detailed inquiries, including the number of persons, facility standard, price, and location, thereby increasing the likelihood of receiving a response. By contrast, individuals from smaller towns more often limit themselves to general questions, which may reduce communication effectiveness. Seasonality of tourist activity is evident, with the peak occurring in July and August, while during the off-season (November-March) the number of posts decreases significantly. Qualitative analysis of post content showed that inquiries containing detailed information are more effective, and tourists are interested not only in basic parameters but also in additional amenities such as pet-friendly options, children’s attractions, or parking availability.

This study has certain limitations. The analysis focused on a single, albeit significant, Facebook group, which may limit the generalizability of the findings to other destinations or platforms. Furthermore, demographic data were estimated based on user profiles, which may introduce a margin of error. From a scientific perspective, the study confirms that demographics, place of residence, and seasonality play a crucial role in shaping tourists’ online behavior and accommodation choices. Despite these limitations, the research makes a substantial contribution to understanding the mechanisms governing direct interactions between tourists and accommodation providers in the era of social media. Expanding the analysis to a larger sample strengthens the validity of the results and supports the appropriateness of the adopted methodology.

The findings provide a foundation for further studies on the effectiveness of user-generated content in social media and the factors determining tourist decisions in empirical contexts. Future research may include analyses of other social media platforms, comparisons of tourist behavior across regions, the conversion of online inquiries into actual bookings, and examinations of language and form in posts, including photos, videos, and emojis. Another promising direction would be sentiment analysis of host responses or the impact of visual content on the effectiveness of listings. Pursuing these research avenues would enrich academic knowledge and equip tourism practitioners with precise tools for managing communication.

The study results also have important practical implications for accommodation providers and tourism organizations. Adapting communication and accommodation offers to age, gender, and place of residence can increase the effectiveness of tourist interactions and the likelihood of booking. Maintaining social media activity throughout the year, including the off-season, through the promotion of local events and attractions, can attract tourists during periods of low demand and support sustainable tourism development. Moreover, in the context of marketing, providers should ensure that their listings contain complete and accurate information, which enhances communication effectiveness and customer satisfaction.

In conclusion, the study highlights significant relationships between demographic characteristics, place of residence, seasonality of activity, and the effectiveness of tourist communication in social media. Incorporating these factors into the marketing strategies of destinations and accommodation providers can improve promotional effectiveness and contribute to the sustainable development of tourism in the Okuninka region.

References

1. An, Q., Ozturk, A.B. (2022). Assessing the effects of user-generated photos on hotel guests' price, service quality, overall image perceptions and booking intention. *Journal of Hospitality and Tourism Technology*, 13(4), 608-625. <https://doi.org/10.1108/JHTT-05-2021-0146>
2. Armutcu, B., Tan, A., Amponsah, M., Parida, S., Ramkissoon, H. (2023). Tourist behaviour: The role of digital marketing and social media. *Acta Psychologica*, 240, 104025. <https://doi.org/10.1016/j.actpsy.2023.104025>
3. Boley, B.B., Jordan, E.J., Kline, C., Knollenberg, W. (2018). Social return and intent to travel. *Tourism Management*, 64, 119–128. <https://doi.org/10.1016/j.tourman.2017.08.008>
4. Canadian Journal of Discovery (2025). *Marketing Destinations to Gen Z: A Study of Social Media Influence on Tourism Behavior*. Zenodo. <https://doi.org/10.5281/ZENODO.15389481>

5. Contu, G., Frigau, L., Ortu, M. (2023). VGLM proportional odds model to infer hosts' Airbnb performance. *Quality & Quantity*, 57(5), 4069-4094. <https://doi.org/10.1007/s11135-022-01550-2>
6. Faculty of the College of Business and Hospitality Management, Madridejos Community College, Cebu, Philippines, Cerna, J.T.D., C. Sonido, J.M., Faculty of the College of Business and Hospitality Management, Madridejos Community College, Cebu, Philippines, Mae Rubio, D.K., Faculty of the College of Technology and Engineering, Cebu Technological University-Bantayan Extension, Cebu, Philippines, V. Sisles, L.F., Faculty of the College of Technology and Engineering, Cebu Technological University-Bantayan Extension, Cebu, Philippines (2024). Analyzing Gen Z's Travel Influence in the Digital Age: The Correlational Effect of Social Media. *International Journal of Multidisciplinary Research and Analysis*, 7(10). <https://doi.org/10.47191/ijmra/v7-i10-01>
7. Fuentes-Moraleda, L., Lafuente-Ibáñez, C., Muñoz-Mazón, A., Villacé-Molinero, T. (2019). Willingness to Pay More to Stay at a Boutique Hotel with an Environmental Management System. A Preliminary Study in Spain. *Sustainability*, 11(18), 5134. <https://doi.org/10.3390/su11185134>
8. Galiano-Coronil, A., Blanco-Moreno, S. (2025). Exploring Rural Tourism Experiences from Social Marketing and Happiness Management Perspective: A Survival Analysis with Instagram. *Revista Empresa y Humanismo*, 133-166. <https://doi.org/10.15581/015.XXVIII.1.133-166>
9. Huang, Y., Basu, C., Hsu, M.K. (2010). Exploring Motivations of Travel Knowledge Sharing on Social Network Sites: An Empirical Investigation of U.S. College Students. *Journal of Hospitality Marketing & Management*, 19(7), 717-734. <https://doi.org/10.1080/19368623.2010.508002>
10. Hussain, K., Didarul Alam, M.M., Malik, A., Tarhini, A., Al Balushi, M.K. (2024). From likes to luggage: The role of social media content in attracting tourists. *Heliyon*, 10(19), e38914. <https://doi.org/10.1016/j.heliyon.2024.e38914>
11. Javed, A., Vardarsuyu, M., Can, A.S., Ekinici, Y. (2025). Social media influencers in tourism and hospitality: A comprehensive review combining bibliometric analysis and systematic literature review. *Anatolia*, 1-31. <https://doi.org/10.1080/13032917.2025.2531563>
12. Jiang, X., Li, Y., Yang, J., Wang, S., Han, C. (2024). Host–Guest Interaction and Sustainable Consumption Behaviour on Sharing-Accommodation Platforms: Using a Big Data Analytic Approach. *Sustainability*, 16(13), 5423. <https://doi.org/10.3390/su16135423>
13. Karatsoli, M., Nathanail, E. (2020). Examining gender differences of social media use for activity planning and travel choices. *European Transport Research Review*, 12(1), 44. <https://doi.org/10.1186/s12544-020-00436-4>

14. Kim, D., Hong, S., Park, B.-J., Kim, I. (2020). Understanding heterogeneous preferences of hotel choice attributes: Do customer segments matter? *Journal of Hospitality and Tourism Management*, 45, 330-337. <https://doi.org/10.1016/j.jhtm.2020.08.014>
15. Krishnan, J., Bhattacharjee, B., Pratap, M., Yadav, J.K., Maiti, M. (2024). Survival strategies for family-run homestays: Analyzing user reviews through text mining. *Data Science and Management*, 7(3), 228-237. <https://doi.org/10.1016/j.dsm.2024.03.003>
16. Kumar, S., Misra, S. (2023). Analytical Study On Preferred Type Of Accommodation. *PUSA Journal of Hospitality and Applied Sciences*, 9(2), 76-80. <https://doi.org/10.48165/pjhas.2023.9.2.10>
17. Lee, K., Gretzel, U. (2010). Differences in Online Travel Planning: A Rural vs. Urban Perspective. *2010 TTRA International Conference*.
18. Leung, D., Law, R., Van Hoof, H., Buhalis, D. (2013). Social Media in Tourism and Hospitality: A Literature Review. *Journal of Travel & Tourism Marketing*, 30(1-2), 3-22. <https://doi.org/10.1080/10548408.2013.750919>
19. Li, H., Zhang, L., Hsu, C.H.C. (2023). Research on user-generated photos in tourism and hospitality: A systematic review and way forward. *Tourism Management*, 96, 104714. <https://doi.org/10.1016/j.tourman.2022.104714>
20. Litvin, S.W., Goldsmith, R.E., Pan, B. (2008). Electronic word-of-mouth in hospitality and tourism management. *Tourism Management*, 29(3), 458-468. <https://doi.org/10.1016/j.tourman.2007.05.011>
21. Martins, W.S., Martins, M., Morais, E.P. (2025). Exploring the Influence of Social Media on Tourist Decision-Making: Insights from Cape Verde. *Tourism and Hospitality*, 6(1), 45. <https://doi.org/10.3390/tourhosp6010045>
22. Mattioli, G., Morton, C., Scheiner, J. (2021). Air Travel and Urbanity: The Role of Migration, Social Networks, Airport Accessibility, and 'Rebound'. *Urban Planning*, 6(2), 232-245. <https://doi.org/10.17645/up.v6i2.3983>
23. Millán, Á., Fanjul, M.L., Retamosa, M. (2024). Gender differences in business travel: implications for hotel and destination management. *Tourism and Hospitality Management*, 30(4). <https://doi.org/10.20867/thm.30.4.2>
24. Minazzi, R., Grechi, D. (2025). Exploring Gen Z Sustainable Behavior in the Hospitality Industry. *Administrative Sciences*, 15(7), 266. <https://doi.org/10.3390/admsci15070266>
25. Montenegro's Adriatic gem struggles with tourist influx (2024, sierpnia 9). *Reuters*. <https://www.reuters.com/world/europe/montenegros-adriatic-gem-struggles-with-tourist-influx-2024-08-09/>
26. Munar, A.M., Jacobsen, J.Kr.S. (2014). Motivations for sharing tourism experiences through social media. *Tourism Management*, 43, 46-54. <https://doi.org/10.1016/j.tourman.2014.01.012>

27. Nicolau, J.L., Rodríguez-Sánchez, C., Ruiz-Moreno, F. (2024). A motivation-based study to explain accommodation choice of senior tourists: Hotel or Airbnb. *International Journal of Hospitality Management*, 123, 103911. <https://doi.org/10.1016/j.ijhm.2024.103911>
28. Palazzo, M., Vollero, A., Vitale, P., Siano, A. (2021). Urban and rural destinations on Instagram: Exploring the influencers' role in #sustainabletourism. *Land Use Policy*, 100, 104915. <https://doi.org/10.1016/j.landusepol.2020.104915>
29. Pop, R.-A., Săplăcan, Z., Dabija, D.-C., Alt, M.-A. (2022). The impact of social media influencers on travel decisions: The role of trust in consumer decision journey. *Current Issues in Tourism*, 25(5), 823-843. <https://doi.org/10.1080/13683500.2021.1895729>
30. *Seasonal Travel Marketing: Peak Season and Shoulder Season Strategies* (2025, lutego 20). <https://maddenmedia.com/mastering-seasonality-a-travel-marketers-essential-guide-to-peak-and-shoulder-seasons/>
31. Shang, Y., Mehmood, K., Iftikhar, Y., Aziz, A., Tao, X., Shi, L. (2021). Energizing Intention to Visit Rural Destinations: How Social Media Disposition and Social Media Use Boost Tourism Through Information Publicity. *Frontiers in Psychology*, 12, 782461. <https://doi.org/10.3389/fpsyg.2021.782461>
32. Smith, H. (2024, sierpnia 30). 'Everywhere jam-packed': Mayor of Santorini warns of overtourism crisis. *The Guardian*. <https://www.theguardian.com/world/article/2024/aug/30/mayor-of-santorini-warns-of-overtourism-crisis-greece>
33. Srivastava, R., Gupta, P., Kumar, H., Tuli, N. (2025). Digital customer engagement: A systematic literature review and research agenda. *Australian Journal of Management*, 50(1), 220-245. <https://doi.org/10.1177/03128962231177096>
34. Vermeulen, I.E., Seegers, D. (2009). Tried and tested: The impact of online hotel reviews on consumer consideration. *Tourism Management*, 30(1), 123-127. <https://doi.org/10.1016/j.tourman.2008.04.008>
35. Villamediana, J., Küster, I., Vila, N. (2019). Destination engagement on Facebook: Time and seasonality. *Annals of Tourism Research*, 79, 102747. <https://doi.org/10.1016/j.annals.2019.102747>
36. Wang, H., Yan, J. (2022). Effects of social media tourism information quality on destination travel intention: Mediation effect of self-congruity and trust. *Frontiers in Psychology*, 13, 1049149. <https://doi.org/10.3389/fpsyg.2022.1049149>
37. *We live in „Little Venice” UK - tourists wee on street & spit at us...it's hell* (2025, września 13). The Sun. <https://www.thesun.co.uk/news/36646580/little-venice-village-tourists-urinate-spit-scared/>
38. Xiang, Z., Gretzel, U. (2010). Role of social media in online travel information search. *Tourism Management*, 31(2), 179-188. <https://doi.org/10.1016/j.tourman.2009.02.016>
39. Ying, T., Tang, J., Ye, S., Tan, X., Wei, W. (2022). Virtual Reality in Destination Marketing: Telepresence, Social Presence, and Tourists' Visit Intentions. *Journal of Travel Research*, 61(8), 1738-1756. <https://doi.org/10.1177/00472875211047273>

40. Zabudská, E., Pompurová, K. (2024). Identifying Patterns among Tourism-Oriented Online Communities on Facebook. *Tourism and Hospitality*, 5(3), 830-847. <https://doi.org/10.3390/tourhosp5030048>
41. Zawadka, J., Liwińska, M. (2022). Influence of social media on shaping tourists' preferences. *Turystyka i Rozwój Regionalny*, 17, 123-133. <https://doi.org/10.22630/TIRR.2022.17.12>
42. Zhang, J., Lai, I.K.W., Wong, J.W.C. (2024). Female travellers in hospitality and tourism industry: A systematic literature review. *Heliyon*, 10(5), e27256. <https://doi.org/10.1016/j.heliyon.2024.e27256>

FACTORS INFLUENCING THE MENTAL HEALTH OF EMPLOYEES FROM AN ORGANIZATION MANAGEMENT PERSPECTIVE

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Purpose: The purpose of this article is to comprehensively analyze and identify both organizational and individual factors that have a significant impact on the mental health of employees. Understanding these elements is crucial for improving work efficiency and satisfaction as perceived through the prism of constantly changing working conditions and the challenges of the modern market.

Design/methodology/approach: The study is based on a detailed analysis of the available literature on the subject and the results of empirical research devoted to various aspects affecting the mental health of employees. Particular attention was paid to organizational culture, organizational structures, and individual personality traits of employees, drawing on the latest scientific achievements in these fields.

Findings: The results of the study clearly indicate that organizations that promote open communication, flexibility, diversity, and offer mental health support programs observe significantly lower levels of stress and burnout among their employees. In addition, personality traits such as extroversion, conscientiousness, and openness to experience play a key role in the ability to cope with stress and influence the overall well-being of employees.

Research limitations/implications: The analysis is mainly based on the source literature its direct application in specific cultural or industry contexts. Future research should focus on empirically confirming these findings in different professional environments, which could lead to more detailed and tailored recommendations.

Practical implications: It is important for human resource management practitioners to implement strategies that support employee mental health, such as developing flexible organizational structures and providing access to psychological support programs. Understanding individual personality differences when designing jobs can significantly increase employee engagement and satisfaction, leading to better organizational performance.

Originality/value: The article is a valuable source of knowledge on the complex relationships between organizational and individual factors and the mental health of employees. Its uniqueness lies in the integration of these aspects in the context of contemporary management challenges, offering practical guidance for leaders and HR professionals who wish to improve the mental well-being of their teams. As a result, this article can serve as inspiration for introducing positive changes in human resource management policy, contributing to the creation of a more supportive and productive work environment.

Keywords: organizational management, organizational (structural) factors, individual factors, employee mental health.

Category of the paper: Testing of data.

1. Introduction

Employee mental health is an important aspect that affects efficiency and satisfaction in the workplace. The reality around us shows that in recent years more and more companies have decided to take measures aimed at providing psychological support to their employees. This translates into reduced absenteeism, increased motivation and commitment, and stimulation of creativity, which in turn leads to better business results. It is worth noting here that many factors can influence an employee's mental health, both those related to the workplace itself, such as stress and the various mental health problems that result from it (anxiety disorders, depression, neurosis), as well as external factors, which include family relationships, the geopolitical situation (e.g., the war in Ukraine), rising living costs, and the Covid-19 pandemic, which has had a significant impact on the mental well-being of employees.

Management is a very complex process because modern organizations operate in an extremely volatile and dynamic environment. This is influenced by a number of different factors, including rapid technological progress, increased global competition, regulatory and legal changes, increased awareness and social and environmental responsibility, and changing employee expectations. Effective management of an organization is an extremely important process, as it contributes to the achievement of the organization's pre-set goals. These goals will be achieved when the resources available to the organization are used optimally. All this means that leaders (managers) are required to have the ability to make rational decisions, often in crisis situations, i.e., under time pressure or in situations of high stress. At the same time, nowadays, changing business models, which emphasize the importance of the mental condition of employees in the context of broadly understood organizational performance, are playing an increasingly significant role.

Therefore, in this article, referring to the latest scientific research, a synthetic characterization of organizational (structural) and individual factors that are an essential building block in shaping the mental health (caring for mental well-being) of employees has been made. In this context, organizational factors included organizational culture (leadership style, type of culture, diversity and inclusiveness, and support programs) as well as organizational structure (hierarchy, structural flexibility, internal communication). Individual factors included personality (neuroticism, extroversion, openness to experience, agreeableness, conscientiousness) and emotional intelligence.

It should be noted that the research sample was characterized by considerable diversity in terms of the industries represented and the professional roles held, which constitutes a significant strength of the study. The participants represented a wide range of positions — from operational to managerial — allowing for the identification of both differences and similarities in professional experiences. The variation in demographic and occupational characteristics enhanced the generalizability of the study's findings to a broader population and

enabled a deeper understanding of the impact of industry-specific context on the phenomenon under investigation.

The data collection process in the presented study was based on a mixed-methods approach, combining qualitative and quantitative techniques. Qualitative data were gathered through individual interviews, which provided deeper insights into employees' experiences, perspectives, and motivations. Quantitative data were collected using psychometric tests, enabling statistical analysis and the identification of patterns in respondents' behaviors and attitudes.

2. Organizational factors and employee mental health

The first of the factors discussed is organizational culture. In the literature on the subject, it is defined, among other things, as *...a set of beliefs, values, and norms that shape the way an organization functions and how its members perceive and respond to their environment...* (Morgan, 2006) or as *...the collective programming of the mind that distinguishes the members of one organization from another...* (Hofstede, 1991). Generally speaking, organizational culture can be defined as a set of certain norms, values, beliefs, or practices that influence how employees of a given organization feel, think, and behave. One of the aspects that organizational culture influences, in addition to employee engagement, customer relations, and the efficiency and effectiveness of work, is employee satisfaction and well-being.

Leadership style has a huge impact on the mental health of employees, as it affects the atmosphere in the workplace and team morale. Research in this area has been conducted in various industries where different leadership styles were used. The results indicate that in organizations with a democratic leadership style, i.e., where employees are involved in decision-making processes, where all members of the organization can clearly express their thoughts and needs, and therefore where there is open communication, lower levels of occupational stress were observed among employees (Ahn, 2025).

Better mental health, higher levels of satisfaction, and lower levels of perceived stress are found in an organizational culture focused on sustainable development (Monteiro, Joseph, 2023). Employees are more committed to performing their professional duties in an organization that not only cares about its image, but above all ensures that its members feel proud to work for a company that cares about the environment and the community.

Another aspect worth noting in the context of mental well-being is diversity and inclusiveness. Research conducted in this area has shown that employees who performed their duties in teams that were diverse in terms of gender, life experience, and ethnicity achieved better mental health outcomes (Dawson, Parker, Okimoto, 2023). What is more, these employees demonstrated greater innovation because they felt appreciated by their superiors and

accepted by the people around them, which reduced their stress levels and increased their overall well-being.

Interesting research results were also presented by R. Joshi and S. Jaffer also presented interesting research results, proving that in organizations where various mental health support programs, psychological counseling, or stress management training for employees are available, there are lower levels of anxiety felt by employees and lower rates of burnout (Joshi, Jaffer, 2022). It is worth noting here that burnout, which is a consequence of occupational stress, occurs when a person assesses that the demands placed on them at work exceed their individual capabilities, or when they encounter obstacles that prevent them from satisfying their needs or achieving certain values (Ogińska-Bulik, 2007), consequently causing psychological dysfunction. Therefore, working in a supportive culture improves employees' overall mental well-being - they have the opportunity to share their problems with both colleagues and supervisors, and they can also participate in meetings with psychologists or psychotherapists or specialized training/courses organized in the workplace. Employees are then less likely to experience stress (and if they do, they know how to deal with it) and emotional exhaustion.

Another organizational factor influencing the mental health of employees is the organizational structure. It shows the interrelationships between all the elements necessary to shape the organization. The design of an organizational structure is not a concept that can be interpreted unambiguously. It refers to both the creation of a new structure from scratch and changes to an existing structure (Kaczmarek, 2022). Understanding the impact of organizational structure on the mental health of employees has become an important element in research on management and occupational psychology.

One of the elements analyzed in terms of employee mental health was the role of hierarchical structure. An analysis of the results showed that employees in organizations with less hierarchical structures reported greater job satisfaction and enjoyment, had better relationships with colleagues and supervisors, and experienced lower levels of stress (Lee, Kim, 2023). It has also been proven that in flat-structured organizations, where the principles of autonomy and flexibility are upheld, employees had lower rates of burnout. In contrast, in organizations where there is a strong emphasis on rigid rules and limited communication, i.e., in hierarchical structures, employees experienced higher levels of stress and more frequent episodes of depression (Sonnentag, Tay, Shoshan, 2023). During the Covid-19 pandemic and the increase in remote work, studies have shown that in hierarchical structures, employees felt isolated and underappreciated, were discouraged from performing their assigned work tasks, and felt a lack of support from their work environment, which in turn led to increased levels of anxiety and depression (Tawas, Kamaluddin, Hadi, Supardi, Irianti, 2024).

In the context of the above considerations, it is also worth noting the importance of organizational flexibility, which is defined in the literature as “the ability to adapt to changing conditions, which may include changes in hierarchy, decision-making processes, and internal

communication methods” (Daft, 2020). Structural flexibility is crucial for innovation and competitiveness, but it also has a significant impact on the mental health of employees.

Flexibility was an important factor that not only promoted work-life balance, but also allowed for better management of working time. Employees were satisfied with their job responsibilities and experienced lower levels of stress (Shagvaliyeva, Yazdanifard, 2014). Work flexibility (regular breaks, choice of place and time of work) has a very significant impact on reducing burnout and increasing job satisfaction (Wheatley, 2017). What is more, employees will increase their commitment if the flexible forms of work they choose help them achieve a work-life balance by reducing stress, fatigue, burnout, etc. (Austin-Egole, Iheriohanma, Nwokorie, 2020). It has been shown that work-related stress negatively affects work-life balance and mental well-being, especially in demanding industries such as e-commerce. The blurring of boundaries between work and personal life, exacerbated by remote working conditions, has further intensified these challenges, leading to increased stress levels and deteriorating well-being (Rasak, Zamri, Suhaimi, Kamaruddin, 2024).

The results of numerous studies also indicate that internal communication is an extremely important factor that positively influences faster decision-making, the atmosphere in the workplace, but above all, the mental health of employees. It is a key element in the effective (free of noise and communication errors) transfer of information at various organizational levels, including between employees, organizational units, and managers (management). In companies that focus on efficient internal communication, cooperation, and support, employees do not feel isolated when performing their professional tasks, which in turn contributes to the elimination of burnout and improves their overall well-being (Truong, McLachlan, 2022).

Effective communication helps to improve the overall efficiency of the organization. It should also be noted that leadership style has a significant impact on work performance and employee satisfaction. Effective leadership has a positive impact on employee motivation, engagement, and productivity, which leads to better organizational performance. Managers who use a democratic communication style make employees more engaged in their duties, more creative, and feel more valued. As a result, employees experience low levels or no burnout and increased job satisfaction (Meiling, Junzahng, Loang, 2023).

An interesting study was also conducted to determine whether regular feedback, appreciation, and recognition by management have an impact on the mental well-being of employees. It turned out that systematic, constructive feedback is extremely important for employees. It improves their overall mood, increases their motivation to work and sense of belonging to the team, boosts their self-esteem, and also reduces their level of work-related stress (Lundqvist, Wallo, 2023).

The impact of open communication on the level of occupational stress was also analyzed. It is worth adding here that open communication is understood as a process in which all employees have free access to information flowing within the organization and can freely

express their thoughts, opinions, and ideas (Łasiński, Głowicki, 2011). Therefore, the main goal of open communication in organizations is to involve employees in the decision-making process, increase their commitment, assertiveness, and motivation to perform their duties, and generally improve the atmosphere in the workplace. In organizations where a culture of transparency and openness in the flow of information has been implemented, there is a lower level of occupational stress among employees. (Smith, Johnson, 2018).

Interesting results were also provided by studies on the use of communication strategies in crisis situations in organizations and their impact on the level of anxiety and uncertainty among employees. The results indicated that the following factors play an important role in these situations: regularity of communication (information about the situation in the company and its updating), transparency of information (understandable and clear messages), and emotional support (access to mental health resources). The provision of these factors by the organization's management led to an overall improvement in the mental health of employees, including: an increased sense of security, a reduction in anxiety and uncertainty, and thus a reduction in perceived stress, as well as increased satisfaction (Castro-Martínez, Díaz-Morilla, Torres-Martín, 2022).

In summary, it should be noted that selected organizational (structural) factors play a significant role in shaping the work environment, and their impact on the mental health of employees is becoming increasingly noticeable.

Organizational culture, defined as a set of values, beliefs, and norms, influences the functioning of the organization and the well-being of employees. A democratic leadership style, characterized by open communication and employee involvement in decision-making processes, reduces occupational stress. Sustainable organizational development, diversity, and inclusiveness also improve mental health by increasing engagement and innovation.

Organizational structure, especially one that is less hierarchical and more flexible, affects job satisfaction and stress reduction. In the context of remote work, hierarchical structures can increase isolation and underappreciation of employees, which increases levels of anxiety and depression. The flexibility of the organizational structure promotes work-life balance, improving employee well-being.

Internal communication, a key element of effective information transfer, affects the workplace atmosphere and the mental health of employees. Effective communication and regular feedback increase motivation, self-esteem, and reduce work-related stress. In crisis situations, regular, transparent communication and emotional support improve mental health by reducing anxiety and uncertainty.

Therefore, organizations of all types should strive to create cultures focused on sustainability, diversity, and inclusivity, which promote the mental health of employees. Leadership style and organizational structure should promote open communication, flexibility, and collaboration, which contributes to reducing stress and burnout. Regular feedback and effective communication strategies during crises are key to maintaining a high level of mental health in the organization.

3. Individual factors and employee mental health

There is no doubt that mental stress related to a person's personality is, in a sense, inherent in the broadly understood management of organizations. Personality is a term that is difficult to define unambiguously. The concept of human personality is a subject of research in psychology, psychiatry, pedagogy, and sociology. In the most common understanding, personality is what we call character, i.e., a person's approach to certain moral beliefs or values that are revealed in their behavior, manner, life or professional aspirations, as well as in interpersonal relationships. On the other hand, the set of traits that manifest themselves in the first year of life and are genetically determined are referred to as temperament, which is responsible for the natural level of activity and shapes the basis for the formation and development of personality (Kaczmarek, 2022). In general, personality is defined as *a relatively stable pattern of emotions, motives, and behavior that distinguishes one person from another* (Rathus, 2006). P.G. Zimbardo, on the other hand, defines personality as “a complex set of psychological properties that influence an individual's characteristic patterns of behavior, unchanged over time and across situations”.

Understanding a person's personality in the context of their functioning in an organization (performing work tasks, responding to emerging threats) has become key in the context of mental health. This is because personality influences how employees cope with stress in the workplace, how they respond to various challenges, and how they build interpersonal relationships. Therefore, special attention should be paid here to the Five Factor Model, known as the Big Five, which is currently one of the most widely used models for describing personality in terms of traits. The factors included in this model form five basic dimensions of personality, which include: neuroticism, extroversion, openness to experience, agreeableness, and conscientiousness (Siuta, 2006). These personality traits will be briefly characterized based on the results of research on the mental health of employees.

Neuroticism is a dimension related to emotional stability versus emotional instability. It means that a person is prone to experiencing various negative emotions, such as anxiety, hostility, depression, impulsiveness, hypersensitivity, shyness, and sensitivity to psychological stress. Research results have shown, among other things, that employees with high neuroticism:

- are prone to increased stress at work (Yan, Ping, Feng, Jin, 2024),
- are more sensitive to burnout, which in turn leads to reduced work performance (Zhang, Sun, Wul, Ma, Shen, Hu, Lang, 2024),
- have problems building positive relationships with colleagues, which results in social isolation and affects their well-being in the workplace (Zhang, Dai, 2014),
- have problems making risky decisions and may also make less effective decisions, which in turn affects the overall performance of the organization (Hilbig, 2008),

- experience lower job satisfaction, which can lead to higher employee turnover in organizations (Judge, Bono, Locke, 2000),
- have difficulty adapting to organizational changes in the workplace, which may result in reduced work performance (Nejad H., Nejad F., Farahani, 2021),
- have limited creative potential (creativity problems), which affects the overall innovation in the organization (Thomas, Khalil, 2022).

Extroversion is characteristic of people who are capable of feeling positive emotions, who are highly active and who engage in intense social interactions. Introverts, on the other hand, keep their distance in social interactions, prefer to be alone rather than in company, and are shy and secretive. Extroverts are more likely to seek social support and are therefore able to build better relationships with their colleagues, which has a positive impact on their mental health. The results of the study indicate, among other things, that:

- extroversion is positively correlated with job satisfaction, and extroverts are more engaged and have better well-being (Ghayas, Shaheen, Devi, 2021),
- people with high levels of extroversion tend to have a positive mood, perform their work competently (Barrick, Mount, 1991), earn higher salaries, and are promoted more often than others (Seibert, Kraimer, 2001),
- extroverts are better able to cope with work-related stress, which in turn leads to fewer symptoms of anxiety and depression, and they show fewer symptoms of burnout (Uliaszek, Zinbarg, Mineka, Craske, Sutton, Griffit, Rose, Waters, Hammen, 2010).

Openness to experience indicates a person's tendency to seek out and positively evaluate various life experiences, openness to novelty, and cognitive curiosity. In the context of the present study, the research proved that:

- employees with higher openness to experience showed a better ability to adapt to organizational changes, higher creativity, innovation, and work flexibility, which in turn led to higher job satisfaction (Madrid, Patterson, 2016),
- employees with higher openness scores are able to build better interpersonal relationships and are also more willing to cooperate, which increases the effectiveness of group work (Reich, Hershcovis, 2011),
- members of organizations with a higher level of openness were less prone to burnout, were able to reduce stress related to performing their professional duties, and manage their working time (Wijaya, Martin, Tambunan, Hou, Chaniago, 2025).

Agreeableness is a dimension that is primarily related to interpersonal relationships – a positive vs. negative attitude toward other people. Employees with high agreeableness, i.e. those who are characterized by sincerity, emotionality, or modesty, generally:

- have the ability to cope with stress and other challenges at work, which reduces the risk of burnout (Patitsa, Sotiropoulou, Giannakouli, Tsaknis, Sahinidis, 2023),

- are less likely to escalate conflicts in the workplace and build positive interpersonal relationships in the professional environment (Ghorpade, Lackritz, Singh 2011),
- they are more committed to performing their professional duties, especially in environments that promote psychological safety (Woods, Sofat, 2013),
- they are able to maintain a balance between their personal and professional lives, which has a positive impact on their mental health (Steel, Schmidt, Bosco, Uggerslev, 2018).

Conscientiousness is a dimension that characterizes people who are persistent, highly motivated to achieve their goals, dutiful, punctual, meticulous, prudent, and reliable at work – usually achieving many successes in their professional lives. In the context of the research conducted, it should be noted that:

- a high level of conscientiousness is closely related to lower stress levels Employees are better organized, less likely to procrastinate (they manage their tasks more effectively), which in turn contributes to reduced mental tension and job satisfaction (Gartland, O'Connor, Lawton, Ferguson, 2014),
- conscientiousness can be an important element in the prevention of burnout, as it has been proven that there is an inverse correlation between conscientiousness and symptoms of burnout (Liu, Li, Zhu, He, Li, 2022),
- a high level of conscientiousness improves team performance by building positive interpersonal relationships and improving the atmosphere in the workplace (Luksyte, Carpini, Parker, Griffin, 2024),
- a high level of conscientiousness promotes adaptation to new conditions and challenges in the workplace, which facilitates overall adaptation to organizational changes (Tu, Lu, Wang, Liu, 2020).

It should be emphasized here that too high a level of this trait may be associated with workaholism, perfectionism, or an excessive tendency to maintain order.

The personality traits that are particularly associated with stress are neuroticism and extroversion, and to a lesser extent conscientiousness and agreeableness. High levels of extroversion and low levels of neuroticism are associated with a task-oriented style of coping with stress, as well as a style of seeking contact. In turn, high levels of neuroticism and high levels of introversion are associated with a stress coping style that is focused on emotions (Terelak, 2008).

In the overall context of the mental health of employees, emotional intelligence should also be taken into account. It has been recognized as an important element of social intelligence and is broadly defined as a person's ability to track their own and others' feelings and emotions, distinguish between them, and use the knowledge gained in this area to guide their thought processes and actions (Ogińska-Bulik, 2008). It should therefore be emphasized that a person's emotional intelligence affects their ability to cope with various life situations, such as establishing contacts, reading other people's feelings, and preventing conflicts, but it also plays an important role in the effective performance of professional tasks (Kaczmarek, 2022).

Research on emotional intelligence shows that people who have a high level of it are more likely to devote their time and energy to other people and their causes. Due to the fact that such people are respected and appreciated by others, they are well suited to managerial positions. What is more, members of an organization in a stressful situation are able to take action to cope with it, are more resistant to it, and thus suffer fewer losses as a result of experiencing stressful situations. It has also been proven that managers (bosses) with high emotional intelligence have better well-being and lower stress levels. On the other hand, people with low emotional intelligence tend to approach life critically and treat others with distance. They are characterized by a reluctance to express their feelings, a tendency to worry, and a tendency to blame themselves. In stressful situations, they use strategies such as distraction, denial, or cognitive blocking (Slaski, Cartwright, 2002).

On the other hand, research conducted by N. Ogińska-Bulik shows that a high level of emotional intelligence can reduce the negative consequences of stress at work and, importantly, reduce the severity of various dimensions of burnout (Ogińska-Bulik, 2007).

From the perspective of an employee's mental health, several important conclusions can be drawn about their tendency to exhibit specific behaviors in situations of conflict, crisis, or stress (Konieczny, 2014):

- a high level of neuroticism makes a person more vulnerable to stress related to interpersonal relationships (the opposite situation occurs among people who are characterized by a high level of agreeableness),
- a lack of emotional stability causes a person to assess a given situation as more threatening than it actually is,
- a person with neurotic traits places greater emphasis on their emotional problems and exhibits aggressive behavior – in stressful situations, their behavior becomes irrational,
- conscientious people cope better in stressful situations because they are more organized, determined, and disciplined, and are able to plan and anticipate the consequences of their actions,
- conscientious, extroverted, and open-minded people view a given situation more as a challenge or a goal to be achieved than as a threat—they are able to objectively assess their own resources,
- people who are open to new experiences are able to function effectively in new situations or environments thanks to their ability to think creatively and flexibly and focus on the task at hand.
- people who are more extroverted and less neurotic will cope better in stressful situations,
- a high level of openness may be associated with better mental health, greater job satisfaction, and lower levels of burnout,

- high conscientiousness can be an effective strategy for counteracting procrastination and improving work efficiency,
- a high level of emotional intelligence can contribute to maintaining the mental health of employees.

In summary, in the context of organizational management, personality is an important determinant of mental health. It is crucial to understand one's own personality predispositions, which contribute significantly to the acquisition of skills for managing one's own mental well-being. This awareness allows for more effective implementation of occupational stress management strategies, better coping with workplace challenges, building interpersonal relationships, and developing adaptive mechanisms. Understanding personality predispositions therefore allows for professional career development. It is also worth emphasizing that using different strategies to regulate emotions in order to cope with emotional demands at work is important for reducing the emotional burnout component. Therefore, training programs in conflict and emotion management are needed to protect the mental health of employees (Michinov, 2022). Understanding an employee's personality type can open up many opportunities for companies to help them shape organizational commitment among employees – an element considered key to the efficient functioning of modern business organizations. Hence, in the context of human resource management, employers should take personality profiles into account when designing jobs or assigning work tasks. Leaders should be aware of the importance of their employees' personality types and their impact on employee behavior and attitudes (Cobanoglu, 2020; Kim, Beehr, 2020; Peng, Liao, Sun, 2020). This can significantly affect both job satisfaction and the mental well-being of employees.

4. The mental health of Polish employees

As previously indicated, the good mental health of employees is a key element of modern organizational management. It affects many aspects of the work environment, including: efficiency and productivity in performing work tasks, creativity and openness to new ideas, interpersonal relationships, stress management skills, as well as overall job satisfaction. It cannot be denied that all of the above-mentioned aspects contribute to a positive image of the company, which in turn can help attract new employees and influence customer loyalty. Therefore, the ability to manage the mental health of employees should be an integral part of human resource management strategy.

In view of the above, this section of the article provides a brief analysis of available data and scientific research on the general mental health of Polish employees.

The COVID-19 pandemic has played a huge role in the context of mental health, forcing radical changes in work models and leading to changes in the perception of employees' mental health. It has been noted that many employees experienced increased levels of work-related stress, anxiety, or depression in the early stages of the pandemic.

Multiple studies and analyses concerning the mental health of employees in 2024 show that employees face ever new and numerous challenges that contribute to increasing levels of occupational stress and difficulties in maintaining a work-life balance.

In a study conducted by the Randstad Research Institute in 2024, a significant increase in the level of work-related stress among Polish employees was observed. The report shows that as many as 62% of employees regularly experience work-related stress, which is an increase of 10% compared to a study conducted in 2023 by the same institution (Randstad, 2024, p. 15). In my opinion, this is a rather worrying result, which should motivate employers to make efforts to prevent stress in the workplace (in the literature on the subject, such measures are referred to as stress management).

The most significant stress factors in the work environment include: lack of job security, tense interpersonal relationships, time pressure, lack of or insufficient support from superiors, task overload, lack of work-life balance, inadequate remuneration in relation to responsibility, ineffective communication within the team, and toxic relationships in the workplace. Prolonged exposure to high levels of stress can lead to many negative psychosomatic consequences for employees, such as burnout, anxiety, depression, or general exhaustion.

Research on burnout shows that as many as 47% of employees in Poland experience symptoms of this syndrome—for comparison, in 2023, 42% of employees experienced symptoms of burnout (Global Talent Trends, Mercer, 2024). According to a report by UCE Research and the ePsycholodzy.pl platform ([epsycholodzy.pl](https://psycholodzy.pl)), as many as 78.3% of Polish employees (especially in the 45-55 age group) recognize at least one of the fourteen symptoms of burnout in themselves. Compared to the survey conducted in 2021, this is an increase of 13 percentage points. The symptoms most frequently mentioned by respondents included (gazetaprawna.pl):

- a prolonged and strong feeling of fatigue or exhaustion and lack of energy – 43.4%,
- lack of job satisfaction and motivation to work – 25.2%,
- increased distance from work – 20.8%,
- irritability and aversion to professional duties – 20.6%,
- decreased productivity – 20.1%.

Considering the above results, it is very important to analyze the occurrence of anxiety and symptoms of depressive disorders among Polish employees. It cannot be denied that these disorders are indicative not only of problems within the organization itself, but also in the personal lives of employees. Nevertheless, employee malaise not only affects their health, but can also have serious negative consequences for the entire organization.

Research published by Wellbee indicates that 27% of employees meet the criteria for anxiety disorders, and 32% meet the criteria for depressive disorders. Women (45%) are significantly more likely to meet the diagnostic criteria than men (31%) (Wellbee, 2024). This is a significant increase compared to, for example, research conducted by Mindgram in 2023 (Mindgram, 2023), where 17% of respondents indicated high severity of depressive symptoms and 16% indicated severe anxiety symptoms. It is worth mentioning here that, according to the latest estimates, depression affects about 4 million Poles, with those working in the service and administration sectors being the most vulnerable. In the group of office workers, the percentage of people reporting symptoms of depression reached as high as 28% (www.medonet.pl). Anxiety and depression not only negatively affect the well-being of employees, but also impact the functioning of the entire company.

It should therefore be concluded that it is in the interest of the organization to implement various psychological support programs for employees. These are activities aimed at increasing productivity, motivation, and employee engagement, thereby improving their mental health. Forms of psychological support include psychological/psychotherapeutic consultations, training, workshops, and coaching. It is particularly important for employees to take advantage of psychological support when they are struggling with excessive stress and various crises. Regular meetings and therapeutic work help not only the employee in question, but also other members of the organization.

5. Summary

In today's rapidly evolving field of organizational management, companies are constantly looking for ways to increase the effectiveness of their employees. However, it cannot be denied that a often overlooked but crucial aspect affecting employee creativity and productivity is their physical and mental health. A comprehensive approach to human resource management that takes into account both organizational and individual factors is key to creating a healthy work environment.

The World Health Organization emphasizes that physical and mental well-being are closely linked and that both are essential for an individual to cope effectively with stress, work efficiently, and have a positive impact on the work environment. Employees with good mental well-being are more motivated, engaged, and satisfied with their work, which translates into lower absenteeism due to mental health issues and better overall performance. It is therefore crucial to understand the sources of occupational stress, anxiety, depression, and other health problems in order to improve the overall mental health of employees. The sources of these emotional problems may be related to factors such as job insecurity, excessive workload, pressure resulting from overly high expectations of superiors, a toxic workplace atmosphere,

responsibility, or lack of adequate support. Therefore, investing in the development of a supportive culture, introducing flexible working hours, understanding personality predispositions, and developing stress management skills can lead to better business results. This approach not only increases employee satisfaction but also translates into better results for the entire organization, which is essential in the face of dynamic market transformations and growing competition.

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References

1. Ahn, D. (2025). The Impact of Leadership Styles on Employee Mental Health and Company Performance in the Finance Industry. *Journal of Student Research*, Vol. 14, Iss. 1, p. 6.
2. Austin-Egole, I.S., Iheriohanma, E.B.J., Nwokorie, C. (2020). Flexible Working Arrangments and Organizational Performance: An Overview. *IOSR Journal Of Humanities And Social Science (IOSR-JHSS)*, Vol. 25, Iss. 5, Series 6, 50-59.
3. *Badanie dobrostanu polskich pracowników. Analiza stanu kondycji psychicznej na rodzimym rynku pracy i rekomendowane działania naprawcze Mindgram*, Raport (2023).
4. Barrick, M.R., Mount, M.K. (1991). The big five personality dimensions and job performance: a meta-analysis. *Personnel Psychology*, 44, 1-26.
5. Castro-Martínez, A., Díaz-Morilla, P., Torres-Martín, J.L. (2022). The role of internal communication in teleworking management during the Covid-19 crisis. *Revista de Comunicación de la SEECI*, 55, 29-51.
6. Cobanoglu, N. (2020). Investigation of Shared Leadership and Organizational Commitment in Primary and Secondary Schools: Malatya Case. *International Journal of Educational Methodology*, 6(3), 613-629;
7. Daft, R.L. (2020). *Organization Theory and Design*. Cengage Learning, p. 102.
8. Dawson, N., Parker, S., Okimoto, T. (2023). Profiles of diversity and inclusion motivation: Toward an employee- centered understanding of why employees put effort into inclusion and exclusion. *Human Resource Management*, 63(1), 45-66.

9. *Epsycholodzy*. Retrieved from: <https://epsycholodzy.pl/blog/2022/04/05/raporty-i-analizy-40-polakow-twierdzi-ze-w-czasie-pandemii-pogorszylo-sie-ich-zdrowie-psychiczne/>, 15.03.2025.
10. Gartland, N., O'Connor, D., Lawton, R., Ferguson, E. (2014). Investigating the effects of conscientiousness on daily stress, affect and physical symptom processes: A daily diary study. *British Journal of Health Psychology*, 19, 311-328.
11. *Gazeta prawną*. Retrieved from: <https://serwisy.gazetaprawna.pl/praca-i-kariera/artykuly/9667045,zbadali-polakow-pod-katem-wypalenia-zawodowego-tak-zle-jeszcze-nie-by.html>, 15.03.2025.
12. Ghayas, M.M., Shaheen, A., Devi, A. (2021). Personality, Job Satisfaction, and Organizational Commitment. *Reviews of Management Sciences*, Vol. III, No. 2.
13. Ghorpade, J., Lackritz, J., Singh, G. (2011). Personality as a Moderator of the Relationship Between Role Conflict, Role Ambiguity, and Burnout. *Journal of Applied Social Psychology*, Vol. 41, Iss. 6, 1275-1298.
14. *Global Talent Trends 2024*, Mercer (2024).
15. Hilbig, B.E. (2008). Individual differences in fast-and-frugal decision making: Neuroticism and the recognition heuristic. *Journal of Research in Personality*, Vol. 42, Iss. 6, 1641-1645.
16. Hofstede, G. (1991). *Cultures and Organizations: Software of the Mind*. London: McGraw-Hill, p. 180.
17. Joshi, R., Jaffer, S. (2024). Impact Of Organizational Culture On Job Stress And Well-Being Among Higher Education Faculty. *Educational Administration: Theory and Practice*, 30(5), 13975-13985.
18. Judge, T., Bono, J., Locke, E.A. (2000). Personality and job satisfaction: The mediating role of job characteristics. *Journal of Applied Psychology*, 85(2), 237-249.
19. Kaczmarek, A. (2021). *Psychologiczne determinanty zarządzania w sytuacjach kryzysowych w wybranych instytucjach bezpieczeństwa*. Warszawa: Wydawnictwo Akademii Sztuki Wojennej, pp. 113, 251-252, 261.
20. Kim, M., Beehr, T.A. (2020). Empowering leadership: leading people to be present through affective organizational commitment? *The International Journal of Human Resource Management*, 31(16), 2017-2044.
21. *Kondycja psychiczna polskich pracowników*. Wellbee, Raport (2024).
22. Konieczny, T. (2014). *Stres w organizacji*. Harmona Universalis, pp. 70-71.
23. Łasiński, G., Głowicki, P. (2011). Komunikacja otwarta jako istotny obszar potencjału rozwojowego zespołów. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 218, p. 146.
24. Lee, M., Kim, B. (2023). Effect of the Employees' Mental Toughness on Organizational Commitment and Job Satisfaction. *Mediating Psychological Well-Being. Administrative Sciences*, 13, 133.

25. Liu, Z., Li, Y., Zhu, W., He, Y., Li, D. (2022). A Meta-Analysis of Teachers' Job Burnout and Big Five Personality Traits. *Frontiers in Education, Vol. 7*.
26. Luksyte, A., Carpini, J.A., Parker, S.K., Griffin, M.A. (2024). Conscientiousness and perceived ethicality: Examining why hierarchy of authority diminishes this positive relationship. *Human Resource Management; 63*, 601-617.
27. Lundqvist, D., Wallo, A. (2023). Leadership and Employee Well-Being and Work Performance when Working from Home: A Systematic Literature Review. *Scandinavian Journal of Work and Organizational Psychology, 8(1)*, 9, 1-19.
28. Madrid, H.P., Patterson, M.G. (2016). Creativity at work as a joint function between openness to experience, need for cognition and organizational fairness. *Learning and Individual Differences, Vol. 51*, 409-416.
29. Medonet. Retrieved from: <https://www.medonet.pl/choroby-od-a-do-z/choroby-i-zaburzenia-psychiczne,depresja-dotyka-juz-blisko-4-mln-polakow--konsultant-krajowy--niepokoi-mnie-jedna-rzecz,artykul,74135122.html>, 20.03.2025.
30. Meiling, G., Junzahng, W., Yu, G., Loang, O.K. (2023). The Impact Of Leadership Styles On Organizational Performance And Employee Satisfaction: A Case Study Approach. *International Journal of Accounting, Finance and Business (IJAFB), 8(50)*, 414-437.
31. Michinov, E. (2022). The Moderating Role of Emotional Intelligence on the Relationship Between Conflict Management Styles and Burnout among Firefighters. *Safety and Health at Work, 13(3)*.
32. Monteiro, E., Joseph, J. (2023). A Review on the Impact of Workplace Culture on Employee Mental Health and Well-Being. *International Journal of Case Studies in Business, IT, and Education, Vol. 7, No. 2*, p. 306.
33. Morgan, G. (2006). *Images of Organization*. Thousand Oaks, CA: Sage Publications, p. 121.
34. Nejad, H.G., Nejad, F.G., Farahani, T. (2021). Adaptability and Workplace Subjective Well-Being: The Effects of Meaning and Purpose on Young Workers in the Workplace. *Canadian Journal of Career Development, Vol. 20, No. 2*.
35. Ogińska-Bulik, N. (2007). *Stres zawodowy u policjantów*. Łódź: Wydawnictwo WSHE, p. 118.
36. Ogińska-Bulik, N. (2008). Stres zawodowy i jego konsekwencje w grupie pracowników sektora usług społecznych – rola inteligencji emocjonalnej. *Przegląd psychologiczny, Tom 51, Nr 1*, 69-85.
37. Patitsa, C.D., Sotiropoulou, K., Giannakouli, V., Tsaknis, P.A., Sahinidis, A.G. (2023). The relationship between personality, well-being, and gratitude in teleworking. *Corporate & Business Strategy Review, 4(4)*, 98-107.
38. Peng, S., Liao, Y., Sun, R. (2020). The influence of transformational leadership on employees' affective organizational commitment in public and nonprofit organizations: A moderated mediation model. *Public Personnel Management, 49(1)*, 29-56.

39. Rasak, N., Zamri, M.N., Suhaimi, M., Kamaruddin, K. (2024). The Role of Leadership Styles, Work-Life Balance and The Physical Environment in Promoting Psychological Well-Being: A Job Demands-Resources Perspective. *Information Management and Business Review*. Vol. 16, No. 3S(a), pp. 88-97.
40. Rathus, S.A. (2006). *Psychologia współczesna*. Gdańsk, p. 480.
41. Reich, T., Hershcovis, S. (2011). Interpersonal relationships at work. In: S. Zedeck, H. Aguinis, W. Cascio, M. Gelfand, K. Leung, S. Parker, J. Zhou, Handbook of industrial and organizational psychology. *American Psychological Association*, Vol. 3, pp. 223-248.
42. Seibert, S., Kraimer, M.L. (2001). The five-factor model of personality and career success. *Journal of Vocational Behavior*, 58(1), 1-21.
43. Shagvaliyeva, S., Yazdanifard, R. (2014). Impact of Flexible Working Hours on Work-Life Balance. *American Journal of Industrial and Business Management*, 4, 20-23.
44. Siuta, J. (2006). *Inwentarz Osobowości NEO-PI-R Paula T. Costy i Roberta R. McCrae*. Warszawa, pp. 26-29.
45. Slaski, M., Cartwright, S. (2002). Health, performance and emotional intelligence: An exploratory study of retail managers. *Stress and Health*, 18, pp. 63-68.
46. Smith, J.K., Johnson, R.H. (2018). The Impact of Technology on Communication and Collaboration in Organizations. *International Journal of Business Communication*, 46, 312-330.
47. Sonnentag, S., Tay L., Shoshan, H.N. (2023). A review on health and well-being at work: More than stressors and strains. *Personnel Psychology*, 76, 473-510.
48. Steel, P., Schmidt, J., Bosco, F., Uggerslev, K. (2018). The effects of personality on job satisfaction and life satisfaction: A meta-analytic investigation accounting for bandwidth-fidelity and commensurability. *Human Relations*, 72(6).
49. Tawas, H.N., Kamaluddin, Hadi, S., Supardi, Irianti (2024). The Impact of Remote Work Policies, Employee Mental Health Support, and Agile Project Management on Organizational Resilience. *Journal of Social Science*, Vol. 1(4), pp. 624-633.
50. Terelak, J.F. (2008). *Człowiek i stress*. Bydgoszcz/Warszawa: Branta, p. 379.
51. Thomas, B.J., Khalil, T. (2022). Innovation and Creativity Among Individuals in Work Environments: The Effect of Personality, Motivation, Psychological, and Task-Oriented Factors. *Eurasian Business and Economics Perspectives. Eurasian Studies in Business and Economics*, 22, p. 37.
52. Truong, H., McLachlan, C.S. (2022). Analysis of Start-Up Digital Mental Health Platforms for Enterprise: Opportunities for Enhancing Communication between Managers and Employees. *Sustainability*, 14, 3929.
53. Tu, Y., Lu, X., Wang, S., Liu, Y. (2020). When and why conscientious employees are proactive: A three-wave investigation on employees' conscientiousness and organizational proactive behavior. *Personality and Individual Differences*, Vol. 159.

54. Uliaszek, A.A., Zinbarg, R., Mineka, S., Craske, M.G., Sutton, J.M., Griffith, J.W., Rose, R., Waters, A., Hammen, C. (2010). The Role of Neuroticism and Extraversion in the Stress-Anxiety and Stress-Depression Relationships. *Anxiety Stress Coping*, 4, 363-381.
55. Wheatley, D. (2017). Employee satisfaction and use of flexible working arrangements. *Work, Employment And Society*, Vol. 31(4), 567-585.
56. Wijaya, E., Martin, M., Tambunan, D., Hou, A., Chaniago, S. (2025). Enhancing Job Satisfaction in Higher Education: The Role of Cultural Openness, Servant Leadership, and Burnout. *Society*, 13(1), 169-191.
57. Woods, S.A., Sofat, J.A. (2013). Personality and engagement at work: the mediating role of psychological meaningfulness. *Journal of Applied Social Psychology*, Vol. 43, Iss. 11.
58. Yan, S., Ping, L., Feng, X., Jin, X. (2024). Highest order moderation of extraversion and neuroticism into the relationship between job stress and flourishing: Mediated by readiness to change among Chinese medical teachers. *Heliyon*, Vol. 10, Iss. 13.
59. *Zarządzanie stresem w miejscu pracy*. Randstad, Raport (2024).
60. Zhang, X., Dai, L. (2015). The Relationship between Neuroticism and Experience of Workplace Ostracism in New Employees. *Open Journal of Social Sciences*, 3, 80-87.
61. Zhang, Y., Sun, J., Wu, C., Ma, Z., Shen, C., Hu, W., Lang, H. (2024). Relationships Between Burnout and Neuroticism Among Emergency Department Nurses: A Network Analysis. *Nursing Open*, 11(11).
62. Zimbardo, P.G. (1999). *Psychologia i życie*. Warszawa: PWN, p. 519.

MODELLING THE DISPERSION OF POLLUTANTS FROM ROAD TRANSPORT IN STREET CANYONS ON THE EXAMPLE OF SZCZECIN AND OSLO

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Purpose: Emissions of nitrogen dioxide (NO₂) and carbon monoxide (CO) from road transport have a notable impact on everyday life of city dwellers, where traffic congestion is one of the major problems. These emissions have an adverse effect on air quality, human health, and climate change. The aim of this study is to present the possibility of applying the analytical Gaussian Plume Dispersion Model (GPDM) to determine the dispersion of air pollutants from freight transport in an urban area with the use of real data obtained from road traffic detectors.

Design/methodology/approach: The pollutant dispersion was modelled for nitrogen dioxide NO₂ and carbon monoxide CO. The study covered the streets of urban agglomerations located near two city centers: in Oslo (Norway) and in Szczecin (Poland). The chemical reactions between NO₂/CO and oxygen were included in the model. Pollutant dispersion was modelled for a height of 2 meters.

Findings: In terms of traffic intensity, the type of vehicles and their speed are the main factors influencing the maximum value of pollutants concentration, occurring along the traffic axis. Both the increase in the share of trucks and the reduction in speed have a negative impact, as they contribute to an increase in local pollution concentrations. It was found that higher wind speeds generally have a positive effect on the faster dispersion of undesirable gas compounds in the air.

Practical implications: The proposed model may be used as a supporting tool when deciding on potential locations for further air quality monitoring stations managed by the city and environmental protection authorities.

Social implications: The proposed modified Gaussian Plume Dispersion Model can be used as a fast-response system for identifying exceedances of permissible pollution standards in urban agglomeration areas which are highly exposed to transport pollution.

Originality/value: In most similar publications, pollutant distribution is modelled at lower heights (reflecting to the emitter heights). Our study results aim to visualize the distribution of

pollutants not in the critical plane parallel to the road, but in the “exposure” plane, particularly in relation to residents of those road segments, as well as pedestrians and workers.

Keywords: Gaussian Plume Dispersion Model, pollution, dispersion, air quality, traffic, urban freight transport, sustainable development.

Category of the paper: Research paper.

1. Introduction

Urban transport system is a complex organizational system, consisting of: pedestrian traffic, bicycle traffic, motorized passenger public transport, individual transport, as well as freight transportation. In recent years, much attention has been paid to the effects of the functioning of freight transport in cities (Taniguchi et al., 2014; Quak, 2008; Macharis, Melo, 2011; Allen et al., 2010; Bjørgen, Ryghaug, 2022; Brusselaers et al., 2023). One of the most important elements affecting air quality in cities, apart from the volume of emissions and the type of pollutants emitted, is the degree of dispersion of emissions. Monitoring the pollutant dispersion in the city influences the management process, especially the planning stage (Chen et al., 2021). Based on the data acquired from the pollution distribution in the city, metropolitan managers can better plan the city’s spatial layout and urban infrastructures.

Air quality in cities

The number of urban residents has been constantly growing — now they account for over 70% of the population — which results in an increased number of motor vehicles, including those used for goods deliveries. The increase in freight transport in urban and metropolitan areas contributes to a rise in congestion, air pollution, noise and logistics costs, which clearly translates into higher product prices (Dablanc et al., 2011; Browne et al., 2016). Additionally, the co-operation of different types of vehicles on the road increases the risk of accidents (Russo, Comi, 2010; Taniguchi, Thomson, 2018). Environmental pollution, and especially the air quality deterioration, poses a particular challenge to today’s society. The extensive impact of transport pollution has an adverse effect on the natural environment, and consequently on the health of inhabitants and city users (Trecuzzi et al., 2022). City managers undertake multifaceted efforts to improve mobility (Taniguchi et al., 2014). However, despite the attempts to reroute motorized transport outside the administrative boundaries of cities, and especially to keep it away from their centers, its complete elimination is not possible. On the one hand, the urban community is not keen on transport, especially freight transport in cities, but at the same time, in pursuit of adequate quality of life, city residents usually require access to various types of goods as close to home as possible (Russo, Comi, 2020). In 2020 in Brussels road transport was the largest source of nitrogen oxides (55%) emitted in the Brussels-Capital Region (BCR) (Brusselaers et al., 2023).

Nowadays, it is possible to observe an increase in ecological awareness as a consequence of the development of technologies for air quality monitoring systems and access to information. City managers implement solutions that are designed to reduce pollution of the urban environment (Holguín-Veras et al., 2016). Monitoring the pollution, especially its spread in real time, is troublesome, costly and not always feasible. In this respect, modeling is helpful, allowing for the forecasting of air pollutant concentrations at the ground level, thus providing a picture of the environmental impact of individual energy sources powering the means of transport.

In the interest of clean air, all European Union countries take measures to reduce the emissions of harmful substances. For this purpose, they implement air quality assessment and control systems through legal regulations at the global, regional, and local level. Additionally, numerous projects in this field are being implemented. They are intended to improve the flow of goods to such an extent and scope that it would simultaneously reduce the negative impact on the urban environment. In Poland, the control system is based on measurements carried out within the national monitoring network. The analysis of measurements does not identify transport as the main pollution generator, but its share in relation to other types of air polluting emissions is significant.

The implementation of distribution processes in urbanized areas faces the greatest challenges within city centers. This is mainly due to the significant concentration of workplaces, commercial and service units, HoReCa sector facilities, schools and universities, as well as public administration units. An additional difficulty is the topological structure of streets, resulting from historical conditions. This applies in particular to European cities, the centers of which were most often developed in periods when the demand for transport services was much lower, and the number of traffic participants did not significantly contribute to the congestion effect. City centers are, on the one hand, hubs of commercial, service, administrative and tourist functions, and on the other hand, they typically concentrate key transport nodes of the urban mobility system. As a result, implementation of deliveries within city centers represents a particular challenge to the efficient functioning of the urban system as a whole, at the same time encountering a significant number of difficulties related to, *inter alia*, traffic restrictions (e.g. restricted zones due to historic buildings), linear infrastructure not adapted to the growing number of vehicles (mainly narrow streets and one-way traffic organization) or the lack of a sufficient number of parking spaces.

Road transport key pollutants – NO₂ and CO

The level of carbon dioxide (CO₂) is most often taken into account as a key factor contributing to the greenhouse effect when analyzing the emissions of anthropogenic pollutants from road transport. In a global context, such an approach is legitimate (Lin, 2010). However, a direct focus on the local impact on the urban environment does not allow for a more complete analysis. Considering the expansion of urban systems into large agglomerations where the number of cars in relation to the number of people per square kilometer is many times higher

than in non-urban areas (Rojas-Rueda et al., 2012), it becomes important to take into account the chemicals directly related to the health condition of the city's population. These pollutants include, first of all, carbon monoxide (CO) which is an odorless and colorless gas with strong toxic properties, nitrogen dioxide (NO₂) — a brown, highly toxic gas with a pungent odor, hydrocarbons (HC) containing carcinogenic compounds, and particulate matter (PM) in the form of carbon-graphite compounds, ashes and soot. Originating from road transport, the compounds: NO_x, HC, CO and CO₂ can form, as a result of photochemical reactions, California smog containing toxic substances such as peroxy-acetyl-nitrile. The detrimental effect of photochemical smog is an increase in morbidity and health disorders of humans, including eye irritation, exacerbation of asthma symptoms, increased sensitivity to infections or pneumonia. Air pollution is a risk factor for cardiovascular and lung diseases including lung cancer. Among others, ischemic heart disease and stroke are the most common causes of deaths attributable to poor air quality (EEA, 2023). Air pollutants known to contribute to cardiovascular diseases include nitrogen dioxide (NO₂), particulate matter (PM), black carbon (BC) and carbon monoxide (CO), even if they are present at concentrations lower than current EU limit values, as the stroke and coronary heart disease risks rise with long-term air pollution exposure. All the above-mentioned compounds are highly exposed in studies on the emission of transport pollutants in urban agglomerations (Kanakoglou, Buliung, 2008; Gallardo et al., 2012). These compounds also form the basis of the European exhaust emission standard (EURO).

According to the European Environment Agency, transport constitutes a primary source of Europe's NO_x emissions (45%) and is also responsible for a significant proportion of the total emissions of other key pollutants (EEA, 2023). In 2022, among 137 air quality measurement stations in Poland, only 32 recorded the annual average NO₂ levels below the threshold recommended by WHO (10 µg/m³), and the majority of the stations (93) showed the annual average concentration in the range of 10-25 µg/m³. Average annual levels exceeding the EU's permissible value (40 µg/m³) were recorded at three urban traffic monitoring stations in large agglomerations (Wrocław, Katowice, Warsaw). In the case of Norway, all of the 46 measurement stations recorded the average annual NO₂ concentrations below 40 µg/m³, among which only 8 stations showed levels below 10 µg/m³. Despite ongoing reductions in key air pollutant emissions, in 2021 most of the EU's urban population was exposed to air pollutant levels detrimental to health. As regards NO₂, the share of the EU urban population exposed to concentrations exceeding the current EU standards was only 1%, but at the same time this share rapidly increased to 90%, while much more severe WHO recommendations for safe concentrations of air pollutants are being considered. In October 2024, the directive on ambient air quality and cleaner air for Europe was adopted, focused on establishment of stricter EU air quality standards, which would apply from 2030. Annual limit values for pollutants with the greatest documented impact on human health will be reduced, for instance in the case of NO₂ from the current level of 40 µg/m³ to 20 µg/m³.

According to Polish national regulations, the permissible level of carbon monoxide in the air established for the protection of human health is 10 mg/m^3 (an 8-hour average), which is compliant with WHO recommendations (WHO, 2021). Typically, such levels are unlikely to be reached in open areas, but long-term exposure to much lower levels of carbon monoxide, which can occur outdoors near roads and parking areas, may also contribute to cardiovascular diseases (Bell et al., 2009). In Norway (Oslo), the average annual CO concentration reached 0.262 mg/m^3 in 2022. In Poland, among 65 measurement stations, the vast majority (55) recorded average annual CO concentrations within the range of $0.25\text{-}0.5 \text{ mg/m}^3$ (EEA, 2023).

In Poland, the analysis of pollutants as part of air quality assessment is carried out by the Voivodship Inspectorates for Environmental Protection and involves testing for compounds directly affecting health, such as CO, NO₂, SO₂, C₆H₆ or PM. Due to the fact that the direct impact of freight transport on the urban environment was assumed to be one of the basic criteria for selecting the research area, its delimitation primarily included data on the level of emissions of toxic compounds, in particular NO₂, which, according to the data of the Voivodship Inspectorate for Environmental Protection, is the highest in the area of Szczecin Śródmieście.

Pollutants dispersion models

The problem with maintaining local concentrations of key air pollutants at a given level is related to the significant impact of factors that go beyond the primary sources of emissions that can be controlled (e.g. by introducing restrictions in city centers, related to the intensity of truck traffic). Air quality in cities is determined by the degree of industrialization, population density, topographic conditions, and meteorological conditions. When analyzing the pollutant dispersion, the following factors may be taken into account: wind speed and direction, precipitation, air temperature, regional topography, amount and type of emission sources, buildings and structures located in the studied area. Numerous models of dispersion can be found in the subject literature (Lushi, Stockie, 2010; Munir et al., 2021; Tominaga, Stathopoulos, 2018; Milando, Batterman, 2018). One of them is the Gaussian Plume Model (GPM) which assumes that pollutant dispersion follows the normal statistical distribution. By assessing various techniques such as CFD simulation (Bady, 2017) or RLiNE (Milando, Batterman, 2018), or Briggs parameterization (Griffiths, 1994), the GPM model is characterized by much higher computational efficiency. The publication (Bady, 2017; Wang et al., 2017) presents a comparison of various models describing the dispersion of inert gas in an idealized urban environment. The authors used experimental data available in the literature as a benchmark to evaluate statistical performance for each model. Their results showed that, using several statistical measures, performance of models such as GPM can be classified differently, based on individual parameters. Consequently, selection of an appropriate parameter can be guided by the intended purpose of the model.

The GPM is based on a single simple formula similar for each receptor point, therefore it has an extremely fast response time, which is important when studying the complex systems. However, the model is constrained by a number of simplifications, one of which is the omission

of chemical reactions in the atmosphere. Only a few studies conducted to date are reported to include chemical reactions — primarily the conversion of NO into NO₂ — in the Gaussian Plume Dispersion Model. Kewley (1978) modelled the atmospheric dispersion of pollutants using the Gaussian plume model, incorporating rapid chemical reactions between NO and NO₂ in the presence of O₃ to achieve instantaneous equilibrium. Kimura (1978) presented a simple reaction model for NO, NO₂, O₃, which could be easily combined with a general atmospheric diffusion model. The constants in the proposed model were estimated directly on the basis of experiments carried out in a smog chamber. Diffusion equations were separated from the chemical reaction equations, and the concentrations of nitrogen oxides and ozone were calculated by means of an approximation method. Arellano et al. (1990) proposed a chemically reactive Gaussian plume model incorporating macro- and micromixing with four chemical reactions of the NO, NO₂ and O₃, which were used to determine the conversion of nitric oxide to nitrogen dioxide. Kitabayashi et al. (2006) developed an Integrated Plume Dispersion Model with Chemical Reactions, where atmospheric diffusion and chemical reactions of NO, NO₂, O₃, O in the plume and ambient atmosphere were described by a set of ordinary differential equations. The model was explored for different emission conditions and background concentrations. Ferrero et al. (2012) developed a fluctuating plume model for pollutant dispersion, taking into account the chemical reactions of NO, O₃ and NO₂ described in the form of partial differential equations. The model was tested against the measured data in a wind tunnel, where NO was emitted from a source in an ozone environment.

The aim of this paper is to present the possibility of applying the analytical Gaussian Plume Dispersion Model (GPDM) to determine the dispersion of air pollutants from freight transport in an urban area with the use of real data obtained from road traffic detectors. In this article, to illustrate the simulation of dispersion of selected pollutants on a plane parallel to the road surface, the height of 2 meters (receptor height) was applied, assuming the constant emitter height of 0.2 m. Similar studies by other authors demonstrate various approaches, including depiction of dispersion of selected pollutants at different heights. However, in most publications pollutant distribution is modelled at lower heights (reflecting to the emitter heights). The concentration of pollutants in the cross-sectional plane relative to the road decreases with increasing height. Therefore, our study results aim to visualize the distribution of pollutants not in the critical plane parallel to the road, but in the “exposure” plane, particularly in relation to residents of those road segments, as well as pedestrians and workers.

In our study, we proposed a model that incorporates chemical reactions for NO₂ and CO pollutants. The reactions were represented by two ordinary differential equations describing the conversion of NO₂ to NO and CO to CO₂. The proposed modified Gaussian Plume Model (GPM) enables identification of street areas that are highly exposed to traffic pollution, and also allows predicting the pollutant dispersion depending not only on the vehicle traffic intensity, but also on the meteorological conditions (wind direction and speed, category of atmospheric stability, etc.). The proposed model may be used as a supporting tool when deciding on potential

locations for further air quality monitoring stations managed by the city and environmental protection authorities.

2. Research area and data

For the purposes of modelling the dispersion of selected pollutants in the urban agglomeration, measurement data concerning traffic intensity and meteorological parameters for two cities: Oslo (Norway) and Szczecin (Poland) were used. When specifying the research area and selecting the certain street sections, the main criteria were the accumulation of commercial and service units in a given area and the intensity of business and private activity, which usually contributes to increased demand for transport. The selected research area was a 300 m long section of Aleja Wojska Polskiego Street in the city of Szczecin, running from the intersection with Jagiellońska Street to Plac Zgody. The entire Aleja Wojska Polskiego Street with the length of 6.9 km is one of the main streets of Szczecin, constituting an important traffic route running from the city center towards the north-west and at the same time being part of regional road No. 115. The street additionally connects national road No. 10 in Szczecin with the Dobieszczyń-Hintersee border crossing between Poland and Germany. The selected research area in Oslo was a 300 m long section of Nylandsveien street, stretching from the roundabout located next to Busterminal and PKS Airport Bus to the intersection with Hausmanns gate. The choice of this section of Nylandsveien Street, located in the very center of Oslo, was determined by the fact that it is part of the access road to the bus and railway stations, and in its close vicinity there are numerous commercial and service facilities, bars and cafes, cultural institutions (opera, museums, etc.), and office buildings.

In the first stage of the research study, traffic intensity and vehicle speed were measured on the selected road sections over a period of 5 weekdays. The data for Aleja Wojska Polskiego in Szczecin were collected from March 7, 2022 to March 11, 2022, while for Nylandsveien in Oslo — from April 4, 2022 to April 8, 2022. The measurements were made using the Sierza SR4 device, over a 15-hour period between 4 a.m. and 7 p.m. for both sections. The measurements were conducted continuously, and the collected data was segmented into one-hour intervals. The device allowed for classification of monitored vehicles into 4 categories: motorcycles, passenger cars, delivery vehicles (6-9.5 m long) and trucks (9.5-25.5 m). Due to the negligible share of motorcycles, this group was eliminated from further research.

Each vehicle category was assigned emission factors, taking into account the speed at which the vehicles were moving. The factors by vehicle class and speed are based on the HBEFA 3.2 emission factor database. Handbook Emission Factors for Road Transport (HBEFA) is a Microsoft Access database application providing emission factors, i.e. the specific emissions

in g/km, for all current road vehicle categories (passenger cars, light duty vehicles, heavy duty vehicles, buses, and motorcycles). Emission factors are provided for all the regulated and the most important non-regulated air pollutants as well as for fuel consumption and CO₂. HBEFA is used to estimate road transport emissions at various spatial aggregation levels, from national to street level.

The second stage of the research data collection included obtaining the meteorological data for Szczecin and Oslo. The parameters related to wind direction and speed for Szczecin were obtained from the available reports issued by the Institute of Meteorology and Water Management (Gdynia Maritime Department), while the corresponding data for central Oslo was sourced from the Norwegian Meteorological Institute (Figure 1). For further research, the wind directions and speeds most frequently occurring in the analyzed area were selected.

3. Research methods

A common application of atmospheric dispersion models can be estimation of emissions of toxic contaminants from cars driving on crowded streets of urban agglomerations, which can be approximated as line sources. One of these models is the Gaussian Plume Dispersion Model (GPDM), which was based on the works of Pasquill (Pasquill, 1961) and Gifford (Gifford, 1961). The GPDM for the continuous point source emitting gaseous pollutants is given by the following equation (Bady, 2017):

$$C(x, y, z) = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \left\{ \exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right) \right\} \quad (1)$$

where:

C is the pollutant concentration (mg/m³) at location of receptor (x, y, z), where x is the downwind distance from source to receptor (m), y is the lateral distance from source to receptor (m), z is the receptor height above the ground (m),

Q is the emission rate from the point source (mg/s), u is the wind velocity (m/s),

σ_y and σ_z are the horizontal and vertical dispersion parameters, respectively (m),

H is the effective emitter height (m). Pollutant dispersion in this study was modelled for height above the ground $z = 2$ m, with effective emitter height of $H = 0,2$ m.

Considering that the model is based on a simple formula describing the three-dimensional concentration field of contaminants generated by a point or line source, and has an extremely fast response time, the dispersion of two key gaseous pollutants from vehicle emissions — carbon monoxide CO and nitrogen dioxide NO₂ — was modeled in this study with the use of the GPDM.

For a line source, the traffic road is treated as a line that contains a large number of continuous point sources (emitters). Thus, in this study, the emitter network was modeled as a line source by dividing the road into equal 1-meter-wide segments, which corresponded to the number of emitters. The mechanism of diffusion from each emitter was assumed to be independent of the presence of other point sources. For each emitter, the origin is shifted to the center of the considered emitter, with the modified x-axis aligned in parallel to the wind direction, and the modified y-axis oriented perpendicular to the wind direction. The concentration of pollutant at any receptor was computed by applying the principle of superposition which states that the concentration at a receptor located at a certain point (x,y,z) is the sum of contributions from all the point sources making up the line source. For the purpose of this study, we assumed a dispersion area (dispersion domain) of 800 x 800 m, with a grid of receptors spaced every 1 meter along the x- and y-axes.

The values of the horizontal (σ_y) and vertical (σ_z) dispersion coefficients for urban areas, used in the model to represent atmospheric diffusion, were determined using the McElroy-Pooler formulas.

The GPDM has some limitations. The model operates under steady-state conditions $\frac{dC(x,y,z)}{dt} = 0$, which implies that the rate of emission from the point source is constant (in this study with an hourly time step). It does not take into account wind variability. The flow is homogeneous, which implies that the wind speed is constant both in time and with height (u does not depend on t and z). It is assumed the pollutant is conservative and there is no gravitational settling. The terrain underlying the plume is flat. Reflection of the plume at the underlying surface is perfect (no ground absorption) and no chemical reactions occur.

Therefore, in the model we included chemical reactions with NO_2 and CO pollutants, which mix with other compounds in the atmosphere and may react with them. Among the numerous reactions occurring in the atmosphere, the following reactions are included:



which can be described by differential equations for second-order reactions:

$$-\frac{d[\text{NO}_2]}{dt} = k_{\text{NO}_2} \cdot [\text{NO}_2] \cdot [\text{O}_2] \quad (4)$$

$$-\frac{d[\text{CO}]}{dt} = k_{\text{CO}} \cdot [\text{CO}] \cdot [\text{O}_2] \quad (5)$$

where $[\text{NO}_2]$, $[\text{CO}]$ and $[\text{O}_2]$ represent the concentration of respective species after time t [mol/cm^3], where t is reaction time [s], k_{NO_2} , k_{CO} is a second-order rate constant [$\text{cm}^3 \text{ mol}^{-1} \text{ s}^{-1}$]. Assuming that the oxygen concentration in the air is much higher than NO_2 and CO ($[\text{NO}_2]$, $[\text{CO}] \ll [\text{O}_2]$), O_2 can be a constant value $[\text{O}_2] = \text{const}$. Separating the variables $[\text{NO}_2]$, $[\text{CO}]$ and t in equations and integrating both sides, we obtain the concentrations of NO_2 and CO after the reaction:

$$[NO_2] = [NO_2]^0 \exp(-k_{NO_2} \cdot [O_2] \cdot t) \quad (6)$$

$$[CO] = [CO]^0 \exp(-k_{CO} \cdot [O_2] \cdot t) \quad (7)$$

where:

$[NO_2]^0$, $[CO]^0$ represent the initial concentration of species $[\text{mol}/\text{cm}^3]$ at the location of receptor (x, y, z) ,

t is the diffusion time of NO_2 and CO molecules from the emitter to the receptor $[s]$.

Taking into account equations (1), (6) and (7), we get the final equations as follows:

$$C(x, y, z)_{NO_2} = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \left\{ \exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right) \right\} \cdot \exp(-k_{NO_2} \cdot [O_2] \cdot t) \quad (8)$$

$$C(x, y, z)_{CO} = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \left\{ \exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right) \right\} \cdot \exp(-k_{CO} \cdot [O_2] \cdot t). \quad (9)$$

Second-order rate constants for reactions (4) and (5) were sourced from (Garvin-Edit., 1973).

4. Results and discussion

To analyze the model outputs shown in Figures (Fig. 2-5) that illustrate the dispersion of selected pollutants, first it is necessary to discuss the data obtained from the measurements of traffic intensity and vehicle speed on the selected road sections. Over the period of 5 weekdays, the total amount of 5960 light- and heavy-duty vehicles were operating on the road section selected for the research study in Szczecin. The delivery vehicle and truck traffic was at its highest on Monday between 10 a.m. and 1 p.m., when 764 vehicles per hour were recorded, while the average for the entire period under study was 80 vehicles from this group per hour. In the case of the road section chosen in central Oslo, a much more even distribution of the traffic intensity of delivery vehicles and trucks was found, both in terms of the time of day and the day of the week, ranging approximately from 60 to 123 vehicles per hour (extreme values for the 4 working days except Thursday, when the number of vehicles of this type per hour did not exceed 29). This relatively even traffic intensity of delivery vehicles and heavy trucks occurred between 10 a.m. and 4 p.m. and was noticeable especially for the first three days of the week (Monday–Wednesday). Over the full workweek, the total amount of 3,453 light- and heavy-duty vehicles were operating on the road section selected for the research study in Oslo, and the average number of vehicles of this type per hour was 46. The total number of passenger cars recorded on the selected road sections in the examined period was similar for both cities and amounted to 48,672 for Nylandsveien in Oslo, and 46,921 for Aleja Wojska Polskiego in Szczecin. The average speed of all the vehicles traveling in the given sections in the entire analyzed period was as follows: 51 km/h for Oslo, and 38 km/h for Szczecin.

Figures 2-5, which show the dispersion of NO_2 and CO on the selected road sections, were prepared based on data from a single hour of measurements on one day (a 1-hour model). The selected period was characterized by relatively high traffic intensity (Wednesday for Szczecin and 12 p.m. for Oslo). The figures show the distribution of concentrations of selected gaseous compounds [mg/m^3] in a horizontal projection (x, y), at a constant vertical distance above the ground ($z = 2 \text{ m}$), assuming that the source of emissions from road transport is at a height of 0.2 m. The displayed concentrations represent an example of NO_2 and CO dispersion from vehicles operating for one hour on the selected road sections, under specific meteorological conditions. In terms of traffic intensity, the type of vehicles and their speed are the main factors influencing the maximum value of pollutants concentration, occurring along the traffic axis. Both the increase in the share of trucks and the reduction in speed have a negative impact, as they contribute to an increase in local pollution concentrations.

Among the meteorological parameters that influence the change in air pollutants concentration in the horizontal projection (x, y), the wind direction and speed are the most important. In order to show an example of an impact of atmospheric conditions on pollutants dispersion, two variants of wind direction were adopted, assuming moderate conditions in terms of atmospheric stability (type C – slightly unstable). In the first option (a), the wind direction and speed occurring most frequently in a given area were selected: wind direction SW with a speed of 4.2 m/s for Szczecin; and wind direction NE with a speed of 2.9 m/s for Oslo. In the second variant (b), a simulation was developed for wind directions aligned with the vehicle movement axis, i.e. longitudinal to the selected road sections. When analyzing individual streets, usually a higher wind speed has a positive effect on the faster spread of undesirable gas compounds in the air and thus reducing their high local concentration, as long as the wind direction allows free air movement, taking into account the building density in urban agglomerations. In extreme cases, in the case of calm weather, local concentrations accumulate, creating an environment conducive to exceeding the permissible concentration levels.

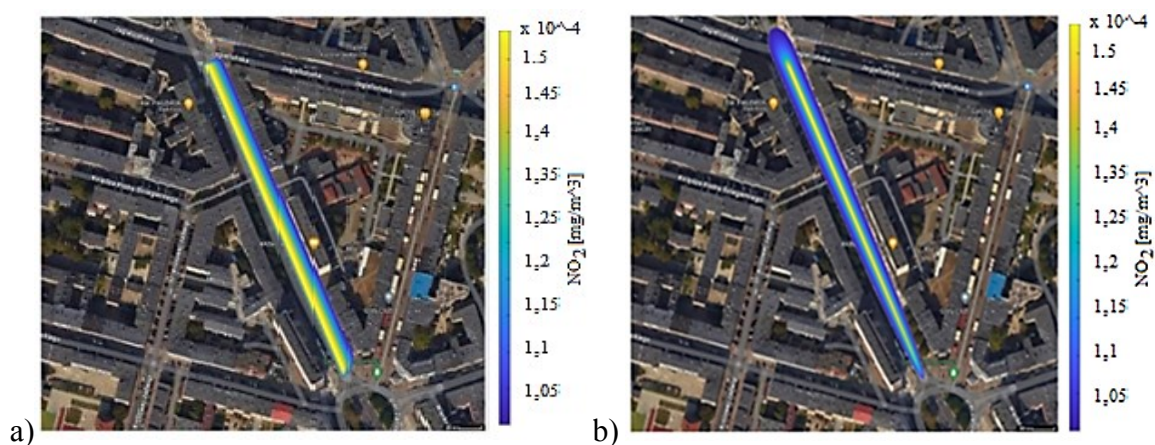


Figure 2. (a) Dispersion of NO_2 in the examined street in Szczecin, under specific traffic intensity and meteorological conditions (SW 225° wind; $v = 4.2 \text{ m/s}$); (b) Dispersion of NO_2 in the examined street in Szczecin, under specific traffic intensity and meteorological conditions (156° wind – aligned with road axis; $v = 4.2 \text{ m/s}$).

Source: Own study.

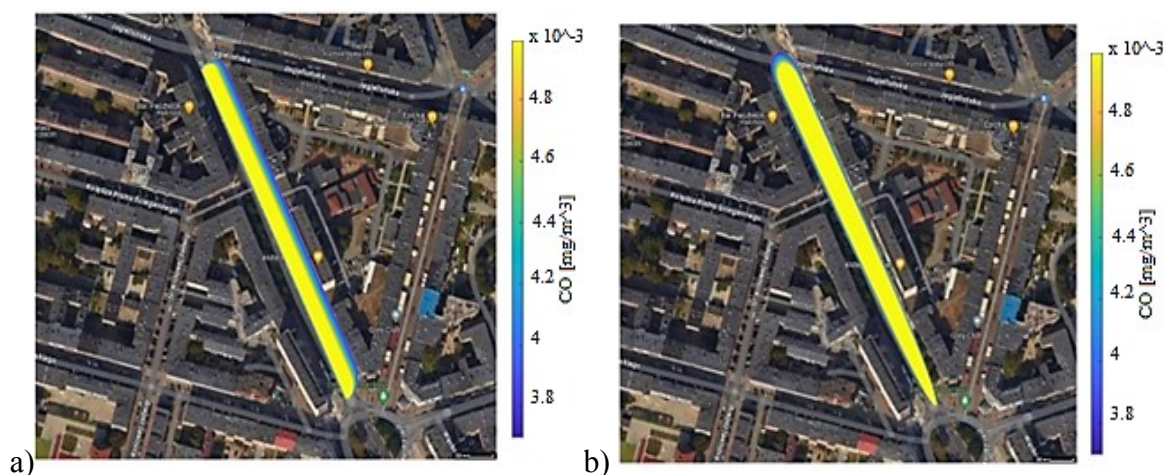


Figure 3. (a) Dispersion of CO in the examined street in Szczecin, under specific traffic intensity and meteorological conditions (SW 225° wind; $v = 4.2$ m/s); (b) Dispersion of CO in the examined street in Szczecin, under specific traffic intensity and meteorological conditions (156° wind – aligned with road axis; $v = 4.2$ m/s).

Source: Own study.

The wind direction changes the pollutant dispersion, but there is no clear pattern of that phenomenon, based on the obtained simulation data. When analyzing Fig. 2a and 2b, in the case of the SW wind, the concentration of NO_2 decreases from the maximum value along the road axis, i.e. $1.5 \times 10^{-4} \text{ mg/m}^3$ to $1 \times 10^{-4} \text{ mg/m}^3$ approximately 14 meters downwind in the northeast (NE) direction, and drops further to the level of $1 \times 10^{-5} \text{ mg/m}^3$ at a distance of ca. 200 meters. At the same traffic intensity level, with the wind parallel to the road axis, the concentration reduction in the range as above (from 1.5 to $1.0 \times 10^{-4} \text{ mg/m}^3$) occurs at a much closer distance, i.e. from about 10 m from the road axis. Smaller concentrations ($1 \times 10^{-5} \text{ mg/m}^3$) are found at a distance of approximately 200 meters (the same as in case of the SW wind), which probably results from the same wind speed. A different pattern is observed in the case of CO dispersion in the examined street in Szczecin: comparison of Fig. 3 a) and b) shows that the area with the highest CO concentration is larger when the wind direction is parallel to the road axis. In the case of SW wind, the width of the street canyon where the CO concentration is the highest reaches about 13 meters, while in the case of a parallel wind — about 21 meters.

Examples of the spread of selected pollutants for the road section in Oslo are shown in Fig. 4 and 5. Compared to the dispersion plots presented for Szczecin, these distributions are generally characterized by higher concentrations at the points (x, y) with the same distances to the road axis, which results from the greater traffic intensity in the examined time period (1276 passenger cars, 83 delivery vehicles and 20 trucks per hour in Oslo versus 947 passenger cars, 48 delivery vehicles and 18 trucks per hour in Szczecin), as well as from the lower wind speed in Oslo (2.9 m/s vs 4.2 m/s in Szczecin).

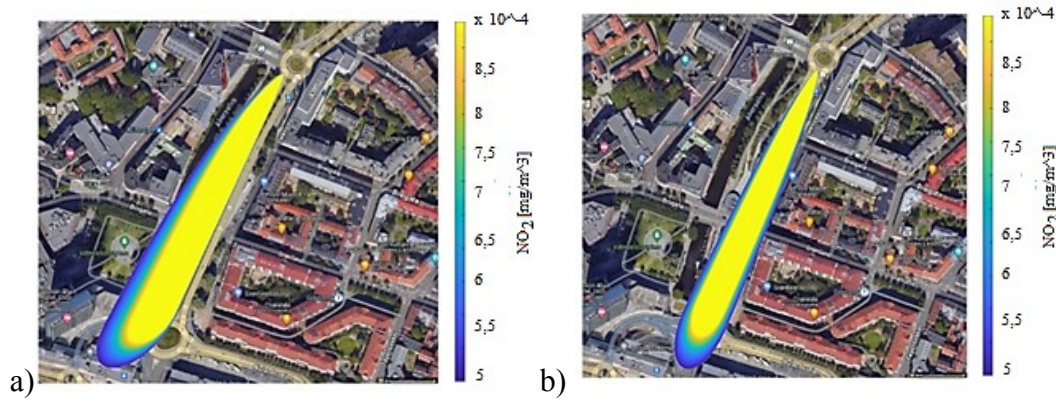


Figure 4. (a) Dispersion of NO₂ in the examined street in Oslo, under specific traffic intensity and meteorological conditions (NE 45° wind; $v = 2.9$ m/s); (b) Dispersion of NO₂ in the examined street in Oslo, under specific traffic intensity and meteorological conditions (25° wind – aligned with road axis; $v = 2.9$ m/s).

Source: Own study.

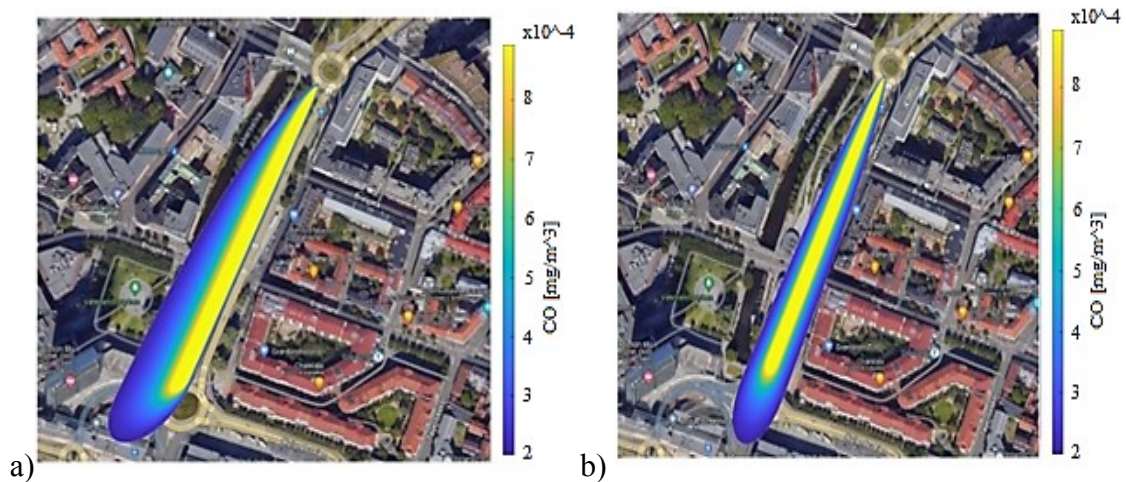


Figure 5. (a) Dispersion of CO in the examined street in Oslo, under specific traffic intensity and meteorological conditions (NE 45° wind; $v = 2.9$ m/s); (b) Dispersion of CO in the examined street in Oslo, under specific traffic intensity and meteorological conditions (25° wind – aligned with road axis; $v = 2.9$ m/s).

Source: Own study.

Despite a slight difference in the wind directions used to illustrate the distribution of pollutants in the selected street section in Oslo (25 and 45 degrees), differences in the dispersion of the tested gaseous compounds are also observed in this case. For example, in the case of NO₂, the maximum concentration of 9×10^{-4} mg/m³ is maintained over a width of approximately 35 m along the traffic axis in the case of the NE wind, and over approximately 20 meters when the wind is aligned with the road axis.

5. Conclusions and future research direction

In this paper, we presented the possibility of applying the modified Gaussian Plume Dispersion Model (GPDM) to study the dispersion of pollutants emitted into the atmosphere from road freight transport. The model was expanded to include chemical reactions of nitrogen dioxide NO_2 and carbon monoxide CO with atmospheric oxygen, allowing for more realistic concentrations and dispersion of contaminants. The study of pollutant dispersion for NO_2 and CO was carried out in the streets of the urban agglomerations of Oslo (Norway) and Szczecin (Poland). The analysis of pollutant distribution was carried out in two variants of wind direction, under moderate conditions in terms of atmospheric stability (type C – slightly unstable). In the first variant, the prevailing wind direction and speed for the area were selected: wind direction SW with a speed of 4.2 m/s for Szczecin; and wind direction NE with a speed of 2.9 m/s for Oslo. In the second variant, a simulation was carried out for wind directions aligned with the vehicle movement axis. It was found that higher wind speeds generally have a positive effect on the faster dispersion of undesirable gas compounds in the air, as long as the wind direction allows free air flow — an effect also influenced by the characteristics of the urban development pattern. The proposed modified Gaussian Plume Dispersion Model can be used as a fast-response system for identifying exceedances of permissible pollution standards in urban agglomeration areas which are highly exposed to transport pollution.

Gaussian Plume Dispersion Model, used in our research is commonly used to map pollution distribution around traffic systems, but has some limitations. One of the limitations is steady-state conditions, which imply that the rate of emission from the source is constant and does not change over 1 h, and the wind speed is constant both in time and with height. This implies that the Gaussian plume equation can be applied only for shorter distances below 10 km, for average wind speeds of more than 1 m/s, and when the meteorological time scale is typically 1 h (Venkatram, Thé, 2003; Khare, Shiva Nagendra, 2007). Despite many limitations Gaussian Plume Model is quite widely used due to appealing conceptually related to a simple mathematical solution, easy of use (require relatively few input data), and high efficient in computer running time. Therefore, our model can be used to forecast, at hourly intervals, dispersion of pollutants from road transport in urban agglomerations. In this case model reflect real-world variability at hourly intervals, taking into account the dynamics of meteorological parameter changes and the flow of vehicle traffic. However, to overcome certain simplifications of the model, further research is necessary in this area, which should include:

- complex terrain in the form of street canyons,
- low wind speeds,
- chemical reactions of pollutants (research proposed in this work),
- absorption of pollutants by the ground or other physical bodies.

Additionally, to monitor the distribution of pollutants over time for a road section/road system, it is necessary to enter additional independent variables in form of meteorological data comprising wind speeds and directions and ambient temperature. Simultaneously, in real-time road traffic measurements must be also performed, in order to obtain data for the number and type of vehicles, and the average speed on the road section.

References

1. Allen, J., Browne, M., Piotrowska, M., Woodburn, A. (2010). *Freight Quality Partnerships in the UK – an analysis of their work and achievements, Report produced as part of the Green Logistics Project: Work Module 9 (Urban Freight Transport)*. London: University of Westminster.
2. Arellano, J.V.-G., Talmon, A.M., Builtjes, P.J.H.A. (1990). chemically reactive plume model for the NO–NO₂ –O₃ system *Atmospheric Environment*, 24A(12), 2237-2246.
3. Bady, M. (2017). Evaluation of Gaussian Plume Model against CFD Simulations through the Estimation of CO and NO Concentrations in an Urban Area. *American Journal of Environmental Sciences*, 13(2), 93-102.
4. Bell, M.L., Peng, R.D., Dominici, F., Samet, J.M. (2009). Emergency Hospital Admissions for Cardiovascular Diseases and Ambient Levels of Carbon Monoxide: Results for 126 United States Urban Counties, 1999-2005. *Circulation*, 120(11).
5. Bjørge, A., Ryghaug, M. (2022). Integration of urban freight transport in city planning: Lesson learned. *Transportation Research Part D: Transport and Environment*, Vol. 107, 103310.
6. Browne, M., Allen, J., Alexander, P. (2016). Business Improvement Districts in Urban Freight Sustainability Initiatives: A Case Study Approach. *Transportation Research Procedia*, 12, 450-460.
7. Brusselaers, N., Macharis, C., Mommens, K. (2023). The health impact of freight transport-related air pollution on vulnerable population groups. *Environmental Pollution*, 329, Jul 15, 121555.
8. Dablanc, L., Diziain, D., Levifve, H. (2011). Urban freight consultations in the Paris region. *European Transport Research Review*, 3, 47-57.
9. EEA European Environmental Agency (2023). <https://www.eea.europa.eu/publications>
10. Ferrero, E., Mortarini, L., Alessandrini, S., Lacagnina, C.A (2012). Fluctuating plume model for pollutant dispersion with chemical reactions. *International Journal of Environment and Pollution*, 48(1/2/3/4), 20-33.
11. Gallardo L., Escriban, J., Dawidowski, L., Rojas, N.Y., Andrade, M.D., Osses, M. (2012). Evaluation of vehicle emission inventories for carbon monoxide and nitrogen oxides for Bogotá, Buenos Aires, Santiago, and São Paulo. *Atmospheric Environment*, 47, 12-19.

12. Garvin, D. (ed.) (1973). *Chemical Kinetics Data Survey V. Sixty-six Contributed Rate and Photochemical Data Evaluations on Ninety-four Reactions*. Washington, D.C.: Physical Chemistry Division Institute for Materials Research National Bureau of Standards.
13. Garvin, D. (ed.) (1973). *Bucknell Review 1973*. Contributors: Annis Pratt, Irving H. Buchen, William A. Johnson, Hamida Bosmajian, Livia E. Bitton, M. A. Blom, Richard P. Wheeler, Joel Mambretti, Charles Segal, and Rob Swigart.
14. Gifford, F.A. (1961). Use of routine meteorological observations for estimating atmospheric diffusion. *Nuclear Safety*, 2(4), 47-51.
15. Griffiths, R.F. (1994). Errors in the use of the Briggs parameterization for atmospheric dispersion coefficients. *Atmospheric Environment*, 28, 2861-2865.
16. Gronowicz, J. (2004). *Ochrona środowiska w transporcie lądowym*. Radom: Wydawnictwo Instytutu Technologii Eksploatacji.
17. Holguín-Veras, J., Sánchez-Díaz, I., Browne, M. (2016). Sustainable Urban Freight system. *Freight Demand Management, Transportation research Procedia*, 12, 40-52.
18. Kanaroglou, P.S., Buliung, R.N. (2008). Estimating the contribution of commercial vehicle movement to mobile emissions in urban areas. *Transportation Research Part E*, 44, 260-276.
19. Kewley, D.J. (1978). Atmospheric dispersion of a chemically reacting plume. *Atmospheric Environment*, 12(9), 1895-1900.
20. Khare, M., Shiva Nagendra, S.M. (2007). *Formulation of Delhi Finite Line Source Model (DFLSM), Artificial Neural Networks in Vehicular Pollution Modelling (SCI)*. Berlin/Heidelberg: Springer-Verlag, 163-173.
21. Kimura, F., Shiihashi, M. (1988). Application of Quasi-Stational Reactive Diffusion Model to Long-Term Average Concentration. *Journal of Japan Society for Atmospheric Environment*, 23(1), 41-51.
22. Kitabayashi, K., Katatani, A., Konishi, S., Hashimoto, K. (2005). Plume dispersion model with chemical reaction in polluted environment. *Proceedings of the JSME Annual Meeting*, 49(1), 42-47.
23. Lin, T.P. (2010). Carbon dioxide emissions from transport in Taiwan's national parks. *Tourism Management*, 31, 285-290.
24. Lushi, E., Stockie, J.M. (2010). An inverse Gaussian plume approach for estimating atmospheric pollutant emissions from multiple point sources. *Atmospheric Environment*, 44, 1097-1107.
25. Macharis, C., Melo, S. (Eds.) (2011). *City Distribution and Urban Freight Transport*. Edward Elgar Publishing Limited.
26. Milando, C.W., Batterman, S.A. (2018). Operational evaluation of the RLINE dispersion model for studies of traffic-related air pollutants. *Atmospheric Environment*, 182, 213-224.
27. Munir, S., Mayfield, M., Coca, D. (2021). Understanding Spatial Variability of NO₂ in Urban Areas Using Spatial Modelling and Data Fusion Approaches. *Atmosphere*, 12(2), 179.

28. Pasquill, F. (1961). The estimation of the dispersion of windborne material. *Meteorological Magazine*, 90, 33-49.
29. Quak, H.J. (2008). Sustainability of Urban Freight Transport Retail Distribution and Local Regulations in Cities, ERIM Ph.D. *Series Research in Management* 124, Rotterdam: Haveka.
30. Rojas-Rueda, D., de Nazelle, A., Teixidó, O., Nieuwenhuijsen, M.J. (2012). Replacing car trips by increasing bike and public transport in the greater Barcelona metropolitan area: A health impact assessment study. *Environment International*, 49, 100-109.
31. Rozporządzenie Ministra Klimatu i Środowiska z dnia 11 grudnia 2020 r. w sprawie dokonywania oceny poziomów substancji w powietrzu (Dz.U. poz. 2279).
32. Russo, F., Comi, A. (2010). A classification of city logistics measures and connected impacts. *Procedia - Social and Behavioral Sciences*, Vol. 2, Iss. 3, pp. 6355-6365.
33. Russo, F., Comi, A. (2020). Investigating the Effects of City Logistics Measures on the Economy of the City. *Sustainability*, 12(4), 1439.
34. Su, H. -I., Gamal, A.E. (2013). Modeling and Analysis of the Role of Energy Storage for Renewable Integration: Power Balancing. *IEEE Transactions on Power Systems*, vol. 28, no. 4, pp. 4109-4117.
35. Taniguchi, E., Thompson, R. (Eds.) (2018). *City Logistics 3 - Towards Sustainable and Liveable Cities*. Wiley-ISTE.
36. Taniguchi, E., Fwa, T.F., Thompson, R.G. (Eds.) (2014). *Urban transportation and logistics: health, safety, and security concerns*. Boca Raton: CRC Press.
37. Tominaga, Y., Stathopoulos, T. (2018). CFD simulations of near-field pollutant dispersion with different plume buoyancies. *Building and Environment*, 131, 128-139.
38. Trecozzi, M.R., Iritano, G., Petrungaro, G. (2022). Liveability and freight transport in urban areas: the example of the Calabria Region for City Logistics. *Transportation Research Procedia*, 60, pp. 116-123.
39. Venkatram, A., Thé, J. (2003) Introduction to Gaussian Plume Models. In: P. Zannetti (Ed.), *Air Quality Modeling - Theories, Methodologies, Computational Techniques, and Available Databases and Software* (pp. 185-207). The EnviroComp Institute and the Air & Waste Management Association.
40. Wang, Y., Huang, H., Huang, L., Ristic, B. (2017). Evaluation of Bayesian source estimation methods with Prairie Grass observations and Gaussian plume model: A comparison of likelihood functions and distance measures. *Atmospheric Environment*, 152, 519-530.
41. WHO (2021). *Global air quality guidelines, particulate matter (PM_{2.5} and PM₁₀), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. Geneva: World Health Organization.

THE USE OF MODERN TECHNOLOGIES BY THE ELDERLY

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Purpose: The aim of this study was to assess the use and perception of e-health systems by older people during the COVID-19 pandemic in Poland.

Design/methodology/approach: A survey was conducted with 50 respondents. Descriptive statistics and statistical graphs were used to describe older people's use and perception of e-health systems. This is the pilot study.

Findings: One-way ANOVA and chi-square test were used to analyse the relationship between e-health use and various characteristics of respondents, including information regarding communication technology (ICT) access, age, health status, marital status, and education level. Older people, less educated, and with more medical problems are less likely to use e-health.

Research limitations/implications: Most of the ANOVA assumptions have been met.

Practical implications: The COVID-19 pandemic limited face-to-face treatment, making remote medical care more widespread.

Social implications: The use of electronic health (e-health) systems is now becoming more and more popular as it is believed that it can help improve access to medical care.

Originality/value: This study examined the determinants of e-health use among older people in Poland. The level of use of e-health by respondents varied in terms of socio-demographic and health aspects. We found that age, education, marital status and health status, among others, influence the likelihood that an older person will use ICT tools for healthcare purposes.

Keywords: modern technologies, e-health use, elderly people, Covid-19.

Category of the paper: Research paper.

1. Introduction

Electronic health (e-health) is one of the fastest-growing areas of healthcare in many countries, including Poland. Several factors contribute to this rapid increase, including an ageing population, patients' preference for care provided in their homes, and earlier discharges from intensive care units. Telehealth systems are becoming increasingly popular as

they allow to maximize productivity and efficiency while reducing costs in home healthcare (Chae et al., 2001). The advantage of telehealth is also the improvement in the availability and quality of healthcare between patients and healthcare providers and saving time. Telehealth breaks space-time constraints to deliver remote treatment and optimize the allocation of medical resources (Triantafillou et al., 2020; Ma et al., 2022).

E-health is defined as the provision of any health service or information that involves the use of the Internet or other forms of information and communication technologies (ICT) (Boogerd et al., 2015), including, for example, digital storage and transmission of medical records, consultations and medical training conducted via video conference (Ali et al., 2021).

Additionally, due to COVID-19, telehealth has expanded to more patients to reduce unnecessary exposure and preserve personal protective equipment. Many organizations then began to use the infrastructure to provide teleconsultations, including video teleconsultations, and to encourage patients to use mobile applications to monitor their health. These applications take into account the user's perspective using Human Centered Design (HCD) methodologies and collect data through various devices (e.g. data with high-quality health information collected from various sources) (Park et al., 2022).

The literature emphasizes that the provision of telehealth services can be particularly beneficial for the elderly because they are overburdened with chronic diseases. A rapidly ageing population entails a significant increase in the incidence of chronic diseases and their consequences, and thus, the need for increased care and well-being (Merrell, 2015). Among the telecare services dedicated in particular to the elderly, two main systems are in the lead: systems for remote monitoring of patient's health, including their vital signs such as heart rate, blood pressure, body temperature and glucose levels; support systems via ICT, e.g. teleconsultations, SMS reminders about appointments and prescribed medications, as well as educational text messages (Barlow et al., 2007).

The data clearly show that the use of telehealth systems exceeds office visits for diabetes (Bashshur et al., 2015), hypertension, pain (Levine et al., 2014), congestive heart failure (Lemay, Azad, Struthers, 2013), cancer treatment, stroke rehabilitation (Chumbler et al., 2015) and dementia (Postma-Nilsenová, Postma, Bates, 2015). Therefore, the elderly have become one of the main target groups of telecare technologies. Telecare solutions provide new opportunities for diagnosis, treatment, education and rehabilitation, enabling monitoring of patients with many chronic diseases. They also reduce socio-economic disparities in access to care and equalize the chances of patients from urban and rural areas (Bujnowska-Fedak, Grata-Borkowska, 2015).

On the other hand, there is a widespread belief that older people cannot use advanced electronics and telecommunications due to their limited computer and technology skills (Merrell, 2015). While older people have much to gain from e-Health, mobility issues and greater vulnerability to infectious diseases such as COVID-19 mean that they also face particularly high barriers to eHealth use. Older people are generally less likely to use digital

technologies (Poli, Kelfve, Motel-Klingebiel, 2019; König, Seifert, Doh, 2018), and this aspect of the digital divide extends to the use of e-health.

Many previous studies have looked at the use and evaluation of telemedicine from the perspective of patients (Merrell, 2015; Isautier et al., 2020; Holtz, 2021; Powell et al., 2017), especially in terms of reliability (Zarate et al., 1997), cost-effectiveness (Doolittle et al., 1998), patient satisfaction (Allen, Hayes, 2009; Mekhjian et al., 1999). However, in Poland, such studies have not been conducted, and there is no detailed report on the use and experience of e-health by older patients. This leads to three research questions:

- What kind of ICT technologies and e-health services were used by the older patients in Poland during COVID-19?
- To what extent did older people use e-health systems during the COVID-19 pandemic?
- How do older people assess the usefulness of remote technologies to monitor the patient's health?

To the best of the authors' knowledge, no attempt has been made to empirically examine the determinants of using e-health among older people. Several studies have looked at predictors of ICT adoption in general (Andrews et al., 2019; Menéndez Álvarez-Dardet, Lorence Lara, Pérez-Padilla, 2020; Jokisch et al., 2020) and e-health use in particular (Andrews et al., 2019; Poli, Kelfve, Motel-Klingebiel, 2019; Knapova, Kloczek, Elavsky, 2020). However, while these studies provide information on the challenges facing e-health, they cannot be generalized to the experiences of older people, who are likely to face additional challenges. This leads to the fourth research question:

- What socio-demographic factors predict the use of e-health among the elderly in Poland?

The answers to the above questions are crucial to promoting the long-term deployment of telehealth services in Poland. Therefore, the aim of this study was to analyze the use of e-health by older patients in Poland and the potential socio-economic factors that may influence this use (Nestlerode et al., 2022).

2. Methods

The survey was conducted from September 13 to September 27, 2021, i.e. during the Covid-19 pandemic, when the transition to remote medical care occurred. Fifty patients were randomly selected for the study from among patients registered in the Otwock poviát in Poland. Participants did not receive any incentive to participate in the study. They were informed that they did not need to have extensive knowledge of ICT and e-health systems to participate in the study. The criteria for inclusion in the study were age over 60 and consent to participate in the

study. No upper age limit has been set. The anonymous survey was conducted during personal visits to senior clubs and the University of the Third Age.

The data presented here were collected using a structured, self-administered questionnaire designed specifically for this study. The order of questions and questionnaires was not changed during the research process. The questions have been grouped into two categories of questionnaire items: 1) The use of ICT and e-health systems 2) data on socio-demographic variables and patients' health status.

In the first part of the survey questionnaire, patients were asked to answer survey questions regarding ICT use. The study used information related to ICT, such as access to ICT tools (e.g. computer, smartphone, RMP - remote patient monitoring devices) and the use of e-health services (electronic data exchange, teleconsultations, video advice, RMP). The variables for measuring access to ICT tools were binary variables that indicated whether the respondent used at least one type of ICT tool, including a computer and mobile phone, to access remote health services. Respondents were also asked to indicate specific tools for remote monitoring of the patient's health (RMP) that they used during the Covid-19 pandemic (e.g. thermometer, blood pressure monitor, heart rate monitor, telemedicine wristband, video monitoring, electronic camera, motion detectors, smartwatches, activity band with geolocation, telemedicine life jacket). The level of use of E-Health systems in the era of the coronavirus pandemic was assessed on a five-point Likert scale ("very poor", "poor", "average", "good", "very good").

The second part of the questionnaire contained questions about the patient's health status and key socio-demographic variables. The following explanatory variables were used in the study: age, education, and marital status. Respondents were also asked to self-assess their health on a five-point scale (very good, good, average, unsatisfactory, very unsatisfactory).

The relationship between e-health use and the studied socio-demographic variables was determined using the chi-square test (χ^2) and ANOVA analysis. Data were calculated and analyzed using Statistica software (version 13.3)

3. Results

Demographic and Socio-economic Characteristics

A total of 50 respondents participated in the survey, of which approximately 68% were women. 52% of the respondents were over 70 years of age. More than half of the respondents (52%) were married, 26% were widows/widowers, and 14% were divorced. There was only one single respondent. Regarding education, 12% of respondents completed only primary school, 22% vocational school, 42% secondary school and 24% higher education. Most of the survey participants came from the city (72%). Nearly half of the respondents (44%) said their health was unsatisfactory or very unsatisfactory, while only 1 respondent reported his/her health

as very good. The socio-demographic characteristics of the respondents are presented in Table 1.

Table 1.
Demographic and socio-economic characteristics

Characteristics	Classification	n	%
Gender	Male	16	32
	Female	34	68
Age	60-64	12	24
	65-69	12	24
	70-74	13	26
	75 or above	13	26
Marital status	Married	26	52
	Single	1	2
	Divorced	7	14
	Widow/Widower	16	33
Education level	Primary	6	12
	Vocational	11	22
	Secondary	21	42
	Tertiary	12	24
Place of residence	City	36	72
	Village	13	26
	No answer	1	2
Health assessment	Very good	1	2
	Good	13	26
	Average	12	24
	Unsatisfactory	9	18
	Very unsatisfactory (chronically ill)	13	26
	No answer	2	4
Using remote medical care	Yes	34	68
	No	16	32

Source: own study.

Use and Personal Experience with ICT Devices and E-health System

In the second part of the study, the respondents were asked to rate the level of use of e-health in medical care on a scale from 1 (very poor) to 5 (very good). The answers to this question are presented in Figure 1.

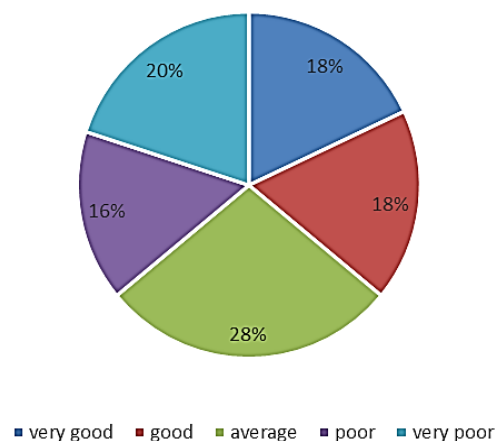


Figure 1. The level of use of e-Health by elderly in Poland during COVID-19.

Source: own study.

The level of e-health use by seniors is average (mean = 2.98). The largest group of seniors (28%) assessed using e-health at an average level. As many as 36% of respondents assess using e-health systems at a poor or very poor level. Conversely, 36% of respondents assess using e-health systems at a good or very good level.

Table 2 presents descriptive statistics on three ICT devices' use and subjective experience. All the surveyed elderly people had access to smartphones in everyday life during the COVID-19 pandemic. Fewer people used computers (46%) and devices for remote medical care (42%).

Table 2.

Descriptive statistics regarding the use and personal experience of ICT devices

		PC n (%)	Smartphone n (%)	RPM n (%)
Availability	Yes	23 (46)	50 (100)	21 (42)
	No	27 (54)	-	29 (58)
Type of use	Contact tool		50 (100)	
	Source of information	27 (54)		
	Online patient portal	22 (44)		
	Electronic data exchange;		28 (56)	
	Health monitoring	10 (20)	21 (42)	
	Teleconsultations		29 (58)	
	Video consultation	10 (20)		
	Thermometer			19 (38)
	Pressure gauge			19 (38)
	Heart rate monitor			18 (36)
	Telemedicine wristband			12 (24)

Source: own study.

For all the surveyed respondents, smartphones were a contact tool, and for as many as 19 people (38%), it was the only purpose of using this device. Patients using telephones for remote medical care used them mainly for teleconsultation (58%) and for exchanging medical data (56%). Some respondents (42%) used these devices for remote health monitoring. For all respondents, using computers was a tool for finding information, and for five people (19%), it was the only purpose for using this device. Patients using computers for remote medical care used them mainly for administrative purposes by online patient portal (44%). Some respondents used these devices for remote health monitoring (10%) and video consultation (10%). Among the devices for remote health monitoring of the patient's health, the most frequently mentioned were a thermometer and a blood pressure monitor (38%), a heart rate monitor (36%) and a telemedicine wristband (24%). The assessment of the usefulness of e-health remote technologies by elderly is presented on Figure 2.

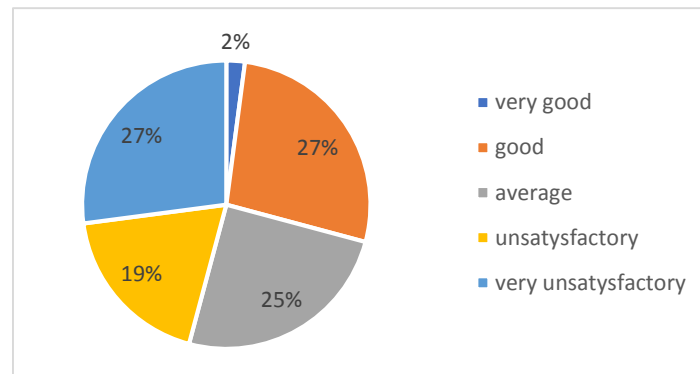


Figure 2. The assessment of the usefulness of e-health remote technologies by elderly.

Source: own study.

The assessment of the usefulness of e-health remote technologies is below average (Mean = 2.58). As many as 46% of respondents assess usefulness of e-health systems at unsatisfactory or very unsatisfactory level. Conversely, 29% of respondents assess usefulness of e-health systems at a good or very good level.

The Relationship between Respondent Characteristics and E-health Use

The statistical study used one-way ANOVA and the χ^2 test. In order to examine the use of e-health systems by seniors, they were asked the following questions:

- Q1 - How do you assess the individual level of use of e-health systems during the coronavirus pandemic? (5 - very good; 4 - good; 3 - average; 2 - poor; 1 - very poor).
- Q2 - Do you use health monitoring devices? (Yes; No).
- Q3 - Do you use teleconsultation? (Yes; No).

The authors checked the existence of a relationship between elements related to e-health systems and a specific feature characterizing seniors in a one-way ANOVA and the χ^2 test by formulating the following hypotheses - null (H0) and alternative (H1):

- H0: The characteristic of seniors has an impact on the variable regarding answers to questions Q1-Q3.
- H1: The characteristic of seniors has no impact on the variable of answers to questions Q1-Q3.

All cases for which H1 was accepted, i.e. cases in which the p-value is less than 0.05, are presented in the tables below (Tables 3 and 4). Based on the mean values (in the case of one-way ANOVA) and percentages (in the case of the χ^2 test), answers to questions Q1-Q3 were determined, which are the least and most important from the point of view of a given feature characterizing seniors.

Table 3.*Relationship between e-Health use level and participant characteristics*

Characteristics	Best rated by	Mean	SD	Worst rated by	Mean	SD	F	p
Age	60-64	4.25	0.87	75 or above	1.85	1.14	16.08	0.00
Education	Tertiary	4.25	0.75	Primary	1.67	0.82	13.34	0.00
Health assessment	Very Good	5.00	0.00	Very poor	2.00	1.14	3,37	0.01

Source: own study.

Table 4.*Relationship between RPM and teleconsultation use and participant characteristics*

Characteristics		RPM use						Teleconsultation use					
		Yes (%)	No (%)	Total (%)	χ^2	DF	p	Yes (%)	No (%)	Total (%)	χ^2	DF	p
Age	60-64	8 (72.7)	3 (27.3)	11 (100)	26,343 10	3	0,00001	8 (72.7)	3 (27.3)	11 (100)	12,675 58	3	0,00539
	75 or above	1 (12.5)	7 (87.5)	8 (100)				5 (62.5)	3 (37.5)	8 (100)			
Education	Tertiary	5 (71.4)	2 (28.6)	7 (100)	17,923 43	3	0,00046	7 (100)	0 (0)	7 (100)	19,591 53	3	0,00021
	Primary	0 (0)	11 (100)	11 (100)				4 (36.4)	7 (63.6)	11 (100)			

Source: own study.

Tables 3 and 4 show the relationship between respondent characteristics and the use of e-health systems. Significant differences in the use of e-health systems concern characteristics such as health, age, and education ($P < 0.05$).

The youngest respondents (60-65) declared a higher level of e-health use compared to the oldest group (>75) ($\chi^2 = 33.41$, $p < 0.001$). As age increases, the individual use of e-health systems is lower. 72.7% of respondents from the youngest group use teleconsultations and systems for remote patient health monitoring. In turn, in the oldest group of respondents, using these systems was much less frequent (RMP -12.5%; teleconsultations - 62.5%).

A higher level of e-health use was also shown by respondents who assessed their health condition better. Seniors in very good health used e-health systems more often than seniors with very poor health during the coronavirus pandemic in Poland ($\chi^2 = 36.93$, $p < 0.012$).

Also, seniors with higher education more often than those with lower education levels used e-health systems very well ($\chi^2 = 28.90$, $p < 0.004$). 71.4% of respondents with higher education use systems for remote monitoring of patient's health, and 100% of respondents from this group use teleconsultations. In turn, in the group of respondents with lower education (primary and vocational), these systems were much less frequent. None of them use the RMP system, and 36.4% use teleconsultations.

According to the research, people in the group that used e-Health more often were, therefore, on average, slightly younger, healthier, and better educated compared to those in the group that used less e-Health. Some determinants examined in the questionnaire did not clearly differentiate the level of e-health use (e.g. gender, place of resident). The lack of clear effects is probably due to the nature and size of the sample.

4. Discussion

The Covid-19 pandemic forced a rapid increase in access to e-health in many countries, including Poland. Previous studies conducted in this country have shown high patient satisfaction with teleconsultations, which are the most popular form of e-health in Poland (Kludacz-Alessandri et al., 2021). In this study, we were interested in the use of different e-health systems by older patients. Based on surveys conducted among older people in Poland during the Covid-19 pandemic, this study examined the use and opinions about e-health, and also examined the socio-demographic factors that influence the use of e-health from the perspective of older patients.

The results obtained indicate, similarly to other studies, the diversified use of ICT by older people (Hur, 2016; Menéndez Álvarez-Dardet, Lorence Lara, Pérez-Padilla, 2020). Most respondents use these devices for instrumental and social purposes, especially to seek information (54%) and communicate with other people (100%). The most popular ICT device was smartphone (100%). Other studies have also shown that the majority of older people believe that ICT devices are useful in everyday life and use them, especially the smartphone, the ICT device used most often and considered the most useful and easy to use/control (Broadly, Chan, Caputi, 2010; Macedo, 2017).

The study showed that only 46% of respondents use a computer. This is puzzling because: this device is quite accessible and is one of the most widely used for a wider range of purposes (especially email, social media use, filling out documents and searching for information). This result does not coincide with other studies indicating that a computer is one of the ICT devices most often used by older people, both for instrumental and social purposes (Ihm, Hsieh, 2015). Therefore, the use of this ICT device among older people in Poland requires further research.

Due to the high potential risk of contracting the Covid-19 virus (Napitupulu, Yacub, Putra, 2021), patients around the world have become more willing to use online treatment (Kruse et al., 2017). Older patients in Poland also gained the opportunity to use e-health systems during the Covid-19 pandemic. However, the level of use of these systems by older people in Poland can be assessed as average (mean = 2.98), which indicates that the use of telemedicine in Poland may not be effective. As many as 42% of older patients did not use teleconsultations, which were the most popular form of remote medical care in Poland. However, it is worth noting that access to ICT devices is at a high level (smartphone - 100%. computer - 46%) among the respondents. Similar research in Australia showed that although most older participants (around 88%) had access to ICT, few (only around 9%) had used e-health services (Ali et al., 2021). There is therefore a significant digital divide that concerns the use of ICT for healthcare purposes, and this study sheds light on the nature of this divide.

Most people in the study showed very negative attitudes towards e-health systems. Our study showed that 46% of older people believed that e-health systems were of little use in the medical care of patients. These results are contrary to those conducted among healthcare workers. For example, studies conducted in China showed relatively positive evaluations and attitudes towards e-health, where only less than 5% of participants believed that telemedicine was not helpful in reducing the medical burden on patients (Ma et al., 2022).

The most popular e-health system available from a computer was access to the online patient portal. On this platform, patients receive prescriptions and referrals for laboratory and imaging tests, access educational information and order services. Previous research has shown that patient portals can improve medication adherence, provide better patient-provider communication, and enable the detection of medical errors (Dendere et al., 2019). This form of access gives patients more control and encourages them to be active members of the healthcare team (Nestlerode et al., 2022).

Our results showed that a higher level of education, lower age and better health are associated with an increased likelihood of using e-health services.

The study showed that age is an important factor influencing the use of telehealth systems, because the oldest respondents (>75) declared a lower level of e-health use compared to younger groups. As age increases, the individual use of e-health systems is lower. This is confirmed by the results of other studies, which showed that older people are less able than younger people to use electronic devices such as telerehabilitation platforms and mobile applications (Cimperman, Makovec Brenčič, Trkman, 2016) and the oldest elderly are particularly digitally impaired (Zambianchi, Rönnlund, Carelli, 2019). In many cases, older people are less likely to take advantage of digital technologies (König, Seifert, Doh, 2018) and therefore risk being disadvantaged by the digital transformation in healthcare. However, it is unclear whether this finding is mainly influenced by life stage, which is associated with greater challenges in implementing new technologies due to chronic diseases or age-related personality changes. Digital impairment may also result from the fact that many e-health systems were introduced after the retirement of the oldest people (Zambianchi, Rönnlund, Carelli, 2019). Therefore, further research is needed to understand the causes of age-related digital impairment. Our findings regarding age are consistent with previous results on the determinants of eHealth use (Ali, Alam, Taylor, 2020; Knapova, Kloczek, Elavsky, 2020; Vroman, Arthanat, Lysack, 2015). Therefore, service providers should offer the oldest patients timely online or telephone support, especially in the form of concise user manuals, help and guidance for older users to understand the use of e-health systems (Chan, Tang, Teng, 2023; Lee, Rho, 2013).

According to our results people with higher education use e-health services more often than elderly with primary and vocationally education. This finding is consistent with previous work on the impact of education on e-health use (Alam et al., 2019; Elliot et al., 2014; Ali, Alam, Taylor, 2020; Menéndez Álvarez-Dardet, Lorence Lara, Pérez-Padilla, 2020; Ali et al., 2021).

Higher educational attainment may have provided older adults with general skills or specific ICT knowledge that facilitates the use of e-health (Elliot et al., 2014). However, people with lower levels of education may lack knowledge about e-health tools and therefore have no motivation to use such technologies (Alam et al., 2019; Elliot et al., 2014). The importance of education highlights the need to address the digital disadvantages faced by older people in a cross-cutting manner.

The study showed that health status is an important factor influencing the use of telehealth systems, because the patients with good and very good health declared a higher level of e-health use compared to the patients with poor or very poor health. Interestingly, other studies have found that self-reported health status does not influence e-health use among older adults. Previous studies have shown that people in good health are less likely to use e-health services (Andreassen et al., 2007; Huang, Yang, Chiang, 2020; Wagner et al., 2004). However, this was based on survey data from the general population, not older people in particular. Further research is needed in this area.

Our study showed that marital status also influences the use of e-health systems. Widowers use these systems much less often than people with other marital status. In our opinion, this may be due to the worse mental health of people who have lost their life partners. Previous research in the UK has shown that symptoms of poor mental health can impact readiness to use technology, and depression is likely to exacerbate difficulties in using digital technologies (Andrews et al., 2019). Further research would be necessary to more fully understand these relationships, such as examining how much depression or anxiety causes a lack of technology engagement among older adults.

This study makes some key contributions to the literature. First, it focuses specifically on older adults rather than broader age groups (Ali et al., 2021). This is the first study focusing on a group of older people conducted in Poland. The study's strengths include the ability to capture the current perspective of older Polish patients on telehealth systems after the outbreak of the pandemic. Unlike previous studies that have shown broad acceptance of telemedicine among the general patient population, our study focused on older adults and examined various e-health systems, not just telemedicine.

However, the study has several limitations. The pilot study was conducted on a small, non-random sample. This study only examined 50 patients in one region of the country. Therefore, the perspectives may not reflect the perspectives of other populations of older people from other regions of Poland, especially in the largest urban centres. To obtain more generalizable results, it is necessary to study a larger sample of older patients across the country. However, recruiting representative samples of older adults will always be challenging. Reaching some people, such as older and less educated people less familiar with technological advances, is particularly difficult. These people are often excluded and underrepresented in research, even though they are the target of the digitization process that is changing the delivery of healthcare services (Poli, Kelfve, Motel-Klingebiel, 2019). There was no follow-up

assessment of patients post-pandemic in this study. Further research is needed to determine continued e-health use once pandemic restrictions are lifted. Due to the development of telemedicine after COVID-19, a survey regarding healthcare workers should also be added. To improve the quality and effectiveness of telehealth services, a mixed-quantitative design is needed to identify factors influencing e-health evaluation at multiple levels, including not only from the perspective of older patients but also from their physicians, health organizations, and the overall policy environment. The study also did not take into account considerations regarding technological constraints such as lack of affordability, low quality of services, lack of enabling technologies and poor knowledge of these technologies. Digital literacy is a particularly pressing issue for older people, especially the oldest (Hsu, 2019). Future work is needed to consider the impact of these factors on e-health use in general and on older adults in particular.

In practice, the research can have several implications for policy priorities in the field of ICT technologies regarding healthcare. First, our finding that older people have poor access to ICT tools such as computers and RMP systems suggests that further programs to increase their accessibility are important. Second, our findings regarding education suggest that digital literacy is also important. Finally, our findings that the oldest people (over 75) are more disadvantaged than younger groups suggest that attention should be paid to this group, in particular in terms of ensuring access to ICT and digital skills. The generational digital divide can be solved through interventions that promote the use and, above all, the personal experience of perceiving the usefulness of ICT among older people who are less familiar with new technologies (Laganá et al., 2011).

5. Conclusions

Older people should be the most important users of e-health systems. Therefore, older people's use and perception of these systems are particularly important for their sustainable development. However, the use of e-health systems by older patients in Poland is relatively insufficient. Most of these people have generally negative opinions and attitudes towards telemedicine services.

This study examined the determinants of e-health use among older people in Poland. The level of use of e-health by respondents varied in terms of socio-demographic and health aspects. We found that age, education, marital status and health status, among others, influence the likelihood that an older person will use ICT tools for healthcare purposes. Younger and healthier people reported higher levels of eHealth use. On the other hand, younger, better-educated people use more devices for remote monitoring of the patient's health. This is an important issue because older people have the most to gain from e-health services (given

their limited mobility and risk of infection related to the Covid-19 pandemic). The importance of e-health will grow as societies age and technology develops.

Given the challenges of ageing populations and pandemics such as COVID-19, e-Health services can be essential to an effective, inclusive and robust healthcare system. This study shows that there is a significant digital divide among the oldest people with lower education levels and poor health. It suggests that public and private efforts to make ICT infrastructure more accessible to these people could also improve this situation.

In future research, it would be worthwhile to investigate problems in the practical application of telehealth that raise deep concerns among older people. The use of incentives could then be increased, thereby increasing satisfaction with using e-health systems.

References

1. Alam, K., Rashidul, A.M., Alam, F., Keramat, S.A., Erdiaw-Kwasie, M.O., Sarker, A.R. (2019). Determinants of Access to EHealth Services in Regional Australia. *International Journal of Medical Informatics*, 131 (November), 103960. <https://doi.org/10.1016/J.IJMEDINF.2019.103960>
2. Ali, M.A., Alam, K., Taylor, B. (2020). Determinants of ICT Usage for Healthcare among People with Disabilities: The Moderating Role of Technological and Behavioural Constraints. *Journal of Biomedical Informatics*, 108 (August), 103480. <https://doi.org/10.1016/J.JBI.2020.103480>
3. Ali, M.A., Alam, K., Taylor, B., Ashraf, M. (2021). Examining the Determinants of EHealth Usage among Elderly People with Disability: The Moderating Role of Behavioural Aspects. *International Journal of Medical Informatics*, 149 (May), 104411. <https://doi.org/10.1016/J.IJMEDINF.2021.104411>
4. Allen, A., Hayes, J. (2009). Patient Satisfaction with Teleoncology: A Pilot Study. *Telemedicine Journal*, 1(1), 41-46. <https://doi.org/10.1089/TMJ.1.1995.1.41>
5. Andreassen, H.K., Bujnowska-Fedak, M., Chronaki, C.E., Dumitru, R.C., Pudule, I., Santana, S., Voss, H., Wynn, R. (2007). European Citizens' Use of E-Health Services: A Study of Seven Countries. *BMC Public Health*, 7(1), 1-7. <https://doi.org/10.1186/1471-2458-7-53/TABLES/5>
6. Andrews, J.A., Brown, L., Hawley, M.S., Astell, A.J. (2019). Older Adults' Perspectives on Using Digital Technology to Maintain Good Mental Health: Interactive Group Study. *Journal of Medical Internet Research*, 21(2), e11694. <https://doi.org/10.2196/11694>
7. Barlow, J., Singh, D., Bayer, S., Curry, R. (2007). A Systematic Review of the Benefits of Home Telecare for Frail Elderly People and Those with Long-Term Conditions. *Journal of Telemedicine and Telecare*, 13(4), 172-79. <https://doi.org/10.1258/135763307780908058>

8. Bashshur, R.L., Shannon, G.W., Smith, B.R., Woodward, M.A. (2015). The Empirical Evidence for the Telemedicine Intervention in Diabetes Management. *Telemedicine and E-Health*, 21(5), 321-54. <https://doi.org/10.1089/TMJ.2015.0029>
9. Boogerd, E.A., Arts, T., Engelen, L., van de Belt, H.H. (2015). What Is EHealth?: Time for An Update? *JMIR Research Protocols*, 4(1), e4065. <https://doi.org/10.2196/RESPROT.4065>
10. Broady, T., Chan, A., Caputi, P. (2010). Comparison of Older and Younger Adults' Attitudes towards and Abilities with Computers: Implications for Training and Learning. *British Journal of Educational Technology*, 41(3), 473-85. <https://doi.org/10.1111/J.1467-8535.2008.00914.X>
11. Bujnowska-Fedak, M., Grata-Borkowska, U. (2015). Use of Telemedicine-Based Care for the Aging and Elderly: Promises and Pitfalls. *Smart Homecare Technology and TeleHealth*, May, 91. <https://doi.org/10.2147/SHTT.S59498>
12. Chae, Y.M., Lee, J.H., Hee, Ho S., Hee, J. K., Ki Hong Jun, Jong Uk Won (2001). Patient Satisfaction with Telemedicine in Home Health Services for the Elderly. *International Journal of Medical Informatics*, 61(2-3), 167-73. [https://doi.org/10.1016/S1386-5056\(01\)00139-3](https://doi.org/10.1016/S1386-5056(01)00139-3)
13. Chan, Y.K., Ming Tang, Y., Teng, L. (2023). A Comparative Analysis of Digital Health Usage Intentions towards the Adoption of Virtual Reality in Telerehabilitation. *International Journal of Medical Informatics*, 174 (June), 105042. <https://doi.org/10.1016/J.IJMEDINF.2023.105042>
14. Chumbler, N.R., Li, X., Quigley, P., Morey, M.C., Rose, D., Griffiths, P., Sanford, J., Hoenig, H. (2015). A Randomized Controlled Trial on Stroke Telerehabilitation: The Effects on Falls Self-Efficacy and Satisfaction with Care. *Journal of Telemedicine and Telecare*, 21(3), 139-43. <https://doi.org/10.1177/1357633X15571995>
15. Cimperman, M., Makovec Brenčič, M., Trkman, P. (2016). Analyzing Older Users' Home Telehealth Services Acceptance Behavior—Applying an Extended UTAUT Model. *International Journal of Medical Informatics*, 90 (June), 22-31. <https://doi.org/10.1016/J.IJMEDINF.2016.03.002>
16. Dendere, R., Slade, C., Burton-Jones, A., Sullivan, C., Staib, A., Janda, M. (2019). Patient Portals Facilitating Engagement With Inpatient Electronic Medical Records: A Systematic Review. *Journal of Medical Internet Research*, 21(4), e12779. <https://doi.org/10.2196/12779>
17. Doolittle, G.C., Williams, A., Harmony, A., Allen, A., Boysen, C.D., Wittman, C., Mair, F., Carlson, E. (1998). A Cost Measurement Study for a Tele-Oncology Practice. *Journal of Telemedicine and Telecare*, 4(2), 84-88. <https://doi.org/10.1258/1357633981932000>
18. Elliot, A.J., Mooney, C.J., Douthit, K.Z., Lynch, M.F. (2014). Predictors of Older Adults' Technology Use and Its Relationship to Depressive Symptoms and Well-Being. *The Journals of Gerontology: Series B*, 69(5), 667-77.

- <https://doi.org/10.1093/GERONB/GBT109>
19. Holtz, B.E. (2021). Patients Perceptions of Telemedicine Visits Before and After the Coronavirus Disease 2019 Pandemic. *Telemedicine and E-Health*, 27(1), 107-12. <https://doi.org/10.1089/TMJ.2020.0168>
 20. Hsu, W.C. (2019). The Effect of Age on Electronic Health Literacy: Mixed-Method Study. *JMIR Human Factors*, 6(2), e11480. <https://doi.org/10.2196/11480>
 21. Huang, C.L., Shu, C.Y., Chiang, C.H. (2020). The Associations between Individual Factors, EHealth Literacy, and Health Behaviors among College Students. *International Journal of Environmental Research and Public Health*, Vol. 17(6), 2108. <https://doi.org/10.3390/IJERPH17062108>
 22. Hur, M.H. (2016). Empowering the Elderly Population through ICT-Based Activities: An Empirical Study of Older Adults in Korea. *Information Technology and People*, 29(2), 318-33. <https://doi.org/10.1108/ITP-03-2015-0052/FULL/XML>
 23. Ihm, J., Hsieh, Y.P. (2015). The Implications of Information and Communication Technology Use for the Social Well-Being of Older Adults. *Information, Communication & Society*, 18(10), 1123-38. <https://doi.org/10.1080/1369118X.2015.1019912>
 24. Isautier, J., Copp, T., Ayre, J., Cvejic, E., Meyerowitz-Katz, G., Batcup, C., Bonner, C. et al. (2020). People's Experiences and Satisfaction With Telehealth During the COVID-19 Pandemic in Australia: Cross-Sectional Survey Study. *Journal of Medical Internet Research*, 22(12), e24531. <https://doi.org/10.2196/24531>
 25. Okisch, M.R., Schmidt, L.I., Doh, M., Marquard, M., Wahl, H.W. (2020). The Role of Internet Self-Efficacy, Innovativeness and Technology Avoidance in Breadth of Internet Use: Comparing Older Technology Experts and Non-Experts. *Computers in Human Behavior*, 111 (October), 106408. <https://doi.org/10.1016/J.CHB.2020.106408>
 26. Kludacz-Alessandri, M., Hawrysz, L., Korneta, P., Gierszewska, G., Pomaranik, W., Walczak, R. (2021). The Impact of Medical Teleconsultations on General Practitioner-Patient Communication during COVID- 19: A Case Study from Poland. *PLOS ONE*, 16(7), e0254960. <https://doi.org/10.1371/JOURNAL.PONE.0254960>
 27. Knapova, L., Kloczek, A., Elavsky, S. (2020). The Role of Psychological Factors in Older Adults' Readiness to Use EHealth Technology: Cross-Sectional Questionnaire Study. *Journal of Medical Internet Research*, 22(5), e14670. <https://doi.org/10.2196/14670>
 28. König, R., Seifert, A., Doh, M. (2018). Internet Use among Older Europeans: An Analysis Based on SHARE Data. *Universal Access in the Information Society*, 17(3), 621-33. <https://doi.org/10.1007/S10209-018-0609-5/TABLES/2>
 29. Kruse, C.S., Krowski, N., Rodriguez, B., Tran, L., Vela, J., Brooks, M. (2017). Telehealth and Patient Satisfaction: A Systematic Review and Narrative Analysis. *BMJ Open*, 7(8), e016242. <https://doi.org/10.1136/BMJOPEN-2017-016242>
 30. Laganá, L., Taylor, O., Ainsworth, A., Edwards, M. (2011). Enhancing Computer Self-Efficacy and Attitudes in Multi-Ethnic Older Adults: A Randomised Controlled Study.

- Ageing & Society*, 31(6), 911-33. <https://doi.org/10.1017/S0144686X10001340>
31. Lee, J., Jung Rho, M. (2013). Perception of Influencing Factors on Acceptance of Mobile Health Monitoring Service: A Comparison between Users and Non-Users. *Healthcare Informatics Research*, 19(3), 167-76. <https://doi.org/10.4258/HIR.2013.19.3.167>
 32. Lemay, G., Azad, N., Struthers, C. (2013). Utilization of Home Telemonitoring in Patients 75 Years of Age and Over with Complex Heart Failure. *Journal of Telemedicine and Telecare*, 19(1), 18-22. <https://doi.org/10.1177/1357633X12473917>
 33. Levine, M., Richardson, J.E., Granieri, E., Reid, C.C. (2014). Novel Telemedicine Technologies in Geriatric Chronic Non-Cancer Pain: Primary Care Providers' Perspectives. *Pain Medicine*, 15(2), 206-13. <https://doi.org/10.1111/PME.12323>
 34. Ma, Q., Sun, D., Tan, Z., Li, C., He, X., Zhai, Y., Wang, L. et al. (2022). Usage and Perceptions of Telemedicine among Health Care Professionals in China. *International Journal of Medical Informatics*, 166 (October), 104856. <https://doi.org/10.1016/J.IJMEDINF.2022.104856>
 35. Macedo, I.M. (2017). Predicting the Acceptance and Use of Information and Communication Technology by Older Adults: An Empirical Examination of the Revised UTAUT2. *Computers in Human Behavior*, 75 (October), 935-48. <https://doi.org/10.1016/J.CHB.2017.06.013>
 36. Mekhjian, H., Turner, J.W., Gailiun, M., McCain, T.A. (1999). Patient Satisfaction with Telemedicine in a Prison Environment. *Journal of Telemedicine and Telecare*, 5(1), 55-61. <https://doi.org/10.1258/1357633991932397>
 37. Menéndez Álvarez-Dardet, S., Lorence Lara, B., Pérez-Padilla, J. (2020). Older Adults and ICT Adoption: Analysis of the Use and Attitudes toward Computers in Elderly Spanish People. *Computers in Human Behavior*, 110 (September), 106377. <https://doi.org/10.1016/J.CHB.2020.106377>
 38. Merrell, R.C. (2015). Geriatric Telemedicine: Background and Evidence for Telemedicine as a Way to Address the Challenges of Geriatrics. *Healthcare Informatics Research*, 21(4), 223-29. <https://doi.org/10.4258/HIR.2015.21.4.223>
 39. Napitupulu, D., Yacub, R. (2021). Halim Perdana Kusuma Putra A., (2021). Factor Influencing of Telehealth Acceptance During COVID-19 Outbreak: Extending UTAUT Model. *International Journal of Intelligent Engineering and Systems*, 14(3), 267-81. <https://doi.org/10.22266/ijies2021.0630.23>
 40. Nestlerode, C., Pavelka, J., Basil, J., Schuler, K., Fellner, A.N., Ghaderian, M., Neff, R. (2022). Patient Perspectives of Telemedicine in Gynecologic Oncology during COVID. *Gynecologic Oncology Reports*, 43 (October), 101071. <https://doi.org/10.1016/J.GORE.2022.101071>
 41. Park, H.S., Sungmoon, J., Chung, H.Y., Soh, J.Y., Hyun, Y.H., Hwan Bang, S., Kim, H.S. (2022). Use of Video-Based Telehealth Services Using a Mobile App for Workers in Underserved Areas during the COVID-19 Pandemic: A Prospective Observational Study.

- International Journal of Medical Informatics*, 166 (October), 104844.
<https://doi.org/10.1016/J.IJMEDINF.2022.104844>
42. Poli, A., Kelfve, S., Motel-Klingebiel, A. (2019). A Research Tool for Measuring Non-Participation of Older People in Research on Digital Health. *BMC Public Health*, 19(1), 1-12. <https://doi.org/10.1186/S12889-019-7830-X/TABLES/5>
43. Postma-Nilsenová, M., Postma, E., Bates, K. (2015). Automatic Detection of Confusion in Elderly Users of a Web-Based Health Instruction Video. *Telemedicine and E-Health*, 21(6), 514-19. <https://doi.org/10.1089/TMJ.2014.0061>
44. Powell, R.E., Henstenburg, J.M., Cooper, G., Hollander, J.E., Rising, K.L. (2017). Patient Perceptions of Telehealth Primary Care Video Visits. *The Annals of Family Medicine*, 15(3), 225-29. <https://doi.org/10.1370/AFM.2095>
45. Triantafyllou, V., Layfield, E., Prasad, A., Deng, J., Shanti, R.M., Newman, J.G., Rajasekaran, K. (2020). Patient Perceptions of Head and Neck Ambulatory Telemedicine Visits: A Qualitative Study. *Otolaryngology-Head and Neck Surgery*, 164(5), 923-31. <https://doi.org/10.1177/0194599820943523>
46. Vroman, K., Arthanat, S., Lysack, C. (2015). Who over 65 Is Online?’ Older Adults’ Dispositions toward Information Communication Technology. *Computers in Human Behavior*, 43 (February), 156-66. <https://doi.org/10.1016/J.CHB.2014.10.018>
47. Wagner, T.H., Baker, L.C., Bundorf, M. K., Singer, S. (2004). Peer Reviewed: Use of the Internet for Health Information by the Chronically Ill. *Preventing Chronic Disease*, 1(4), /pmc/articles/PMC1277953/
48. Zambianchi, M., Rönnlund, M., Carelli, M.G. (2019). Attitudes Towards and Use of Information and Communication Technologies (ICTs) Among Older Adults in Italy and Sweden: The Influence of Cultural Context, Socio-Demographic Factors, and Time Perspective. *Journal of Cross-Cultural Gerontology*, 34(3), 291-306. <https://doi.org/10.1007/S10823-019-09370-Y/TABLES/3>.
49. Zarate, C.A., Weinstock, L., Cukor, P., Morabito, C., Leahy, L., Burns, C., Baer, L. (1997). Applicability of Telemedicine for Assessing Patients with Schizophrenia: Acceptance and Reliability. *Journal of Clinical Psychiatry*, 58(1), 22-25. <https://doi.org/10.4088/JCP.v58n0104>.

THE IMPACT OF ORGANIZATIONAL TRUST ON JOB SATISFACTION

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Purpose: Organizational trust is a fundamental construct upon which both interpersonal and business relationships are based. It is an essential element of running a business, closely linked to the management of social capital, which is the foundation of a company's operations. It is worth emphasizing the importance of employee satisfaction, which can significantly contribute to an organization's success. Therefore, the main goal of this article is to determine whether vertical trust can influence perceived satisfaction in the workplace.

Design/methodology/approach: The results presented in this article come from quantitative research. A total of 153 respondents participated in the survey. The research was conducted in Poland in early 2025 using electronic surveys. Statistical analysis was performed using descriptive statistics and correlation indicators.

Findings: Overall, organizational trust and job satisfaction are moderately positively related (0.456). All correlations were statistically significant at $p < 0.001$. The higher the level of confidence, the higher the job satisfaction. Of the examined component variables of organizational trust (OT), fair employee evaluation (0.469) and trust in the decisions made by their leaders (0.424) have the most significant impact on overall job satisfaction.

Research limitations/implications: Small research sample (153 people) uses only a few component variables of organizational trust and satisfaction. This area may be a potential field for continuing research.

Practical implications: The results of the conducted research can be used by management to build lasting relationships based on trust, which can translate into employee satisfaction and, consequently, into the success of the entire organization.

Originality/value: Previous research has demonstrated a relationship between trust levels and job satisfaction. This study expands on this relationship by analyzing the impact of individual components of organizational trust on job satisfaction.

Keywords: organizational trust, intra-organizational relations, job satisfaction.

Category of the paper: research paper.

1. Introduction

Social capital, which is the key to a prosperous enterprise, is increasingly becoming the subject of research. Therefore, the effective operation of the entity is influenced by human resources management. Trust is the basic factor building the entire organization, as it is on it that its functioning is based, and satisfied employees are the basis for the effective operation of the organization. Organizational trust has a significant impact on the achievement of the intended effects and results of a given organization (Schwabe, 2023; Lewicka et al., 2023). Job satisfaction can affect the proactivity or innovativeness of employees, which translates into the overall development of the organization (Biesok Wyród-Wróbel, 2018). So far, organizational trust or job satisfaction have been considered many times by scientists. However, there is a certain research gap in the literature on the subject – there is a lack of in-depth analyses of the relationship between these two variables. In addition, this topic is of a dynamic nature, and the relationship between trust and job satisfaction changes both over time and under the influence of many factors, hence the need for successive research on this phenomenon. It is also worth emphasizing generational changes, which may indicate a constant need to analyze this relationship, which may be especially important for managers, company owners during e.g. employee recruitment, or in order to create an effective, coherent organization. Therefore, the following research question should be asked: can vertical trust affect job satisfaction? The aim of the article will be to determine and assess the relationship between organizational trust, mainly of a vertical nature, and employee satisfaction. Thanks to trust, employees can show greater openness, boldness to point out ambiguities, problems, or admit mistakes. Therefore, vertical trust can contribute to faster and more effective conflict resolution and closer ties between employees and superiors. At the same time, greater cooperation can translate into the effectiveness of the organization's operations and building its competitive advantage, which can also affect the perceived satisfaction with the work performed. Taking into account the above aspects, the following research hypothesis should be put forward: H1: Vertical trust has a positive effect on the sense of job satisfaction. In order to verify the hypothesis, a quantitative study (electronic surveys) was carried out and descriptive statistics were used, as well as the Tau-Kendall correlation coefficient.

This article expands scientific knowledge on job satisfaction as well as organizational trust, and in particular vertical trust. In addition, the results achieved can provide guidance for management to build relationships based on trust.

2. Literature review

2.1. The role of trust in human resource management

In general, trust can be defined as a complex relationship in which the trustor consents to be vulnerable in the hopes that the trustee will be advantageous to them (Andersson, 2024). Organizational trust is defined as the positive expectations that people have regarding the intentions and behaviors of members of the organization based on their roles, relationships, experiences, and interdependencies within the organization. Trust is considered to be the result of interactions among people, which contributes to work performance in the workplace (Kidron, Vinarski-Peretz, 2025). Organizational trust is also viewed as essential for a healthy, satisfied, and engaged workforce (Guzzo et al., 2021). To achieve a competitive advantage, companies are currently striving to enhance the trust of their employees and customers (Ahteela, Vanhala, 2018). Consequently, building a trust mechanism has become a primary goal for the company (Dahiya, 2023).

According to many researchers dealing with the aspect of trust, it is emphasized that it significantly impacts effective and efficient human resources management in an organization (Paliszkiwicz, 2013). Researchers Shockley-Zalabak and Fraihat emphasize that organizational trust affects the more straightforward implementation of innovative projects and the introduction of changes. When there is organizational trust in the company, the team can observe excellent communication and collaboration, which leads to achieving desired results. On the other hand, the lack of organizational trust causes resistance, reluctance to change, and reluctance to perform tasks. Fear of expressing one's ideas, lack of creativity, or withholding information is common (Bani et al., 2024). Trust is crucial in managing an organization. It makes it easier to achieve your goals. This is essential in teamwork, and its absence can lead to dissatisfaction, communication difficulties, or a frequent desire to change jobs (Tomaszuk, Wsiluk, 2023).

A link between organizational trust and employee action is indicated. A team with high trust performs the assigned tasks with greater commitment, which brings satisfactory results in the strategic management of the unit (Lewicka et al., 2023). It also impacts building a competitive advantage, a kind of social capital that is the foundation of running a business (Okręglička, Lemańska-Majdzik, 2024). The determinants of organizational trust include: honesty, competence, predictability, and credibility (Schwabe, 2023). An important role in trust is the ability to trust another person (Maicki, 2016). Organizational trust can be understood through three critical dimensions: the ability, benevolence, and integrity of managers/owners. The ability-based trust dimension focuses on the belief in the other party's abilities, skills, and characteristics. The benevolence-based trust dimension is rooted in the notion that the trusted person has good intentions and acts selflessly. Finally, integrity-based trust revolves

around the principles and values that the trustor upholds, indicating that they can rely on the actions and words of the other person (Hameli, Aktaş, 2024).

It is worth noting that organizational trust (OT) can be considered in terms of the management staff's skills, kindness, and impeccable attitude. Through the prism of skills, it is understood as faith in another person, in their qualifications and professional competencies. Kindness, on the other hand, indicates having good intentions. On the other hand, the impeccable attitude of the management suggests the maintenance of sound principles and values (Hameli, Aktaş, 2024).

Effective running of an organization should be based on trust, which must be constantly maintained and developed in order not to lose it (Stelmaszczyk, 2010). The level of trust also reduces the costs associated with hiring employees, because trusted employees do not need to be checked often, and errors occur less frequently when performing their work (Györfi, 2018). Therefore, trust in human resources management undoubtedly plays a key role.

People who are integral to the organization may trust their managers but not their co-workers. Hence, vertical trust (between the supervisor and the employee) and horizontal trust (between employees in a similar professional situation) are distinguished (Kmieciak, 2021).

It is indicated that vertical trust is crucial, i.e., trust between the employee and the supervisor (Lewicka, 2013). The literature suggests that greater efficiency and work productivity are observed in a high-quality relationship between the employee and the supervisor. It is also emphasized that employees who trust their supervisors are more willing to accept introduced changes or be influenced by team leaders. In addition, in an organization with trust at the vertical level, employees are more proactive, take their own initiative more often, and introduce positive value to the organization (Guinot, Chiva, 2019). Vertical trust is crucial for satisfying the need for self-fulfillment, which is at the top of Maslow's pyramid. Namely, when an employee feels motivated to act and the relations between them and their superior are positive, their sense of value and perceived satisfaction increase, directly impacting the quality of work performed and professional fulfillment (Hampton, 2019).

2.2. The role of leaders in enhancing job satisfaction

Satisfaction is a key variable in employees' overall perception of the workplace (Cao et al., 2025). It is a positive feeling resulting from the nature of the work performed and the assessment of its conditions. (Indrayani et al., 2024). The concept of satisfaction can also be defined as the difference between the employee's expectations and what they actually experience in the workplace (Białas, Litwin, 2013). Satisfaction comprises many factors, including opportunities for development, career advancement, well-being, and motivation (Duarte et al., 2024).

Effective communication and openness throughout the organization are essential, especially during change. This is where leaders play a significant role and should greatly support employees. It is emphasized that positive relationships between leaders and employees result

in greater commitment to their work and general openness among employees (Robinson et al., 2004). Trust in one's superior can affect the productivity and effectiveness of the entire organization (Özdemir et al., 2024).

Team and organization leaders should have the appropriate skills, which include: listening, delegating tasks, mentoring, coaching, effective conflict resolution, building a sense of belonging, and unity with the enterprise. A leader should have the skills to strengthen bonds, constantly creating and maintaining trust (Turaga, 2013). Additionally, the features that a leader should have are primarily: creativity, knowledge, experience, the ability to learn quickly, good communication, and building positive relationships. A supervisor should inspire others (Gadomska-Lila, 2017). This person should also be open to diversity and empathy, which will help build employee trust (Rzepka, Bańkowski, 2024). It is also emphasized that the supervisor's role is to provide a friendly atmosphere, opportunities for development, and rapid resolution of conflicts so that they do not have the chance to create a threat to relationships in the organization (Głowienka, 2021). Business management staff who cannot inspire trust may have difficulty running and developing the organization (Rudzewicz, 2016). Having a vision and clearly defined goals for the organization is essential for success. However, the people who carry out these tasks determine the enterprise's success. Therefore, superiors must focus primarily on building the best possible mutual relations and bonds with employees.

It is the role of leaders that is crucial in building job satisfaction. Employees who feel appreciated and supported are more motivated to work. Regular conversations, discussing the results of tasks performed, indicate interest, which increases the sense of belonging, and can also translate into understanding the needs of both the supervisor and the employee (Bartkowiak, 2011). Leaders play a key role in shaping the overall organizational culture, translating the company's values and mission into specific actions that define employees' everyday experiences. Their attitude and decisions directly impact the commitment, openness of the team, and work efficiency. The role of leaders is crucial here because they are the people who create organizations and their actions. The work performed translates into the organization's success, achieving the intended goals and profits (Kruk, 2024).

2.3. The influence of trust in superiors on job satisfaction

Trust is a critical element of the functioning of an organization, as it affects interpersonal relationships, cooperation in general, and the results achieved by a given unit. (Haridas et al., 2022). Many studies indicate the relationship between trust in the workplace, increased employee productivity, reduced willingness to change jobs, and higher satisfaction with the duties performed (Zak, 2017). Trust refers to the employee's perception of their relationship with the work environment, the organization, and people. This image evolves through accumulated experiences and interactions in a given organization (Dirks, Ferrin, 2001). Vertical trust significantly impacts the organizational support perceived by employees and the appreciation of their work effort (Ozyilmaz et al., 2018).

Trust in superiors results in openness and good communication, which is also an element of satisfaction (Colquitt et al., 2013). A superior who inspires trust can build a workplace in which employees feel appreciated, because then they show greater job satisfaction (Yang, Mossholder, 2010). Vertical trust causes employees to tend to show greater satisfaction because they have a friendly and safe work environment. It is assumed that trust is not a mediating factor in cooperation between the superior, his support, and employee satisfaction (Gopalan et al., 2023).

Scientists increasingly consider building good relationships, referring to the "soft" areas of human resources management (Białas et al., 2021). This may be due to the changing expectations of employees and supervisors. It should be emphasized that young generations entering the labor market are more focused on work and balance, i.e., not only on work but also on private life and pursuing their hobbies. Previous studies have shown that a high level of trust in an organization positively correlates with job satisfaction. Employees who had higher trust more often declared satisfaction with their profession (Biesok et al., 2017). It should be emphasized that vertical trust plays an essential role in the employee's emotional attachment, stress reduction, and job satisfaction (Wnuk, 2020). However, it will also be beneficial to examine this phenomenon in terms of the impact of the components of vertical trust on the components of satisfaction. Expectations and approaches to work are constantly changing, so it is worth monitoring the needs of employees to manage human capital even better.

3. Methods

The results presented in this article come from quantitative research. A total of 153 respondents took part in the survey, of which 77.6% were women and 22.4% were men. In addition, 57.1% of respondents were aged 18-25, 35.1% were aged 26-45 and 7.8% were respondents aged 46-60. The survey was attended by 54.2% of people with higher education, 39.9% with secondary education and 5.9% with vocational education. The research was carried out in Poland at the beginning of 2025, using electronic surveys. The sample was randomly selected, and the respondents answered using a five-point Likert scale according to their own subjective feelings. The results obtained were verified and then subjected to statistical analysis. Taking into account the main objective of the article, i.e. to examine the impact of organizational trust (mainly vertical trust) on employee satisfaction, the following research hypothesis has been put forward:

H1: Vertical trust correlates positively with the sense of job satisfaction.

Based on the literature, questions regarding vertical trust and job satisfaction were built and placed in the questionnaire. The respondents assessed the variables studied on a 5-point scale according to their subjective feelings. The following coding of component variables was

adopted, which constitute the organizational trust variable (OT) and the job satisfaction variable (WS):

OT1. I trust the decisions my supervisor makes.

OT2. Supervisors evaluate employee performance fairly.

OT3. Supervisors set a model for building positive relationships.

OT4. Supervisors discuss the results of my work with me.

WS1. I feel satisfied with the work I do.

WS2. I feel appreciated.

WS3. The company provides development opportunities.

The study used statistical analysis methods such as descriptive statistics and the Kendall's Tau correlation coefficient, which is used to describe the correlation between ordinal variables.

4. Results

The following figures present descriptive statistics for the questions asked in the survey. The first figure shows the organizational trust (OT) variable, which is the average of four component variables.

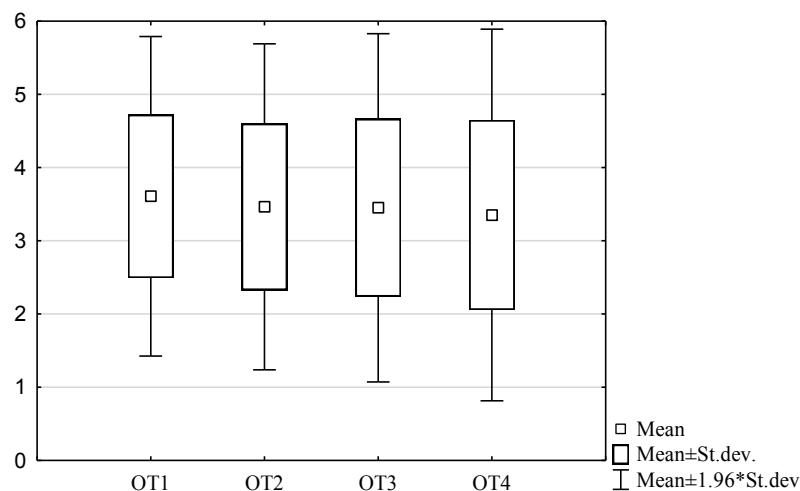


Figure 1. Box plot for the organizational trust variable.

Source: Own study based on survey results.

It can be stated that the respondents generally have a favorable opinion of their superiors. The respondents show the most significant trust in the decisions made by the leaders and declare that the leaders set a model for building positive relationships with their attitude. On the other hand, the discussion of the work results and the sense of justice in the workplace is assessed slightly worse. This may suggest that it is in these areas that the leaders should focus more on increasing employee satisfaction, which may translate into the organization's overall prosperity.

Table 1.

Descriptive statistics and Cronbach's alpha reliability coefficient for the organizational trust variable

Variable	n	Mean	Median	Q1	Q3	St. dev.	Skewness	Kurtosis	Cronbach's alpha
OT1	153	3.608	4.000	3.000	4.000	1.114	-0.536	-0.424	0.921
OT2	153	3.464	4.000	3.000	4.000	1.136	-0.361	-0.560	
OT3	153	3.451	4.000	3.000	4.000	1.214	-0.432	-0.736	
OT4	153	3.353	4.000	3.000	4.000	1.295	-0.462	-0.827	
OT	153	3.469	3.750	2.750	4.250	1.071	-0.510	-0.376	

Source: Own study based on survey results.

Based on the results obtained, it can be seen that the respondents demonstrate a moderately high level of trust in their superiors. The average results of the individual indicators (from 3.353 to 3.608) on a five-point scale suggest that the assessments are close to their upper limit, indicating a positive attitude of most respondents. Medians equal to 4 confirm that at least half of the respondents assess the trust component variables as high. Negative skewness values indicate that the OT component variables are shifted towards higher assessments. However, it should be mentioned that there is a small number of extreme answers, which is indicated by the negative kurtosis value. The reliability of the research tool for the OT variable is high, which is confirmed by the Cronbach's alpha value of 0.921.

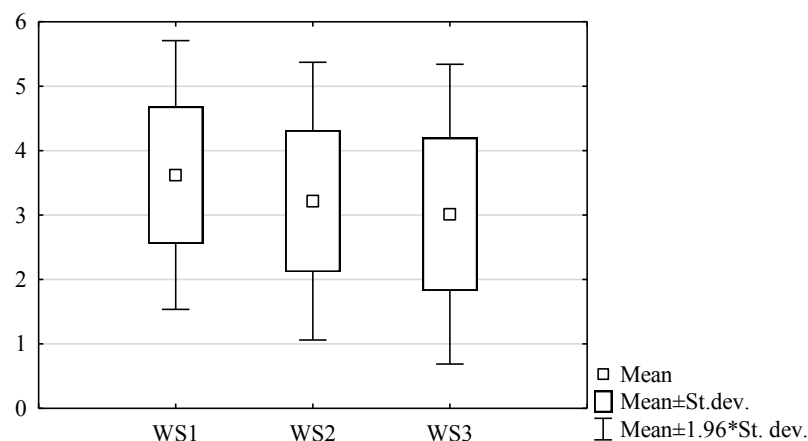


Figure 2. Box plot for the work satisfaction variable.

Source: Own study based on survey results.

It can be stated that the majority of respondents feel satisfied with their work. At the same time, respondents indicate slightly lower values regarding their superiors' appreciation of their work. The respondents also assess development opportunities in a given company as lower. Although these two component variables (WS2, WS3) are rated lower on a 5-point Likert scale, overall job satisfaction is rated relatively high (average 3.6).

Table 2.

Descriptive statistics and Cronbach's alpha reliability coefficient for the work satisfaction variable

Variable	n	Mean	Median	Q1	Q3	St. dev.	Skewness	Kurtosis	Cronbach's alpha
WS1	153	3.621	4.000	3.000	4.000	1.064	-0.587	-0.229	0.818
WS2	153	3.216	3.000	2.000	4.000	1.100	-0.168	-0.646	
WS3	153	3.013	3.000	2.000	4.000	1.186	-0.121	-0.659	
WS	153	3.283	3.333	2.667	4.000	0.957	-0.327	-0.555	

Source: Own study based on survey results.

It is worth noting that the component variables are consistent and are a good measure of satisfaction, as the results are reliable (0.818 - Cronbach's alpha). The overall satisfaction index allows us to state that the respondents show moderate satisfaction with the work performed (average 3.283), and the negative skewness (-0.327) confirms that more people indicated higher than average satisfaction. However, it should be remembered that employees more often declare a lower level of feeling appreciated by leaders, and that the company does not provide them with many development opportunities.

Table 3.

Kendall's tau correlation between organizational trust and work satisfaction ($p < 0.001$)

	WS1	WS2	WS3	WS
OT1	0.403	0.481	0.270	0.424
OT2	0.412	0.557	0.304	0.469
OT3	0.359	0.452	0.299	0.401
OT4	0.340	0.430	0.329	0.397
OT	0.396	0.514	0.323	0.456

Source: Own study based on survey results.

In general, it can be stated that organizational trust and job satisfaction are positively dependent with moderate intensity (0.456). All correlations were statistically significant at the level of $p < 0.001$. The higher the level of trust, the higher the job satisfaction. Of the examined component variables of organizational trust (OT), fair evaluation of employees and trust in decisions made by their leaders are most strongly related to overall job satisfaction. It should be pointed out that building positive relationships and discussing the results of work leaders perform with employees is less correlated with overall job satisfaction. Therefore, it can be concluded that other factors may determine job satisfaction to a greater extent.

5. Discussion

According to the conducted research, people who declared a high level of trust also felt high satisfaction with their work, and people with a low level of trust declared lower job satisfaction (Biesok, 2013). Thus, even then, a certain relationship between the declared trust and the satisfaction felt was detected. It was emphasized that job satisfaction has a significant impact

on employee productivity (Budiono, 2024). In addition, it has been noted that building trust also plays a special role in shaping the dimensions of leadership (Bylok, 2025). Thus, organizational trust and job satisfaction are a frequent topic of researchers' considerations, but in the conducted research it has been expanded by examining how organizational trust affects overall job satisfaction, taking into account the variables that build organizational trust and the variable components that build overall satisfaction. The conducted research confirmed a positive relationship between organizational trust and job satisfaction. Namely, it was pointed out that the main influence on job satisfaction is exerted by a variable component of organizational trust, which is fair evaluation of employees by their leaders. On the other hand, the weakest relationship between job satisfaction was shown by the OT4 component variable concerning the discussion of work results by the supervisor. However, this variable can affect employee trust in leaders. It is also worth mentioning that when employees feel satisfied with their work, they identify more with the company's goals, put up less resistance to change, or show greater commitment, they are more loyal (Białas, Litwin, 2013). Therefore, it is undoubtedly an important area of research, which can be extended to include the OT and WS component variables, in order to better examine which factors are most interdependent and which of them have the greatest impact on job satisfaction. The research conducted (Tomaszuk, Wasiluk, 2023) also pointed out the importance of cultural differences in building organizational trust, which should be taken into account by managers in managing an international team. Namely, it should be pointed out that the conducted research may be a kind of guideline for the management in building relationships based on organizational trust, and in particular on vertical trust. At the same time, it should be emphasized that the practical application of these conclusions may be conditioned by cultural or organizational differences, so in the future it would be worth considering this aspect, as well as expanding the research, for example, by in-depth interviews with managers, or by conducting specific case study analyses.

6. Conclusion

Organizational trust is still an interesting phenomenon in human resources management. It can be pointed out that it is essential for the functioning of an entity, because all the organization's activities are based on it. Employees who show greater trust in their superiors declare satisfaction and contentment with their work. This issue is significant because a satisfied employee can show greater work efficiency. Their general feelings and emotional state can manifest in maintaining a higher quality of fulfilled duties. Therefore, this area can be a challenge for future research.

The article's main goal was achieved by examining the relationship between organizational trust and job satisfaction. The hypothesis put forward can be confirmed because organizational trust positively correlates with overall satisfaction in the workplace. The greater the trust, the greater the satisfaction with the work performed. The analyzed OT component variables indicate that justice is key in building organizational trust. It is mainly on the development of this aspect that leaders and superiors should focus to create a harmonious, trusting team. Thanks to this, the entire organization can gain a competitive advantage, because the higher the trust, the higher the satisfaction with the work performed, which in turn translates into greater efficiency, effectiveness, and quality of work among employees. It should also be emphasized that trust in the decisions made by the superior is a crucial element in building overall job satisfaction. Namely, leaders should consider them carefully so as not to disappoint employees' trust. Discussing the results of work by superiors with employees does not have a high impact on overall satisfaction with their performance. However, the research also shows that discussing the work results impacts employees' perception of the company's development opportunities. This factor, in turn, may already impact satisfaction with the profession performed.

At the same time, it is important to highlight the limitations of the study, such as the small research sample (153 people), where 57.5% are people aged 18-25. The use of only a few variables of organizational trust and satisfaction will also be a limitation. This area may be a potential field for continuing research in this area. In the future, the research can be developed by determining the impact of trust on job satisfaction based on regression models and indicating the factors mediating this relationship. In future research, it is also worth taking into account the cultural differences that occur.

References

1. Ahteela, R., Vanhala, M. (2018). HRM bundles and organizational trust. *Knowledge and Process Management*, Vol. 25(1), pp. 3-11, doi: 10.1002/kpm.1561
2. Andersson, C., Berman, A.H., Lindfors, P., Bendtsen, M. (2024). Trust in academic management during the COVID-19 pandemic: Longitudinal effects on mental health and academic self-efficacy. *Cogent Education*, Vol. 11(1), pp. 1-12, doi: 10.1080/2331186X.2024.2327779
3. Bani, A.Y.A., Fraihat, A.B.A.M., Hamdan, M.N., Ayasrah, F.T.M., Alhawamdeh, M.M., Al-Shakri, K.S. (2024). Examining the mediating role of organizational trust in the relationship between organizational learning and innovation performance: A study of information systems and computer science service firms. *Uncertain Supply Chain Management*, Vol. 12, pp. 2317-2330, doi: 10.5267/j.uscm.2024.6.001

4. Bartkowiak, G. (2011). Dobrostan pracowników oraz poziom „zdrowia organizacji” a zadowolenie z pracy i zaangażowanie w osiąganie celów organizacji. In: M. Gableta, A. Pietroń-Pyszczyk (Eds.), *Człowiek i praca w zmieniającej się organizacji. W kierunku respektowania interesów pracobiorców* (pp. 199-210). Wrocław: Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu.
5. Białas, S., Litwin, J. (2013). Kierunki badań nad satysfakcją z pracy. *Organizacja i Kierowanie, Vol. 3(156)*, pp. 161-170. doi:10.2478/oam-2013-0029
6. Białas, S., Molek-Winiarska, D., Pelc, A. (2023). Kultura organizacyjna sprzyjająca poprawie dobrostanu pracowników. *Zarządzanie Zasobami Ludzkimi, Vol. 1(150)*, pp. 73-92, doi:10.5604/01.3001.0016.2926
7. Biesok, G., Wyród-Wróbel, J. (2017). Zaufanie jako czynnik satysfakcji pracowników. *Rynek, Społeczeństwo, Kultura, Vol. 1(22)*, pp. 167-176.
8. Biesok, G., Wyród-Wróbel, J. (2018). Satysfakcja z pracy i jej znaczenie w organizacjach. In: M. Jakubiec, A. Barcik (Eds.), *Wielowymiarowość zarządzania XXI wieku* (pp.26-37). Wydawnictwo Naukowe Akademii Techniczno-Humanistycznej w Bielsku-Białej.
9. Budiono, A. (2024). Job performance influenced by leadership and training: Job satisfaction and organizational commitment as mediator variables. *Folia Oeconomica Steinensia, Vol. 24(2)*, pp. 20-40, doi: <https://doi.org/10.2478/fofi-2024-0015>
10. Bylok, F. (2025). Examining the Relationships Between Leadership Attributes and Organisational Trust in Companies in Innovative Industries. *Annales Universitatis Mariae Curie-Skłodowska, sectio H – Oeconomia, Vol. 59(2)*, pp. 39-56, doi: <https://doi.org/10.17951/h.2025.59.2.39-56>
11. Cao, T.H.V., Chai, D.S., Nguyen, L.P., Nguyen, H.T.H., Han, C.S.-H., Park, S. (2025). Learning organization and employee performance: The mediating role of job satisfaction in the Vietnamese context. *The Learning Organization, Vol. 32(7)*, pp. 53-73, doi: 10.1108/TLO-09-2023-0177
12. Colquitt, J.A., Scott, B.A., Rodell, J.B., Long, D.M., Zapata, C.P., Conlon, D.E., Wesson, M.J. (2013). Justice at the millennium, a decade later: A meta-analytic test of social exchange and affect-based perspectives. *Journal of Applied Psychology, Vol. 98(2)*, pp. 199-236, doi: 10.1037/a0031757
13. Dahiya, R. (2023). Build trust in the organization because it matters: Exploring the nexus of enablers of organizational trust through DEMATEL. *Global Knowledge, Memory and Communication*, pp. 1069-1089, doi: 10.1108/GKMC-11-2022-0251
14. Dirks, K.T., Ferrin, D.L. (2001). The role of trust in organizational settings. *Organization Science, Vol. 12(4)*, pp. 450-467. Retrieved from: <http://www.jstor.org/stable/3085982>
15. Duarte, N., Majewska, M., Niezurowski, L., Rawińska-Gawrot, J. (2024). Job satisfaction in the digitalisation era: A bibliometric analysis. *Research on Enterprise in Modern Economy - Theory and Practice, Vol. 1(38)*, pp. 11-36, doi:10.19253/rem.2024.01.002

16. Gadomska-Lila, M. (2017). Rola lidera w budowaniu potencjału zespołu do zmian. *Management Forum*, Vol 5(2), pp. 19-25, doi:10.15611/mf.2017.2.04
17. Głowienka, W. (2021). Rola lidera w zarządzaniu zasobami ludzkimi. *Zarządzanie Innowacyjne w Gospodarce i Biznesie*, Vol. 32(1), pp. 93-101, doi: 10.25312/2391-5129.32/2021_07
18. Gopalan, N., Beutell, N.J., Alstete, J.W. (2023). Can trust in management help? Job satisfaction, healthy lifestyle, and turnover intentions. *International Journal of Organization Theory & Behavior*, Vol. 26(3), pp. 185-202, doi: 10.1108/IJOTB-09-2022-0180
19. Guinot, J., Chiva, R. (2019). Vertical trust within organizations and performance: A systematic review. *Human Resource Development Review*, Vol. 18(2), pp. 160-182, doi: 10.1177/1534484319842992
20. Guzzo, R.F., Wang, X., Madera, J.M., Abbott, J. (2021). Organizational trust in times of COVID-19: Hospitality employees' affective responses to managers' communication. *International Journal of Hospitality Management*, Vol. 93, pp. 1-11, doi: 10.1016/j.ijhm.2020.102778
21. Györfi, D. (2018). *Trust and crisis management in the European Union: An institutional account of success and failure in program countries*. Cham: Springer International Publishing, pp. 1-244, doi: 10.1007/978-3-319-69212-8
22. Hameli, K., Aktaş, H. (2024). The relationship between organizational spirituality, leadership styles and employee well-being: The moderating role of organizational trust. *International Journal of Ethics and Systems*. Retrieved from: <https://doi.org/10.1108/IJOES-07-2024-0215>
23. Hampton, C.T. Jr. (2019). *Supervisor-subordinate relationships and its effect on job satisfaction and job performance* (Undergraduate thesis). University of Tennessee Knoxville.
24. Haridas, J., Ture, R.S., Nayanpally, A.K. (2022). Organizational career management and turnover intentions: Mediating role of trust in management. *European Journal of Training and Development*, Vol. 46(1/2), pp. 257-275, doi: 10.1108/EJTD-09-2020-0136
25. Indrayani, I., Nurhatisyah, N., Damsar, D., Wibisono, C. (2024). How does millennial employee job satisfaction affect performance? *Higher Education, Skills and Work-Based Learning*, Vol. 14(1), pp. 22-40, doi: 10.1108/HESWBL-01-2023-0004
26. Kidron, A., Vinarski Peretz, H. (2025). The influence of organizational trust and social exchange on organizational citizenship behavior: The mediating role of workplace spirituality. *Journal of Organizational Effectiveness: People and Performance*. Retrieved from: <https://doi.org/10.1108/JOEPP-08-2024-0410>
27. Kmiecik, R. (2021). Trust, knowledge sharing, and innovative work behavior: Empirical evidence from Poland. *European Journal of Innovation Management*, Vol. 24(5), pp. 1832-1859, doi:10.1108/EJIM-04-2020-0134

28. Kruk, A. (2024). *Rola lidera w kształtowaniu kultury organizacyjnej*. Retrieved from: <https://leanpassion.pl/blog/rola-lidera-w-ksztaltowaniu-kultury-organizacyjnej/>, 01.03.2025.
29. Lewicka, D. (2013). Wpływ zaufania wertykalnego na zaangażowanie pracowników. *Acta Universitatis Lodzensis*, pp. 179-186.
30. Lewicka, D., Krot, K., Petryshyn, L., Rehmann, H.U. (2023). Relationship between institutional trust, intra-organizational collaboration, and commitment to strategic business development. *Organization and Management Series, No. 186*, pp. 317-328, doi: 10.29119/1641-3466.2023.186.23
31. Maicki, M. (2016). Zarządzanie organizacją przez zaufanie. In: E. Gołębiowska (Ed.), *Przedsiębiorczość i zarządzanie* (p. 24). Społeczna Akademia Nauk.
32. Okręglika, M., Lemańska-Majdzik, A. (2024). Proactivity, organizational trust, and motivation in development potential of franchising companies. *Organization and Management Series, No. 191*, pp. 415-426, doi: 10.29119/1641-3466.2024.191.27
33. Özdemir, M., Abaslı, K., Mavi, D., Tuti, G., Karataş, E. (2024). School and teacher level predictors of organizational loyalty in an era of school reform. *Asia Pacific Education Review, Vol. 25(1)*, pp. 57-72, doi: 10.1007/s12564-023-09874-w
34. Ozyilmaz, A., Erdogan, B., Karaeminogullari, A. (2018). Trust in organization as a moderator of the relationship between self-efficacy and workplace outcomes: a social cognitive theory-based examination. *Journal of Occupational and Organizational Psychology, Vol. 91(1)*, pp. 181-204, doi:10.1111/joop.12189
35. Paliszewicz, J. (2013). *Zaufanie w zarządzaniu*. Warsaw: PWN.
36. Robinson, D., Perryman, S., Hayday, S. (2004). *The drivers of employee engagement*. Brighton: Institute for Employment Studies, pp. 1-73.
37. Rudzewicz, A. (2016). Zaufanie wewnętrzne i zewnętrzne w przedsiębiorstwie. *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach, No. 255*, pp. 261-269.
38. Rzepka, A., Bańkowski, P. (2024). Cechy lidera/przywódcy inkluzywnego w oparciu o badania własne. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, Vol. 68(1)*, pp. 110-120, doi: 10.15611/pn.2024.1.1
39. Schwabe, M. (2023). Zaufanie jako niezbędny element funkcjonowania organizacji. *Studia i Prace Kolegium Zarządzania i Finansów*, pp. 113-131, doi: 10.33119/SIP.2023.189.7
40. Stelmaszczyk, M. (2010). Zarządzanie istotnym elementem w zarządzaniu przedsiębiorstwem. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, No. 102*, pp. 260-265.
41. Tomaszuk, A., Wasiłuk, A. (2023). Pokolenie Z – perspektywa zaufania do przełożonych i współpracowników. *Przegląd Organizacji, Vol. 2(997)*, pp. 8393, doi: 10.33141/po.2023.02.09

42. Turaga, R. (2013). Building trust in teams: A leader's role. *The IUP Journal of Soft Skills*, Vol. 7(2), pp. 13-31.
43. Wnuk, M. (2020). Skala zaufania do przełożonego jako narzędzie do mierzenia zaufania do menadżerów. *Humaniora. Czasopismo Internetowe*, Vol. 31(3), pp. 97-115, doi: 10.14746/h.2020.3.7
44. Yang, J., Mossholder, K. (2010). Examining the effects of trust in leaders: a bases-and-foci approach. *Leadership Quarterly*, Vol. 21(1), pp. 50-63, doi: <https://doi.org/10.1016/j.leaqua.2009.10.004>
45. Zak, P.J. (2017). The neuroscience of trust: management behaviors that foster employee engagement. *Harvard Business Review*, Vol. 95(1), pp. 84-90.

THE PROCESS OF ENTERPRISE INTERNATIONALIZATION – AN ANALYSIS OF COMPANIES OPERATING IN HIGHLY SPECIALIZED NICHE INDUSTRIAL SEGMENTS

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Purpose: The aim of this paper is to determine the nature of the internationalization process and to identify the distinguishing features of small and medium-sized enterprises operating in highly specialized niche industrial segments.

Design/methodology/approach: The research process was designed as a multi-stage study. In the first stage, a comprehensive review of the literature was conducted. The next stage consisted of qualitative empirical research based on the case study method. Within its framework, in-depth interviews with company managers were conducted, and the collected material was analyzed using the content analysis approach proposed by P. Mayring. Two techniques were employed: summarizing and explicative analysis. The net result of this stage consisted of compiling case reports and presenting the conclusions.

Findings: The findings of the study allowed for the identification of the features distinguishing entities operating in highly specialized niche industrial segments, as well as the specific nature of the internationalization process in the analyzed small and medium-sized enterprises, the forms and markets of their foreign expansion, and the driving force behind their engagement in international activities.

Research limitations/implications: The presented results provide an introduction and contribution to further, more in-depth analyses, which appear essential for a more comprehensive understanding of the internationalization processes of small and medium-sized enterprises operating in highly specialized niche industrial segments. This paper lays the groundwork for future research that may employ both qualitative and quantitative methods.

Originality/value: The enterprises under study offer comprehensive and individually customized solutions addressing their clients' specific needs. They provide purchasers with specialized offers designed to meet the particular challenges faced by industrial customers. A key element of their strategic approach involves implementing innovation, developing new technological solutions, and expanding engineering services in close collaboration with clients. They are innovators and leaders within their respective highly specialized niche industrial segments, successfully pursuing internationalization across numerous European and global markets.

Keywords: internationalization, small and medium-sized enterprises, case study.

Category of the paper: Research paper.

1. Introduction

The history of the internationalization of economic activity can be traced back to the antiquity, when the main cross-border occupation was trade between countries and empires, such as Greece, Egypt or Rome. Last century, especially the post-war period, witnessed development of international commerce. It was the time when numerous entities and concerns undertook international activities, which led to increased economic exchange between states.

The dynamic development of the internationalization of European companies was significantly shaped by reinforcing economic integration within the European Union, especially when the single EU market was introduced in 1993. Key factors that played a crucial role in the process were the deregulation and liberalization of many sectors, the elimination of administrative barriers and the arrangements of conditions for the free movement of goods, services, capital and people. The implementation of the single internal market principles was particularly crucial, as it facilitated the access to foreign markets for smaller entities without the necessity to invest capital or managerial resources in these markets. The companies were able to conduct foreign sales in a manner similar to domestic sales, taking advantage of unified regulations and simplified trade procedures. At that time, many small and medium-sized enterprises, niche market providers as well as firms conducting business in narrowly specialized sectors of the economy engaged in internationalization.

For the above reasons, the internationalization of small and medium-sized enterprises operating in specialized areas of the economy, conducting business in niche industrial segments, and offering innovative products or solutions for highly specialized market segments is an especially captivating scope of research.

The aim of this paper is to define the specific nature of the internationalization process and to identify the features that determine small and medium-sized enterprises operating in highly specialized niche segments of the industry.

The research process has been designed in stages. The first part comprised a literature review. The next stage consisted of qualitative empirical research based on the case study method. In-depth interviews with company managers were also conducted as part of this stage. The collected material was then subjected to content analysis according to the approach proposed by P. Mayring. The net result was the compilation of case reports and the presentation of conclusions drawn from the conducted studies of the enterprises.

2. Theoretical background

In recent years, an intensification of internationalization processes undertaken by enterprises has been observed. These activities are no longer the exclusive domain of large corporations, but are increasingly undertaken by small and medium-sized enterprises as well. It should be noted that small and medium-sized enterprises, especially those having an innovative nature and emerging from countries with relatively small domestic markets, may face the necessity of engaging into internationalization at an early stage of their development. (Petraite et al., 2022). Companies operating in specialized niche industrial segments, where competitiveness is based on distinctive competencies and innovative solutions, demonstrate remarkable foreign market activity. According to the OECD a broader concept of internationalization incorporating entities involved in the social and solidarity economy “can be defined as a set of processes involving multilateral flows of goods, services, financial resources and “intangible assets” (information, skills, business models, knowledge and more) within and between organisations and across countries. More importantly, this set of processes can be both outward-oriented (selling or investing abroad) or inward (such as acquiring know-how or other intangibles assets from international sources)” (OECD, 2023, p. 17). Firms’ internationalization process, “perceived as the temporal and spatial evolution of firms’ distribution of resources and governance structures across national borders” (Gammeltoft, Cuervo-Cazurra, 2021, p. 4).

In the subject literature, many scholars conceptualize the internationalization of enterprises in two fundamental approaches: the static and the dynamic, the latter also referred to as the process-oriented perspective (Kutschker, Schmid, 2011; Richta, 2012; Perlitz, 2004).

The first approach—static internationalization—refers to a situation in which a company establishes foreign connections or undertakes activities of an international nature without the necessity of continuing them in the future. Such an activity may take a form of one-time or occasional venture, often unrelated to any long-term internationalization strategy, e.g. a single export transaction or an ad hoc action driven by arising market opportunities, undertaken without the intention of building a sustained presence in foreign markets.

The second approach—dynamic internationalization—assumes that internationalization is continuous, sequential, and long-term in nature. Within this framework, foreign activities develop gradually, progressing from simpler forms (e.g. exporting) to more advanced ones (e.g. foreign direct investment, establishment of subsidiaries, or manufacturing abroad). A key element of this approach is the temporal context — the enterprise moves through successive phases of international development as it gains experience, knowledge, and competencies. Internationalization understood as a process is accompanied by increasing levels of engagement in foreign markets and the adoption of progressively more complex forms of international activity. Within the process-oriented approach, specific models of

internationalization can be distinguished, such as the stages model of the Uppsala School (Johanson, Wiedersheim-Paul, 1975; Johanson, Vahlne, 1977) which conceptualizes a defined sequence of actions based on the growth of organizational experience, or innovative internationalization models (Bilkey, Tesar, 1977; Lim et al., 1991). According to this approach, internationalization is a dynamic phenomenon, evolving over time and dependent on a range of internal and external factors.

In the process of enterprise internationalization, key strategic decisions include the choice of the form of internationalization, the appropriate timing of foreign expansion, and the sequence of entering foreign markets.

The internationalization of a company involves a set of crucial strategic decisions that significantly influence its presence and development in international markets. The decision regarding the mode of entry into foreign markets constitutes one of the fundamental parts of an enterprise's internationalization strategy. It affects not only the scope and form of the firm's presence beyond home country's borders, but also the level of capital involvement and the risk associated with international operations. The literature identifies broad range of possible forms of business activity in foreign markets, encompassing both entry modes with relatively low levels of commitment and risk, and more advanced forms characterized by higher levels of risk. The most frequently quoted modes include: direct and indirect exports, licensing agreements, franchising, management contracts, subcontracting, cooperative forms such as joint ventures and strategic alliances, as well as foreign direct investment in the form of foreign subsidiaries, representative offices, or minority shareholdings in foreign entities. (Jeannet, Hennessey, 2004; Bradley, 2005; Duliniec, 2009; Berndt, Altobelli, Sander, 2023) The choice of a specific form depends on a variety of factors, such as industry characteristics, the level of specialization, resource availability, degree of risk, as well as the company's experience and strategic objectives. In case of firms operating in highly specialized niche industrial segments, the most prevailing forms of internationalization are based primarily on exporting and direct foreign investment. In this context, foreign representative offices play a particularly important role, as they allow companies to enter international markets with relatively low level of capital and managerial commitment abroad. Another commonly used form of direct foreign investment is the establishment of wholly-owned subsidiaries, that is, dependent entities created by the parent company outside its home country. Such investments represent an example of the so-called internal, organic international growth (greenfield investment), which involves building a new organizational structure from the ground up in a foreign market. Greenfield investments enable a company to maintain full control over its operations, tailor its strategy to host country conditions, and preserve organizational culture consistency across borders. However, the most common form of entry into foreign markets remains exporting, which may take two main forms: indirect and direct. Indirect exporting involves selling products through a domestic intermediary, meaning the company does not establish direct relationships with foreign buyers, does not commit resources abroad, and faces relatively low international business risk.

This form of exporting is often chosen by small and medium-sized enterprises or during the early stages of internationalization, as it minimizes the costs and risks related to market entry and does not require capital or personnel involvement abroad. The form is mainly employed in less strategically significant markets. Direct exporting, on the other hand, involves delivering products directly to foreign customers or intermediaries responsible for further distribution, which requires greater resource commitment and the establishment of business relationships. Thus, the difference between these two forms of exporting lies not only in the level of risk and control over foreign market operations, but also in the degree of activity and engagement of the company in international markets.

The existing literature and management practice identify various typologies of temporal approaches (timing) to international expansion. The most common classification distinguishes three main strategy models: successive, simultaneous, and mixed (Swoboda, 2021; Hollensen, 2007; Backhaus, Voeth, 2010).

The successive strategy, also referred to as the cascade or waterfall model, involves entering consecutive foreign markets gradually and in stages. A company first initiates activities in one foreign market, and only after gaining experience and consolidating its position there does it decide to expand into another market. This approach minimizes risk and allows the company to adapt to the conditions of individual foreign markets better. It may, however, result in a slower pace of international expansion.

In contrast, the simultaneous strategy, also known as the sprinkler model, relies on entering multiple foreign markets at the same time. The company undertakes internationalization in several countries simultaneously, aiming to rapidly gain market share across individual national markets. This model is characteristic of large enterprises possessing adequate resources. It enables dynamic expansion, but is also associated with higher risk.

The third option is the mixed strategy, which combines elements of both successive and simultaneous models. As part of this strategy, a business entity may initially enter a few select markets concurrently (e.g., the most significant ones from the company's perspective), and then gradually develop its foreign presence in subsequent stages. The mixed model enables flexible adaptation to changing conditions in foreign markets.

The choice of the appropriate temporal approach to internationalization should be preceded by a comprehensive analysis of the company's potential, resources, strategic objectives, as well as conditions in target markets. Proper planning of the sequence and pace of foreign market expansion is crucial for the effectiveness of the internationalization process.

Internationalization is a complex and dynamic process that necessitates continuous analysis of the external environment. Therefore, decisions related to the form and timing of expansion are of paramount importance to succeed in foreign markets. It should be noted that expanding sales markets and exporting business models increase and entail the labor input needed to understand, implement and adapt to the specific conditions of foreign markets (Kumar, 2018, p. 7). A misexecuted internationalization process may lead to severe consequences for

enterprises, including the need to withdraw from previously captured foreign markets. This process is referred to as de-internationalization, which means exiting from a foreign market previously targeted for expansion (Tang, Zhu, Cai, Han, 2021; Trąpczynski, 2016). Causes for this state of affairs may include poor decisions regarding the form of expansion, inappropriate timing of entry, or insufficient foreign market intelligence. This process not only involves financial costs, but may also undermine a company's reputation and its prospective expansion opportunities in other countries.

Technological innovations play a crucial role in shaping competitive capabilities of enterprises, constituting one of the pillars of their internationalization. These technological innovations enable enterprises to increase efficiency and productivity, as well as implement solutions that support the goals of corporate social responsibility. In this context, such responsibility can be broadly understood as a sustainable interdisciplinary integration of technical, ecological, social, and economic progress (Zweck, 2007). The ability to create and adapt new technological solutions empowers companies to compete more effectively in foreign markets, particularly in niche segments where competitive advantage is built on unique competencies and innovative solutions.

Technological progress and innovation may be understood as a complex process encompassing exploration, discovery, experimentation, development, imitation, and adoption of new products, manufacturing processes, business models, or organizational structures (Dosi, 1988). The above-mentioned factors are especially important in the context of internationalization, as they allow companies to compete successfully beyond domestic borders. Moreover, implemented innovations often enable entities to replace existing solutions with more efficient, less resource-intensive, and more environmentally friendly alternatives, enhancing the firm's reputation and competitive position. Enterprises that actively invest in technological development possess a lasting source of competitive advantage, including foreign markets, by offering innovative products or inventive technological solutions.

The internationalization of small and medium-sized enterprises operating in niche highly specialized industrial segments plays a critical role in the context of innovativeness. These entities operate in small markets, often with highly specialized, and narrow product portfolio, which requires extensive industry expertise, as well as a premium, carefully customized offer. A peculiar group of enterprises comprise the so-called hidden champions—relatively small or medium-sized entities with a strong position in a narrow industrial segment, holding leading positions in their lines of business, exporting products to a wide range of countries, and generating a substantial proportion of their revenues abroad. Hidden champions implement niche strategies focused on innovation and internationalization, which form the foundation of their competitive advantage and position them as leaders in foreign markets (Zastempowski, 2011; Witt et al., 2024). Due to the limited domestic demand, these enterprises face the necessity of acquiring clients abroad at the nascent stage of their development. Internationalization is not an optional growth trajectory for them, but rather a strategic

imperative delivering increased revenues, optimal use of production capacities, and improved profitability of the business. It should be noted that the considerable share of internationalization of the entities called hidden champions is difficult to reconcile with study findings and literature on internationalization of small and medium-sized enterprises due to the fact that a significant part of their revenue is generated in foreign markets (Audretsch et al., 2018). Enterprises, especially small and medium-sized ones, operating in niche specialized industrial segments (within the B2B model) sometimes expand their international presence without establishing extortionate foreign structures, taking advantage of networks of trading partners, technical representatives, or other foreign distributors. These companies present their products at major international fairs, using them as important channels for establishing contacts with foreign partners and acquiring sales contracts abroad. Enterprises operating in highly specialized niche industrial segments are playing an increasingly significant role in global internationalization processes.

3. Research method

The conducted exploratory study employed a qualitative approach using the case study method. Both secondary and primary data were analyzed, the latter obtained through in-depth interviews with representatives of selected enterprises. The empirical material was processed using qualitative content analysis, which allowed for the identification of key categories and behavioral patterns. As a recognized research method in management sciences, the case study approach made it possible to capture the specific nature of internationalization processes profoundly, particularly in the context of small and medium-sized enterprises operating in highly specialized niche industrial segments. The study contributed to a better understanding of the mechanisms determining innovation processes within enterprises, as well as the dynamics of their internationalization processes.

A case study is an empirical research method aimed at a detailed examination of a contemporary phenomenon set in its real-life context—especially in situations where the boundaries between the phenomenon and its environment are not clearly defined. The approach relies on multiple data sources and types of evidence, while data collection and analysis are guided by predefined theoretical assumptions (Yin, 2015). The implementation process of the case study comprises several key stages, beginning with the development of the research concept and the formulation of specific research questions. Subsequently, a detailed research plan is prepared, including appropriate data collection procedures and tools. The next stage involves fieldwork, during which empirical material is systematically collected. The gathered data are then subjected to in-depth analysis and evaluation, leading to the final elaboration and presentation of results in the form of a case description.

The first stage of the study focuses on designing the case study, which includes defining the purpose, scope, and subject of analysis, as well as formulating research questions. This stage forms the groundwork of the entire research process, setting the direction for subsequent exploratory activities. In the present study, the objective was to determine the specific characteristics of the internationalization process and to identify distinguishing features of small and medium-sized enterprises operating in highly specialized niche industrial segments.

Due to the adoption of the case study method, a set of research questions was formulated to identify the key aspects of the analyzed enterprises:

- What features distinguish entities operating in highly specialized niche industrial segments?
- How did the internationalization process of the analyzed enterprises progress?
- In what forms and in which foreign markets do these entities conduct their international activities?
- What factors propelled the enterprises to undertake internationalization?

In the subsequent stage, a detailed research design was developed, including the selection of appropriate data collection instruments and analytical procedures to obtain answers to the research questions. A multiple-case study strategy was adopted, with cases selected purposefully based on criteria consistent with the research assumptions. In the present study, the selection of enterprises for the case studies was undertaken purposively, taking into account criteria designed to address the formulated research questions. The key criteria included conducting international business activities and operating in highly specialized niche industrial segments, as well as ensuring diversity among the surveyed entities in terms of industry, company size, and legal and organizational form. A supplementary criterion constituted the possibility of conducting interviews with senior executives, such as board presidents or sales and export directors. Conclusively, two enterprises were selected: Evers GmbH and Masterflex SE. The empirical material was derived from both primary data, collected through in-depth interviews conducted in selected enterprises, and a variety of secondary sources (e.g., reports, websites, industry articles, and publications). In order to analyze the qualitative data, the content analysis method was applied, following the approach proposed by P. Mayring (2022a, 2022b, 2023), which allows for the systematic structuring, reduction, and interpretation of respondents' statements (Komor, Grzyb, 2023).

The next stage involved preparing data collection tools and conducting field research. An interview scenario was designed at this stage, which was followed by a pilot study aimed at identifying potential ambiguities in the research instrument, after which enhancements were introduced. Empirical data were collected from both primary and secondary sources. During fieldwork, semi-structured expert interviews were conducted with first-level management representatives. The interviews were carried out personally by the study's author at company headquarters in Germany, recorded digitally, and supplemented with notes. Then, full transcriptions of the recordings were produced using the "F4" software.

In the data analysis and interpretation stage, the empirical material was systematically processed to provide answers to the previously formulated research questions. The interview data were analyzed using qualitative content analysis, in accordance with the methodological guidelines of P. Mayring (2022b, 2023), which enabled the interpretation of textual data within the research framework. In order to streamline the efficiency of the process of data analysis, the MAXQDA software (version 2020) was utilized, facilitating effective coding, reduction, and organization of the collected empirical material. Two complementary techniques were employed following Mayring's (2022b, 2023) approach: summarizing and explicative analysis (Komor, Grzyb, 2023). The summarizing analysis aimed to reduce the original research material by developing inductive analytical categories that served as the basis for further interpretation. In turn, the explicative analysis expanded and refined the meaning of content extracts, requiring broader interpretive context. Additional contextual information and references were considered to achieve a more comprehensive understanding of the processes under study.

The final stage of the study involved the preparation of a case study report. This report contains a synthesized presentation of the analytical results and provides a holistic view of the phenomena accompanying the internationalization processes of the analyzed enterprises.

3. Case studies of small and medium-sized enterprises

The following case studies are based on the results of an analysis of primary data obtained from in-depth interviews conducted between 2023 and 2024 with individuals holding executive positions: the President (first entity), the European Sales Director, the European Export Director, as well as the Export Manager (three respondents from the second entity). The analysis also included secondary data obtained from other available sources. Such elaboration of case studies enables a comprehensive insight into the internationalization processes undertaken by entities operating within highly specialized niche industrial segments.

3.1. Case study of Evers GmbH

Evers GmbH was established in the 1930s by Rudolf Evers as a wholesale enterprise designed to meet the supply needs of local industry. Over the time, the company's scope of activities underwent a transformation. Currently, Evers is engaged in market activities focused on innovational solutions in four areas: lifting, securing, transportation, and packaging. Evers GmbH is a relatively small company. In 2024 it employed 80 people and generated revenues of approximately EUR 25 million.

In the 1970s and 1980s, the company began to offer a new product portfolio, including securing pallet transportation by means of wrappers, carton sealing machines, and strapping equipment. It was the time when Evers started presenting its products at fairs, including the largest packaging fair in the world - “Interpack” in Düsseldorf. From the 1990s, the company continued to expand its product range, becoming a significant player in the German market in four business areas. In the following years, Evers, together with manufacturers such as SpanSet, Rieger & Dietz Kettenfabrik, and other trading companies, founded SIP GbR (a cooperative service venture), creating a unique collaboration network between leading manufacturers and industrial trade.

Currently, Evers provides solutions for industry in the areas of lifting, securing, transportation, and packaging. In the “lifting” sector, it offers solutions and products such as slings, load-lifting equipment, lifting devices, crane technology, and hydraulics. In the “securing” division, the company provides comprehensive solutions for load safety and fall protection, as well as special products. In the scope of “transportation” the entity supplies transport systems, horizontal transport equipment, and pallet-related lifting systems. In the area of packaging, the company offers eco-friendly packagings, tables and weighing technology, pallet securing equipment, transportation packaging, and cushioning materials. As one company representative points out in this context, *We are not a manufacturer of goods, but we rather offer innovative solutions for industrial companies that come to us with specific problems. Then, our team works on appropriate solutions – we act as an industrial advisor.* The company purchases suitable products, make adjustments, and delivers ready solutions for industrial enterprises. In order to serve its clients fully and attract new customers, the company also organizes seminars on topics such as workplace safety, lifting and transporting loads, and courses for crane and forklift operators. The company also offers services for its clients, including maintenance, diagnostics, and technical inspections in accordance with occupational safety and health regulations.

Evers GmbH places great importance on innovation, and therefore the company has established a strategy and innovation management department to dynamically adapt internal and external processes of the company to changing client needs. It also develops custom-designed solutions for offshore applications, the transport of oversize machines, and other forms of transportation requiring moving heavy loads. The company has developed and patented a lifting device, which allows safe and easy adjustment of length under load. Evers’ innovative solutions were recognized in the 27th edition of the TOP 100 innovation competition for midsize companies, when the company won an award for its exceptional innovativeness and outstanding innovation results. It also won the “Tackern” marketing award for overall marketing communication.

A distinguishing feature of Evers GmbH is that it is not a manufacturer of goods, but it focuses on consulting and solving client problems in term of lifting, securing, transportation, and packaging, offering individually customized comprehensive solutions for

industrial customers. The entity uses products already existing in the market, refines them to a certain extent and by the means of innovative approach it prepares a comprehensive individual offer in order to solve problems of its clients. As one respondent points out, *projects are carefully adjusted to individual specifications in order to meet customer's needs and optimal solutions – we mainly sell comprehensive solutions.*

Initially, the company expanded its sales activities in Germany, then in Europe, and later to other markets. Internationalization began at the beginning of the current century. At that time, the company was partaking in international fairs, gaining experience in projects collaborating with large corporations, and conducting various marketing activities. At present, as a well-known supplier, the company receives most inquiries from clients via online channels. The main driving force behind foreign activity was the expansion of its existing customers abroad, which gave rise to a demand for Evers GmbH's innovative solutions. Currently, the company markets its comprehensive range of products to more than 50 countries worldwide, where it holds a well-established position as an international solutions provider. It has no foreign branches or representative offices. It is reasonable to assume that the company operates in the form of exporting. In the context of sales to the USA, a respondent states "We hold video conferences with interested companies and offer solutions that are exported to this market, or our employees travel to the USA to implement our solutions onsite, but all activities are managed from the company headquarters in Oberhausen. The main outlet markets for the company are the USA and European countries. Some international projects continue for years – for instance, one project in the USA was first successfully implemented in one branch and then it was gradually extended to other branches over the following years. It should be noted that, offer inquiries are not always forwarded from foreign branches of industrial corporations, but purchases for individual foreign markets are often made by headquarters. At Evers GmbH, all sales representatives have excellent fluency in English, which allows them to coordinate and support projects in foreign markets. Moreover, employees specialize in individual product groups and they are able to provide professional and customized consulting. As one representative observes in this context: *This is precisely our internationalization strategy.*

Although Evers GmbH is recognized as a small enterprise, thanks to its innovativeness and provision of individual, comprehensive industrial solutions, it operates globally and sells its products to many countries worldwide.

3.2. Case study of Masterflex SE

Masterflex SE is a publicly traded company dealing in plastics processing and based in Gelsenkirchen. The enterprise was founded in 1987 in Herten as Masterflex Kunststofftechnik GmbH. In 1994, the entity was relocated to Gelsenkirchen, where it remains to this day.

The company specializes in the production of high-quality flexible hoses and connection systems used in numerous sectors of the industry. Masterflex operates in more than 250 specialized industry segments, such as aviation and space industry, medical technology, machinery and equipment manufacturing, chemical industry, food industry and pharmaceuticals, transportation, robotics, automotive industry, and wood, metal, and paper processing industries. The Masterflex Group mainly produces hoses made of polyurethane-based products, e.g. extraction hoses and hoses for transporting materials, dust and gases. The Masterflex Group markets its products under five brands: Masterflex, Matzen & Timm, Novoplast Schlauchtechnik, Fleima-Plastic, and Masterduct.

The Masterflex Group operates globally, primarily in Europe, South and North America, as well as in Asia and Oceania. It employs approximately 660 staff members. In 2023 the revenues amounted to 101 million euros and an operating profit (EBIT) reached 12.4 million euros. The main manufacturing plants of the Masterflex Group comprising a portfolio of six corporate brands and 14 operational subsidiaries are located in Gelsenkirchen, Düsseldorf, Halberstadt, Norderstedt, and Houston (USA). The company is a global market and innovation leader in terms of technically advanced hoses and connection systems.

Since its establishment, the company has followed a development strategy based on two key areas:

- internationalization –expansion into foreign markets,
- implementation of technological product innovations – continuous innovations in terms of new, technologically advanced hoses and connection systems.

Foreign expansion became a priority already in the nascent stages of the company's activity.

Just four years after its establishment, Masterflex founded a subsidiary in Lyon, France. In the same year, it began its expansion into the British market by creating a subsidiary - Masterflex Technical Hoses Ltd. Three years later, a branch was opened in the United States, which also manufactures high-tech hose systems for the American market. In the following years, another branch was established in Sweden, serving as a sales representative office for the Scandinavian markets. In 2011, through a subsidiary, Masterflex launched manufacturing and its own distribution network in the Czech Republic and Slovakia. As a respondent accounts in this aspect: *the subsidiary in the Czech Republic is now also responsible for product sales in Central and Eastern Europe, including the Polish market.* In 2010 Brazil became another direction of expansion, where a distribution company was established. The following year, the Asian management company Masterflex Asia Pte. Ltd. was founded in Singapore, along with a branch near Shanghai, China. The main driving force behind internationalization was the existence of a global market for industrial hoses, the opportunity to sell comprehensive solutions abroad, and the development strategy adopted by the company.

The company markets its products in all European countries, where key markets include France, Spain, Italy, the Scandinavian countries, and Central and Eastern Europe. Over 50% of Masterflex's revenue is generated in foreign markets. It should be noted, however, that as one

respondent points out, the actual level of export may be significantly higher than indicated by available data: *our German customers purchase Masterflex products and then transport them to their production facilities outside Germany. The scale of this indirect export cannot be explicitly estimated.* The company cooperates in many countries with technical trade partners, such as specialized wholesale companies or independent representatives of the hose industry operating on their own behalf. Wholesale sales account for approximately 50% of revenues, the remaining revenues are earned from individual custom solutions for end customers. As a respondent accounts: *Apart from our own foreign branches, we conduct sales mainly through direct business contacts with large industrial clients, as well as through our intermediaries, i.e., foreign business partners.* The distribution model based on intermediaries does not always bring the expected results in foreign markets, because the price margins imposed by brokers may negatively impact the price competitiveness of Masterflex products. The company adjusts its expansion strategy to the specific nature of individual domestic markets, taking into account the diversity of the market environment, including existing cultural conditions. As one of the respondents notices in the above context: *We have a general corporate strategy, but in certain foreign markets, we adapt our strategy to the local realities and how things work in a given country, because a strategy that is effective in Germany will never fully function in France or Poland.*

Wholesale sales account for approximately 50% of the company's revenue. The remaining revenue comes from provision of individual, comprehensive solutions to end customers in the industrial sector. The Masterflex Group offers consulting services and designs specific custom solutions as part of the so-called Engineering Services. These include additional engineering services, the fulfillment of comprehensive technical orders, and the delivery of complete systems based on hose technology, which enables building competitive advantages and generating additional sources of income. As a respondent observes: *We are strongly oriented towards consulting to recommend optimal hoses for our clients. We are an innovative company, dedicated to solving our customers' problems by offering them specific, individualized solutions.*

Since its inception, the enterprise has followed the development strategy based on innovativeness and implementation of technologically advanced solutions in the area of hoses and connection systems. Just five years after its establishment, Masterflex developed a world-class novelty, that is a plastic compound formula that enabled the production of flame-retardant polyurethane (PU) hoses as an alternative to traditional PVC hoses for the first time. In 1997, the company developed an innovative method of lining steel pipes with highly abrasion-resistant polyurethane (PU). In subsequent years, the research and development department systematically introduced numerous innovations in the area of technologically advanced hoses and connection systems to the market. The most important innovative products are, for example: the electrically heated hose "Templine", the spiral hose Master-PUR Trivolution,

flame-retardant hoses used, among others, in welding robots, and the Master-PUR DualFlow connection designed for the food industry.

The enterprise has been repeatedly recognized for its innovative activities and development of new technologies. The Masterflex Group has been named several times as one of the most innovative medium-sized companies in Germany in the TOP100 ranking, which acknowledges entities for effective innovation management and innovative achievements. Furthermore, the "Capital" magazine, together with the research institute Statista, have honored Masterflex as one of the most innovative companies in Germany. Particularly noteworthy is the fact that Masterflex has been repeatedly included in the "world market leader" index in German-speaking countries, developed by the University of St. Gallen in Switzerland, published by WirtschaftsWoche magazine. This distinction is only awarded to companies characterized by leading technologies and the highest product quality. In order to be ranked among the world market leaders, companies must meet numerous criteria, including holding the first or second position in terms of revenue in at least one significant global market segment, the annual revenue (at least 50 million euros) must derive at least 50% from foreign markets on at least three continents.

The distinguishing feature of Masterflex is not only the production and sale of innovative products, but also counseling services and solving customers' problems related to flexible hoses and connection systems through the design of custom-made systems under the so-called Engineering Services, as well as the provision of specialized, individual, and comprehensive solutions for the industrial sector. What sets Masterflex apart from other enterprises is the fact that, despite being a medium-sized entity, it is an innovator in its industrial segment and successfully implements an internationalization strategy across numerous global markets.

Based on its innovative achievements to date, the development of hi-tech products and new hose technologies, and the awards received for their contribution to the said areas, the Masterflex Group considers itself a global innovator and market leader in hose and transmission systems and defines itself as one of the Hidden Champions.

Summary

The conducted exploratory study, serving as a preliminary study, allowed the formulation of a characterization of the internationalization process and to identify the key distinguishing features of small and medium-sized enterprises operating in highly specialized niche industrial segments. Thereby, the aim of the research was fulfilled. The descriptions of individual company case studies presented in the previous section address the research questions formulated in the paper. The study revealed several key phenomena and mechanisms accompanying the internationalization process of the companies under study, as well as the

distinguishing features of companies operating in highly specialized niche segments of industry, which are presented below. In spite of the fact that the analyzed enterprises belong to the group of small and medium-sized entities, they are engaged in internationalization in numerous countries worldwide, and foreign operations are an essential part of their development. The enterprises undertake internationalization mainly in the markets of EU countries and selected major global markets, including the United States and China. In the context of the expansion, they apply both exporting and foreign direct investment schemes in foreign markets. Due to the specific nature of their activities in highly specialized niche industrial segments, exporting typically take the form of direct sales to the end customer (a business) or through foreign partners, mainly technical wholesalers. In terms of foreign direct investment, these include foreign branches serving as sales representative offices and/or manufacturing plants. The driving force behind the internationalization of the said companies is based on the adoption of development strategies, the existence of a highly specialized global industrial market, and the international expansion of their existing clients.

Significant differences were identified between the analyzed firms with regard to the forms of foreign expansion pursued, resulting from their size, legal and organizational form, available resources, and stage of internationalization development. The first enterprise, a smaller entity operating as a limited liability company, possesses relatively modest resources and has been engaged in international activity for approximately 20 years. Its foreign activities are mainly limited to export-based forms, occasionally carried out as comprehensive solutions implemented directly at clients' sites by its own employees. However, the majority of international activities are conducted from the headquarters, using modern communication tools. The second of the analyzed enterprises operates on a substantially larger scale, being a European public limited company, endowed with substantial resources and pursuing international activities nearly since its establishment. It is currently at an advanced stage of internationalization development, generating over 50% of its revenues in foreign markets. This company employs diversified forms of expansion, such as exports, foreign capital subsidiaries (both production and commercial), as well as sales through trading partners and foreign representatives.

The common distinguishing feature of the analyzed enterprises is their strong orientation toward meeting the needs of industrial customers. These entities provide comprehensive and individually customized solutions to their clients' problems, combining consulting, designing and technical competencies. They offer, manufacture, and deliver specialized, comprehensive solutions as part of a personalized offer in response to specific challenges faced by industrial-sector clients. The active implementation of innovations, new technological solutions, and the development of engineering services in close collaboration with customers is an essential element of their strategy. These entities are innovators and leaders in their highly specialized niche industrial segments, successfully operating in numerous foreign markets.

Limitations and future research

The findings of the study presented herein have certain limitations. The article serves as a starting point for further, more in-depth qualitative and/or quantitative analyses, which seem to be necessary for a more comprehensive understanding of the nature of small and medium-sized enterprises operating in highly specialized niche industrial segments. The presented research was based on an exploratory approach aimed at providing preliminary study and contributing to further analyses that would enable the identification of the internationalization process and the characteristic features of these entities. Future qualitative research may expand the analysis of certain behaviors of enterprises in the internationalization process, basing on the initial observations and research questions formulated in this study. At the same time, the preliminary results obtained in the paper may prepare a groundwork for formulating and developing research hypotheses or provide valuable information for prospective quantitative studies. It would be crucial to obtain more detailed insights into the internationalization of entities referred to as hidden champions, particularly those operating in specialized niche industrial segments that pursue global internationalization despite their limited recognizability.

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References

1. Audretsch, D.B., Lehmann, E.E., Schenkenhofer, J. (2018). Internationalization strategies of hidden champions: lessons from Germany. *Multinational Business Review*, Vol. 26, Iss. 1, pp. 2-24, doi: DOI: 10.1108/MBR-01-2018-0006
2. Backhaus, K., Voeth, M. (2010). *Internationales Marketing*. Stuttgart: Schaeffer-Poeschel.
3. Berndt, R., Altobelli, C.F., Sander, M. (2023). *Internationales Marketing-Management*, Berlin, Heidelberg, New York: Springer.
4. Bilkey, W.J., Tesar, G. (1977). The Export Behaviour of Smaller-Sized Wisconsin Manufacturing Firms. *Journal of International Business Studies*, Vol. 8, Iss. 1, pp. 93-98, doi: 10.1057/palgrave.jibs.8490783

5. Bradley, F. (2005). *International marketing strategy*. Harlow: Financial Times/Prentice Hall.
6. Dosi, G. (1988). The nature of the innovative process. In: G. Dosi, C. Freeman, R. Nelson, G. Silverberg, L. Soete (Eds.), *Technical Change and Economic Theory* (pp. 221-237). IFIAS research series; 6. London: Pinter Publishers.
7. Duliniec, E. (2007). *Marketing międzynarodowy*, Warszawa: PWE.
8. Gammeltoft, P., Cuervo-Cazurra, A. (2021). Enriching internationalization process theory: insights from the study of emerging market multinationals. *Journal of International Management*, Vol. 27, Iss. 4, 100884, doi: 10.1016/j.intman.2021.100884
9. Hollensen, S. (2007). *Global Marketing: A decision-oriented approach*. Harlow: Financial Times/Prentice Hall.
10. Jeannet, J.P., Hennessey, H.D. (2004). *Global Marketing Strategies*. Boston: Houghton Mifflin.
11. Johanson, J., Vahlne, J.E. (1977), The Internationalization Process of the Firm—A Model of Knowledge Development and Increasing Foreign Market Commitments. *Journal of International Business Studies*, Vol. 8, Iss. 1, pp. 23-32, doi: 10.1057/palgrave.jibs.8490676
12. Johanson, J., Wiedersheim-Paul, F. (1975). The internationalization of the firm – Four Swedish cases. *Journal of Management Studies*, Vol. 12, Iss. 3, pp. 305-323, doi: 10.1111/j.1467-6486.1975.tb00514.x
13. Komor, M., Grzyb K. (2023). Qualitative Content Analysis—A Research Method in Social Science, *Educational Studies Review (Przegląd Badań Edukacyjnych)*, Vol. 43, Iss. 2, pp. 143-163, doi: 10.12775/PBE.2023.032
14. Kumar, V. (2018). Transformative marketing: The next 20 years. *Journal of Marketing*, Vol. 82, Iss. 4, pp. 1-12, doi: 10.1509/jm.82.41
15. Kutschker, M., Schmid, S. (2011). *Internationales Management*. München: Oldenbourg Verlag.
16. Lim, J.-S., Sharkey, T.W., Kim, K.I. (1991). An Empirical Test of an Export Adoption Model. *MIR: Management International Review*, Vol. 31, Iss. 1, pp. 51-62.
17. Mayring, P. (2023). *Einführung in die qualitative Sozialforschung*. Weinheim Basel: Beltz.
18. Mayring, P. (2022a). *Qualitative Content Analysis: A Step-by-Step Guide*. Los Angeles: Sage.
19. Mayring, P. (2022b). *Qualitative Inhaltsanalyse, Grundlagen und Techniken*. Weinheim, Basel: Beltz.
20. OECD (2023). *Promoting internationalization of the social and solidarity economy: From local to global*. Retrieved from: https://www.oecd.org/content/dam/oecd/en/publications/reports/2023/09/promoting-internationalisation-of-the-social-and-solidarity-economy_f4a127e9/7287db10-en.pdf
21. Perlitz, M. (2004). *Internationales Management*. Stuttgart: UTB, Lucius & Lucius.

22. Petraite, M., Mubarak, M.F., Rimantas, M., Zedtwitz von, M. (2022). The role of international networks in upgrading national innovation systems. *Technological Forecasting and Social Change*, Vol. 184, 121873, doi: 10.1016/j.techfore.2022.121873
23. Richta, H.N. (2012). *Organisationales Lernen als erfolgsrelevantes Konstrukt im Rahmen der Internationalisierung von Unternehmen*. Wiesbaden: Springer Gabler.
24. Swoboda, B., Schramm-Klein, H., Halaszovich, T. (2022). *Internationales Marketing, Going und Being International*. Wiesbaden: Gabler.
25. Tang, R.W., Zhu, Y., Cai, H., Han, J. (2021). De-internationalization: A Thematic Review and the Directions Forward. *Management International Review*, Vol. 61, pp. 267-312, doi: 10.1007/s11575-021-00446-x
26. Trąpczyński, P. (2016) De-internationalisation: A review of empirical studies and implications for international business research. *Baltic Journal of Management*, Vol. 11, Iss. 4, pp. 350-379, doi: 10.1108/BJM-08-2015-0153
27. Witt, A., Khalik, M., Godinez, J. (2024). The internationalization of hidden champions from Germany and the UK: An extension to the Born-Again Global path. *Journal of International Management*, Vol. 30, Iss. 2, doi: 10.1016/j.intman.2024.101129
28. Yin, R.K. (2015). *Studium przypadku w badaniach naukowych. Projektowanie i metody*. Kraków: Wydawnictwo Uniwersytetu Jagiellońskiego.
29. Zastempowski, M. (2011). The Innovative Potential of the Hidden Champions of the Polish Economy. *Contemporary Management Quarterly [Współczesne Zarządzanie]*, Vol. 4, pp. 52-58.
30. Zweck, A. (2007). Technologies and the future. In: H.J. Bullinger (Ed.), *Technology Guide Principles - Applications - Trends* (pp. 1-5). Berlin, Heidelberg: Springer.

MODERN LIBRARY MANAGEMENT IN THE ERA OF DIGITAL TRANSFORMATION - FROM A CULTURAL INSTITUTION TO A KNOWLEDGE AND INNOVATION CENTER

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Purpose: The aim of the article is to analyze the transformation of public libraries in Poland in the context of digital transformation, using the Mediateka - the main branch of the Municipal Public Library (MBP) in Tychy - as a case study. The author seeks to illustrate the transition from a traditional cultural institution to a modern center of knowledge and innovation. The article also aims to highlight the changing role of libraries in the knowledge society and the importance of concepts such as the “third place” and the hybrid library, as well as the role of modern technologies (book dispensers, return boxes, self-check machines, RFID systems) in expanding access to resources and services.

Design/methodology/approach: The study employs a qualitative approach based on the case study method. The subject of analysis was the Municipal Public Library in Tychy, selected for its implementation of innovative technological solutions. The research included an expert interview with the institution’s director and an analysis of secondary data, encompassing internal documents, professional publications, reports, and online sources. The case study method enabled an in-depth examination of the library’s operational context, its relationships with the local community, and the impact of implemented technologies on its functioning and public perception. The scope of the study includes both theoretical aspects (knowledge society, hybrid library, “third place” concept) and practical dimensions (modernization, digitization, new roles of librarians).

Findings: The analysis showed that the Municipal Public Library in Tychy has evolved from a traditional book-lending institution into a modern center of knowledge, culture, and social integration. The implementation of RFID systems, book dispensers, return boxes, and self-check machines has improved user service and increased access to library services, particularly during the COVID-19 pandemic. The library effectively combines informational, educational, and cultural functions, fulfilling the role of a “third place” - an open, neutral space for meeting and cultural participation. The Mediateka case confirms that combining the library’s educational and cultural mission with modern technological solutions enables libraries to effectively meet the needs of contemporary users and strengthen their position as local community hubs.

Research limitations/implications: The study is qualitative and based on a single case - the Municipal Public Library in Tychy. This approach allowed for an in-depth analysis but limits the generalizability of the findings to all public libraries in Poland. Another identified limitation concerns the dependence of libraries on local government budgets and the

infrastructural disparities between large cities and rural municipalities, which influence the pace and scope of modernization. Future research should extend the analysis to multiple institutions to compare the effectiveness of technological implementations and different management models in libraries of various sizes and profiles.

Practical implications: The findings indicate that implementing modern technologies - such as book dispensers, return boxes, self-check machines, and RFID systems - significantly improves user service quality and library work efficiency. The example of the MBP in Tychy can serve as a model of good practice for other local government units and cultural institutions planning infrastructure modernization and digital service development. The implemented solutions enable better resource utilization, reduced queues, process automation, and increased accessibility to cultural offerings. These results can also support policymakers in developing library development strategies and planning public investments in culture and digital education.

Social implications: The transformation of libraries into centers of knowledge, culture, and social integration has a significant impact on building social capital and combating digital exclusion. The example of the Mediateka in Tychy demonstrates that a library can function as a “third place” - a neutral space that fosters meetings, education, and cultural participation. The technological solutions and educational programs introduced increase service accessibility for various social groups, including seniors and people with limited mobility, promoting equal opportunities and strengthening social bonds. The study confirms that the modern library supports the development of digital and cultural competences, thereby contributing to the improvement of local community quality of life.

Originality/value: The article provides new insights through a comprehensive analysis of the transformation of a public library in Poland within the context of digital modernization, based on an empirical case study of the MBP in Tychy. It demonstrates how combining traditional library functions with modern technologies and a user-centered approach can transform a cultural institution into a center of knowledge and innovation. The study offers value for academic communities focused on cultural institution management, for local governments responsible for cultural policy, and for practitioners - library directors and staff - seeking inspiration for implementing modern technological and organizational solutions.

Keywords: public library, Mediateka Tychy, knowledge society, third place, hybrid library, technological innovations, digitization.

Category of the paper: Case Study.

JEL: M31.

1. Introduction

„One does not need to be a book lover or a reader to use a library nowadays”, notes Richard Reyes-Gavilan, Director of the Martin Luther King Jr. Library (Kapla, 2023). Today, public libraries are discussed not only in terms of readers but, above all, users. The modern public library has become an innovative, active, and multifunctional institution - both in Poland and in other countries. It is a place open to children, adults, and seniors, and its role goes far beyond traditional book lending. A contemporary library is a space that meets broadly understood cultural, educational, and social needs. As Wolf (Wolf, 2009, p. 51) emphasizes, the public

library is an institution around which there exists a broad social consensus and which does not provoke controversy, as it is perceived as a natural common good.

Public libraries today offer not only access to traditional books but also to audiobooks, e-books, periodicals, the Internet, films, music, computer programs, and a wide range of cultural events. They are becoming centers of local social activity - places for workshops, meetings, clubs, and events, as well as sources of information about the region and the everyday life of residents (Wolf, 2009, p. 52). As Kalinowska notes (Kalinowska, 2009, p. 35), modernizing libraries and adapting them to users' expectations is crucial for attracting new audiences.

Therefore, the contemporary library is not a mere repository of books but an information hub where tradition meets modernity. Although - as Cicero reminds us - "a book is a man's best friend, and a library is the temple of his thoughts", in the 21st century the library also serves as a laboratory of technology and a space of digital culture. As Gmiterek emphasizes (Gmiterek, 2012, p. 99), these institutions not only accompany the transformations of the information society but actively co-create the resources of the global network.

The aim of the study focuses on the analysis of the transformations of public libraries in Poland in the context of digital transformation, showing on the example of the Mediatheque in Tychy the transition from a traditional cultural institution to a modern center of knowledge and innovation. The study aims to indicate the changing role of libraries in the knowledge society, the significance of concepts such as "third place" and hybrid library, as well as the role of technological innovations – book dispensers, drop boxes, self-checks or RFID systems – in broadening access to resources and services.

The results may be useful for local governments and public institutions, which are responsible for the development of cultural infrastructure and counteracting digital exclusion, as well as for directors and employees of libraries as a source of good practices in the field of modernization of services and implementation of new technological solutions. They are also important for creators of cultural and educational policies, who, on the basis of the experiences of the Municipal Public Library in Tychy, can shape programs supporting libraries as local centers of social life. The study is also significant for library users, as it shows how contemporary libraries can respond to their diverse cultural, educational and social needs.

2. Modern Technologies in Mediatekas - Theoretical Approach

Contemporary libraries operate within the framework of the knowledge society, where access to information constitutes the basis for the development of individuals and communities. UNESCO emphasizes that libraries, alongside schools and academic institutions, are "a fundamental infrastructure of the knowledge society" (UNESCO, 2025, p. 34).

Oldenburg (1989), in his concept of the “third place,” indicated that cultural institutions can serve as neutral social spaces that promote integration and dialogue. Library studies (Aabø, Audunson, 2012, p. 139) adapt this idea to library practice, noting that in Central and Eastern Europe libraries have begun to fulfill the role of a “democratic agora” (Audunson, 2005, p. 429).

Another concept is the hybrid library - combining traditional and digital collections, enabling remote access to catalogs, databases, and educational services (Pinfield, 1998, p. 34). In Poland, the process of hybridization is uneven, depending on the wealth of local governments and available EU programs (Koryś, Chlebicka, 2021, p. 57).

Equally significant is the theory of information literacy, which considers libraries as key institutions in the education of critical information consumption (Eisenberg, 2008, p. 45; IFLA, 2017, p. 7).

The transformation of public libraries in Poland toward modern centers of knowledge and innovation faces numerous financial, organizational, and social barriers. An analysis of modernization processes shows that, although many infrastructural and digitization investments have been implemented over the past two decades, the pace of change remains uneven, and libraries continue to struggle with systemic problems. Polish public libraries are largely dependent on local government budgets, which often treat them as secondary institutions compared to schools or cultural centers (Majewska, 2017). Although ministerial programs - such as the National Reading Development Program (NPRCz, 2016-2020; 2021-2025) - provide funding for the purchase of new publications and infrastructure modernization, they do not solve the problem of chronic underfunding for ongoing operations. According to GUS data (2022), average financial expenditures on a library in a rural municipality are several times lower than in large cities, perpetuating inequalities in access to modern library services.

Technological transformations have necessitated a redefinition of the librarian's role - from a custodian of collections to an educator, cultural animator, and guide to digital resources (Derfert-Wolf, 2019). However, research shows that in many libraries, especially in smaller towns, there is a lack of systematic training in new technologies, media pedagogy, or social animation (BN Report, Public Libraries in Numbers, 2021). The problem is exacerbated by an aging workforce - the average age of librarians in Poland exceeds 45 years, limiting adaptive flexibility to new work models. In recent years, the Municipal Public Library in Tychy has undertaken intensive training activities aimed at developing the professional competencies of its staff and aligning their qualifications with changing legal, technological, and social conditions. In 2024, employees participated in courses covering, among others, issues related to management control in cultural institutions, electronic deliveries, amendments concerning the Company Social Benefits Fund, as well as the organization and maintenance of institutional archives. An important component was also participation in the 9th Forum on the Responsibility of Heads of Public Finance Sector Units and in workshops devoted to communication and leadership in the context of the challenges of the VUCA reality. In 2023, staff members also

took part in a particularly broad range of training activities, which addressed such topics as planning, reporting, and management control, inventory processes, and regulatory changes concerning the CSBF. Special attention was given to the development of digital and creative skills through workshops in programming, comic and board game design, as well as media training in photography, film, and public speaking. Equally important were sectoral initiatives, including librarian forums and study visits to the Jagiellonian Library and the National Ossoliński Institute, along with activities directed at working with seniors and enhancing computer and language proficiency.

Such a wide-ranging training policy demonstrates that the Municipal Public Library in Tychy consistently undertakes efforts to reduce competency deficits resulting, among others, from the aging of staff, while at the same time strengthening employees' potential in the areas of law, public finance, information technology, and cultural animation. These initiatives have a direct impact on the quality of services provided and on the library's ability to respond effectively to the needs of contemporary users.

While modern mediatekas and hybrid libraries have emerged in large cities, in many rural municipalities libraries still operate in outdated buildings without adequate computer equipment or access to high-speed internet (GUS Report, 2020). This deepens the so-called digital divide between users from metropolitan centers and residents of peripheral areas.

The phenomenon of mass digitization of content, the development of streaming platforms, and commercial knowledge providers place libraries in competition for the attention of audiences. BN reports on reading (2022) indicate that only 38% of Poles read at least one book in a year. For libraries, this means the need to expand their offerings to include multimedia, cultural events, and coworking spaces in order to remain attractive compared to other forms of leisure.

The mediateka, referred to as a multimedia library, is a modern institution whose aim is not only to collect materials but also to support education, social integration, and participation in digital culture. This is particularly important for younger generations, for whom contact with technology is a natural part of daily life. The contemporary public library becomes a "first-contact institution", offering residents various forms of participation in culture and digital education (Koryś et al., 2019, p. 28).

Modern libraries in Poland - including the Mediateka in Tychy - perform not only informational functions but also integrative and recreational roles. Research by Dąbrowska emphasizes that the role of libraries in small and medium-sized towns increasingly includes bridging the digital gap through access to technology and media education (Dąbrowska, 2013, p. 119). Similar conclusions are drawn from the NIK report, which indicates that public libraries, through the introduction of digital services, strengthen social cohesion and facilitate access to culture for people at risk of exclusion (NIK, 2018, p. 44).

Modern library systems are today one of the key solutions supporting the functioning of contemporary libraries. Several such programs are already available on the market, offering

a wide range of tools tailored to the current needs of institutions and their users. Software producers - including PROLIB, SOWA, MAK, LIBRA, ALEPH, and VIRTUA - emphasize that they continuously develop their products in cooperation with librarians and readers, while also monitoring developments in information technology. As a result, library systems not only use modern solutions in integration and communication but also genuinely support the daily work of libraries.

Such software enables full automation of library processes - from serving users and managing loans, to collecting and processing documents, as well as providing online catalogs and enabling the search for specific resources. Built-in multifunctional search engines allow full-text searches, the use of headings and keywords, and the application of preset filters, significantly facilitating access to information (<https://sygnitybs.pl/rozwiwania-dla-bibliotek-prolib-system-biblioteczny/>, 8.08.2025).

Contemporary libraries increasingly adopt modern technological solutions, among which book lockers deserve special attention. These innovative devices, operating similarly to popular parcel lockers, are steadily gaining recognition among Polish libraries and their users. Thanks to book lockers (produced by Arfido Sp. z o.o.), a reader can conveniently order a selected item via the online catalog and then pick it up at a convenient time - even outside library opening hours. The device is fully integrated with the library system in use. The first implementations of this solution, carried out by Sygnity Business Solutions SA in cooperation with Arfido Sp. z o.o., took place at the Municipal Public Library in Tychy, followed by Sosnowiec (<https://sygnitybs.pl/ksiazkomaty-zintegrowane-z-system-prolib-rosna-jak-grzyby-po-deszczu/>, 7.08.2025).

The book locker allows not only collection but also the return of previously ordered items. The process is fully self-service - the reader places an order via the library website, and when the book is prepared, the librarian places it in the device and marks it as ready for pickup. The system sends a notification to the user, who identifies themselves at the locker using their library card and then retrieves the book from the assigned compartment. Returns are equally smooth - it is enough to place the item in a free locker, which opens after scanning the card. The device is equipped with lockable compartments, a touchscreen, and a library card reader, ensuring safety and intuitive operation. This solution, as part of a comprehensive IT system, has become a kind of technological standard in libraries. Growing usage statistics confirm that readers are increasingly adopting book lockers, including those previously attached to traditional service (<https://sygnitybs.pl/ksiazkomaty-zintegrowane-z-system-prolib-rosna-jak-grzyby-po-deszczu/>, 7.08.2025).

Another convenience introduced in libraries is book drop boxes, which enable quick and contactless return of borrowed items. They allow readers to return books at any time by following instructions displayed on the screen. It is enough to scan the barcode of each returned item, and the information is immediately updated in the library system. Although a library card is not required for the return itself, scanning it allows printing of the current account status.

These devices are available in several language versions, including Polish, English, and German (<https://bs.katowice.pl/dla-czytelnikow/czytelnie-i-wypożyczalnie/wypożyczalnia/ksiazkomat-i-wrzutnia/> 7.08.2025). In libraries where efficient return processing is a priority, RFID drop boxes are increasingly used. They recognize books through RFID tags attached to items, and books go directly to a special cart with a moving bottom. Advanced RFID systems may also be equipped with sorters, which direct returned items to appropriate containers according to established criteria (<https://www.arfido.com/wrzutnia-rfid.html>, 8.08.2025).

It is also worth mentioning Selfcheck devices, which allow readers to borrow and return books, audiobooks, or films independently, without staff assistance. The operation is very simple - the library card is scanned to access the user account and register the transaction. Information about the loan or return appears immediately in the system, and the user can print a confirmation and account status. Thanks to Selfchecks, the library can offer efficient and modern service while relieving staff of some routine tasks.

The COVID-19 pandemic highlighted deficiencies in libraries' digital services. Some facilities quickly implemented remote e-book lending systems or online meetings (e.g., Legimi, Empik Go in cooperation with public libraries), but many institutions – especially smaller ones - lacked the infrastructure or staff prepared for such solutions. This experience pointed to the need for a long-term digital strategy encompassing not only the largest centers but also small municipal libraries. The pandemic significantly changed the way residents of Tychy use the library. The Municipal Public Library developed its digital offer to compensate for the closures of traditional branches. Since 2022, readers have had access to paid e-book services – Legimi and Empik Go – and the library issues free codes for both platforms as well as lends e-book readers. Thanks to this, it is easier for the residents of Tychy to reach for literature without the need to visit the library. Interest in this form of borrowing is growing – codes are distributed very quickly, and readers use the rich digital offer, including over 50 thousand publications. Although budget constraints reduce the number of traditional book purchases, the library tries to balance these shortages with a strong digital offer. In 2024, 11,083 new titles were purchased for 289,917 PLN, which meant 3656 fewer copies than in the previous year. This difference is offset precisely by access to e-book services and scientific e-libraries such as IBUK Libra or Academica.

After the reopening of the facilities, residents also willingly began to use self-service solutions. The number of visits and borrowings carried out through the book dispenser increased during the pandemic by 190% and 151%, respectively. While before 2020 only about 12% of readers used this form, after the lockdown this percentage increased significantly, especially among older people seeking safe ways to access books. All this shows that the development of digital and self-service offerings effectively compensated for the temporary closures of the library.

3. Institutional Support: National and Local Programs

The transformation of libraries has been supported by cultural policy and public funding. Long-term ministerial programs played a key role, such as the National Reading Development Program 2016 - 2020 and its continuation 2.0 (2021-2025), which treat public libraries as “local centers of social life” and access points to culture (<https://www.gov.pl/web/kultura/nprcz>, 8.08.2025). Within the NPRC framework, libraries were awarded grants for the purchase of books (including remote access to e-books) and the modernization of infrastructure. Particularly, Priority 2, “Investments in Library Infrastructure”, enabled local governments to co-finance the construction, expansion, and equipping of library facilities (<https://www.gov.pl/web/kultura/nprcz>, 8.08.2025). EU programs (especially between 2007-2013) and national initiatives such as “Library Infrastructure” or “Library+” also supported the modernization or renovation of facilities. As a result, many cities and municipalities now have new library buildings and mediatekas designed as open, multifunctional spaces (including multimedia rooms, conference halls, galleries, or cafés) that align with the “third place” concept for local communities (<https://www.nprcz.pl>, 8.08.2025). Infrastructure funding was complemented by training and animation programs. Priority 4 of NPRCz 2.0 includes enhancing librarians’ competencies in understanding community needs and promoting local partnerships for reading promotion (<https://www.gov.pl/web/kultura/nprcz>, 8.08.2025). Consequently, library staff received support for acquiring new skills (technological and pedagogical), essential for working with diverse and active audiences.

4. Research Methodology

The empirical study conducted for the purposes of this publication employs qualitative research methods, specifically the case study approach. Qualitative research is one of the fundamental scientific research methods, alongside quantitative research. It is widely used across various academic disciplines, including marketing research. Marketing research involves diagnosing an organization’s informational needs, selecting variables, and collecting, analyzing, and interpreting data to support marketing decision-making (Komor, 2011, p. 224).

Sources indicate that case study research is defined as an intensive and detailed examination of a particular case, as well as an analysis of its real context and the relationships occurring among its various elements. There are numerous definitions of case study research; it can be described as an empirical investigation of a contemporary phenomenon in its real-life context, especially when the boundaries between the phenomenon and the context are not entirely clear. The study is conducted using evidence from multiple sources to confirm the consistency of

information through triangulation, while data collection and analysis refer to pre-established theoretical assumptions (Komor, 2011, p. 224). Such an analysis focuses on the actual context of the phenomenon under study and allows researchers to gather extensive information and analyze numerous data related to management in a modern cultural institution.

In the literature, empirical research is described as research that utilizes evidence and knowledge collected through observation and experience, satisfying the researcher's curiosity and desire for a better understanding of the subject under study. For the purposes of this study, research questions were formulated and an interview was conducted:

- What role do modern solutions play in a public library?
- What motives guided the institution in deciding to implement modern technological solutions in a cultural institution?
- What solutions have been introduced into the operations of the public library?
- What is the significance of modern technology used in the library?

To prepare the case study project, a single cultural institution was selected: the Municipal Public Library in Tychy, which met the research criteria. It was decided to conduct an expert interview with the library's director, who possesses knowledge and information about the library's operations. For the purposes of this interview, appropriate questions were prepared, and secondary sources were used, including internal data, the MBP Tychy profile, brochures, industry press publications, and information from websites.

Case Study of a Local Government Cultural Institution - Municipal Public Library in Tychy

The Municipal Public Library in Tychy is a local government cultural institution established in August 1956. Its structure includes the Main Library and 12 branches located throughout the city. Under the Library Act, it operates as a public institution with legal personality. Its organizer is the local government, and it is supervised by the city mayor, who is legally obliged to provide the library with suitable premises and fund staff salaries. The MBP is headed by a director, and the primary role of the library is to meet the educational, informational, and cultural needs of residents. Today, the institution also plays an important role in cultural animation, integrating the local community around culture and knowledge.

The library's mission guides its activities. The Tychy library offers readers a wide range of educational, informational, and animation services. To meet user expectations, it regularly updates its collection with new publications and considers suggestions and requests submitted by readers. It also carries out numerous activities aimed at enhancing the cultural engagement of residents.

For years, the library has placed strong emphasis on service quality and implementing modern solutions. MBP in Tychy was the first in Poland to introduce a book locker, a device that allows 24/7 pickup of books ordered online. This equipment, operating similarly to parcel lockers, has gained immense popularity among users. In addition, the library is equipped with

self-service lending and return stations (selfchecks), a 24-hour drop box, an RFID system, as well as access to computers with Internet, tablets, e-readers, audiobooks, board and strategy games, DVDs, Blu-rays, and virtual reality. Readers can also borrow e-readers with active codes for Legimi or Empik Go platforms. All these services are entirely free, and the modern Mediateka building encourages use by entire families.

Technological development has enabled contemporary libraries, including MBP Tychy, to use the MARC21 format. This allows not only efficient cataloging of collections but also global exchange of bibliographic data. A librarian processing a book in Tychy can check how the same publication has been cataloged, for example, in the Library of Congress in Washington.

This connectivity integrates catalogs into a worldwide network, making information about major institutions' collections widely accessible.

It is difficult to imagine a library today without modern ICT tools. Technology forms the foundation of its development and service quality, supporting collection, processing, and sharing of resources. As Gmiterek (Gmiterek, 2012, p. 99) notes, the introduction of innovative systems increases productivity, streamlines scholarly communication, and enables better response to the diverse needs of users. Jacek Wojciechowski (Wojciechowski, 2017, p. 108) emphasizes that the 21st-century library should function as a super-technical organism creatively responding to the challenges of modern media.

This vision is realized by the Mediateka, opened in 2016, which serves as the main branch of MBP Tychy and is located at al. Marszałka Józefa Piłsudskiego 16. The facility, covering 2700 m², combines the function of a traditional public library with a modern cultural center. The Mediateka hosts author meetings with writers, journalists, and creators, workshops for children and adults, contests, exhibitions, and film screenings. The architecture features a raw concrete-and-glass structure with numerous windows, skylights, and modern spatial solutions.

On the ground floor, there is an adult lending section, a children's department, a fairy tale library, a multimedia reading room, a music and audiobook section, as well as conference rooms and staff facilities. The first floor houses the scientific reading room, press reading room, server room, and IT offices. The second floor is used for computer courses, promotional and methodological activities, and library administration.

The MBP Tychy collection includes over 100,000 volumes. Its rich offerings include books, daily newspapers, periodicals, audiobooks, films, and music collections. The music section is equipped with high-quality audio equipment and a television for concerts and film screenings. The multimedia reading room offers multiple computer stations, board games, VR, and the possibility to watch films and fairy tales. Film screenings under the "Art x Music" series and fairy tale projections in the Fairy Tale Library are particularly popular. Free computer courses for seniors are also organized in a professionally equipped room with 12 workstations.

A milestone in the library's history was the introduction of the RFID system in 2017. The entire collection was tagged, and readers received new library cards with RFID

functionality. Security gates, selfchecks, a drop box, and a book locker - the first such device in a public library in Poland - were launched. The system was fully integrated with PROLIB, ensuring efficient and fault-free operation. Staff emphasize that these solutions not only simplify life for readers but also reduce queues and lighten the workload of librarians.

It is also worth mentioning the self-service lending of new books, "Przystań Książka", located at the PKP train station in Tychy. This is the third such device in Poland and the first fully integrated with the PROLIB system. It operates 24/7, available to all MBP cardholders.

Modern solutions have contributed to the library's growing popularity - today, the number of registered readers exceeds 26,000, placing MBP Tychy among the top municipal libraries in the Silesian Voivodeship. The management emphasizes that a contemporary library cannot afford stagnation. It must actively shape its image, implement innovative methods of promoting reading, and consistently invest in modernity - only then will it be noticed and appreciated by the local community.

In 2025, the Municipal Public Library in Tychy will provide access to library resources both in traditional and digital form, including books, DVDs, as well as modern technologies, including virtual reality (VR). Planned is also the purchase and lending of several e-book readers enabling the use of the Legimi, Empik Go, and IBUK Libra platforms.

The library will continue existing educational and cultural programs and projects, such as the Active Senior Library, Digital Poland Equal Opportunities, Cultural Commentary, and Regional Lessons – Tychy Stop. Furthermore, the project Storyteller in the Library will continue, consisting of individually presenting fairy tales, fables, and therapeutic stories using props, costumes, and musical background in the concert hall of the Mediateka.

The activities of the MPL also include organizing cyclical events, such as Culture Tours, Tychy Literature Days, Academy of All Arts, seasonal workshops, Santa from the Fairy Tale, family festival "With Mediateka towards summer", as well as Fair on the Promenade. On the occasion of celebrating the Year of Fr. Prof. Józef Tischner, Maria Pawlikowska-Jasnorzewska, and Władysław Stanisław Reymont, planned are library lessons, literary competitions, thematic exhibitions, and special bulletins. Projects Two Hands and Something More and Fun with Art will also continue.

For the implementation of tasks in 2025, the Municipal Public Library in Tychy received a city grant in the amount of 10,237,685 PLN, of which 150,000 PLN was allocated for the purchase of library collections. Forecasted own revenues amount to 300,000 PLN, and the institution also plans to apply for financial support from the Ministry of Culture and National Heritage.

5. Conclusion

The transformations that have taken place in public libraries in Poland - particularly in the Mediateka in Tychy - demonstrate that the contemporary library is no longer merely a repository of books, but a modern center of knowledge, culture, and social integration. Thanks to infrastructural investments, support from national and EU programs, and the consistent implementation of innovative technological solutions, it has become possible to create a space that is welcoming and attractive to all user groups.

RFID systems, book lockers, drop boxes, and selfchecks are today not only convenient service tools but also symbols of the transformation of libraries into places where tradition meets digital modernity. The Tychy library serves as an example of an institution that has successfully harnessed the potential of new technologies to fully fulfill the role of the “third place” - a neutral, open, and inspiring space for the local community.

Although libraries still face challenges related to funding, staff training, and bridging digital divides, the experience of MBP in Tychy demonstrates that modernity combined with an educational and cultural mission allows them to effectively reshape their image. The 21st-century library supports reading, develops digital competencies, strengthens social bonds, and becomes an indispensable element of local life - a place to which people want to return.

References

1. Aabø, S., Audunson, R. (2012). Use of library space and the library as place. *Library & Information Science Research*, 34(2), 138-149. <https://doi.org/10.1016/j.lisr.2011.06.002>
2. Arfido Sp. z o.o. (2025). *Wrzutnia RFID*. <https://www.arfido.com/wrzutnia-rfid.html>
3. Audunson, R. (2005). The public library as a meeting-place in a multicultural and digital context: The necessity of low-intensive meeting-places. *Journal of Documentation*, 61(3), 429-441. <https://doi.org/10.1108/00220410510598562>
4. Biblioteka Śląska w Katowicach (2025). *Książkomat i wrzutnia*. <https://bs.katowice.pl/dla-czytelnikow/czytelnie-i-wypożyczalnie/wypożyczalnia/ksiazkomat-i-wrzutnia/>
5. Cycon, M.T. (n.d.). *Cytat: Książka to najlepszy przyjaciel człowieka, a biblioteka to świątynia jego myśli*.
6. Dąbrowska, M. (2013). *Biblioteka publiczna w małym i średnim mieście: Funkcje, zadania, użytkownicy*. Warszawa: Stowarzyszenie Bibliotekarzy Polskich.
7. Derfert-Wolf, L. (2019). Nowe role bibliotekarza w dobie cyfryzacji. *Biuletyn EBIB*, 3(180). <http://open.ebib.pl/>

8. Eisenberg, M.B. (2008). Information literacy: Essential skills for the information age. *Journal of Library & Information Services in Distance Learning*, 2(2-3), 3-17. <https://doi.org/10.1080/15332900802126783>
9. Gmiterek, G. (2012). *Biblioteki cyfrowe i wirtualne: Wprowadzenie*. Warszawa: Stowarzyszenie Bibliotekarzy Polskich.
10. gov.pl (2021). *Narodowy Program Rozwoju Czytelnictwa 2.0 (2021-2025)*. <https://www.gov.pl/web/kultura/nprcz>
11. IFLA (2017). *Global vision report*. International Federation of Library Associations and Institutions. <https://www.ifla.org/>
12. Kalinowska, A. (2009). *Biblioteka w społeczeństwie wiedzy*. Warszawa: Stowarzyszenie Bibliotekarzy Polskich.
13. Kapla, M. (2023). Nowe oblicze bibliotek publicznych. *Bibliotekarz*, 6, 12-18.
14. Koryś, I., Chlebicka, M. (2021). *Biblioteki w Polsce: Rozwój i wyzwania*. Warszawa: Biblioteka Narodowa.
15. Koryś, I., Antczak, M., Chlebicka, M. (2019). *Biblioteki jako lokalne centra życia społecznego*. Warszawa: Biblioteka Narodowa.
16. Majewska, K. (2017). Biblioteki publiczne a samorządy lokalne – problemy i perspektywy. *Przegląd Biblioteczny*, 85(3), 257-270. <https://doi.org/10.36702/pb.123>
17. Najwyższa Izba Kontroli (2018). *Informacja o wynikach kontroli: Biblioteki publiczne jako ośrodki dostępu do kultury i wiedzy*. Warszawa: NIK. <https://www.nik.gov.pl>
18. nprcz.pl (2022). *Infrastruktura bibliotek – programy wsparcia*. <https://www.nprcz.pl>
19. Oldenburg, R. (1989). *The great good place*. New York, NY: Paragon House.
20. Pinfield, S. (1998). The hybrid library: A strategic model for the integration of traditional and electronic information services. *British Library Research and Innovation Report*, 34, 1-48.
21. Raport BN (2021). *Biblioteki publiczne w liczbach 2020*. Warszawa: Biblioteka Narodowa.
22. Raport BN (2022). *Stan czytelnictwa w Polsce w 2021 roku*. Warszawa: Biblioteka Narodowa.
23. Raport GUS (2020). *Kultura w 2019 roku*. Warszawa: Główny Urząd Statystyczny. <https://stat.gov.pl>
24. Raport GUS (2022). *Działalność bibliotek publicznych w 2021 roku*. Warszawa: Główny Urząd Statystyczny. <https://stat.gov.pl>
25. Sygnity Business Solutions (2025a). *PROLIB – system biblioteczny*. <https://sygnitybs.pl/rozwiazania-dla-bibliotek-prolib-system-biblioteczny/>
26. Sygnity Business Solutions (2025b). *Książkomaty zintegrowane z system PROLIB rosną jak grzyby po deszczu*. <https://sygnitybs.pl/ksiazkomaty-zintegrowane-z-system-prolib-rosna-jak-grzyby-po-deszczu/>

27. UNESCO (2025). *Biblioteki w społeczeństwie wiedzy*. Paryż: UNESCO Publishing.
28. Wojciechowski, J. (2017). *Biblioteka jako organizm supertechniczny*. Kraków: Universitas.
29. Wolf, M. (2009). *Biblioteka jako instytucja społeczna*. Warszawa: Stowarzyszenie Bibliotekarzy Polskich.

FACTORS FACING THE IMPLEMENTATION OF ECO-INNOVATIVE SOLUTIONS IN CITIES IN POLAND – A REVIEW OF LITERATURE AND GOOD PRACTICES

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Purpose: The paper examines the role of eco-innovations in driving sustainable urban development in Poland. It identifies institutional, financial, and social factors that determine their implementation and presents good practices from major Polish cities. The study expands current knowledge by linking eco-innovation with governance capacity, citizen participation, and adaptive urban management.

Design/methodology/approach: A triangulated analysis combining literature review, EU and national policy documents, and case studies from selected Polish cities was conducted. The comparative and desk research methods enabled the integration of theoretical frameworks with practical insights.

Findings: The research reveals that the effectiveness of eco-innovation in Polish cities depends on the integration of legal frameworks, financial mechanisms, and public awareness. Successful cases (Warszawa, Kraków, Łódź, Wrocław, Rzeszów, Gliwice) show that combining technological, social, and organizational innovation enhances environmental performance, resilience, and quality of life. The study provides new evidence that strengthening institutional capacity and citizen engagement accelerates green transformation.

Practical implications: The findings support urban policymakers and practitioners in designing coherent strategies that connect financial instruments, certification systems, and education to foster sustainable urban governance.

Social implications: By emphasizing participatory and educational dimensions, the study demonstrates how eco-innovation builds environmental awareness, promotes social inclusion, and enhances local resilience to climate change.

Originality/value: This paper offers an integrated framework linking policy instruments with practical applications of eco-innovation in Polish cities, contributing to the understanding of how institutional and social mechanisms shape sustainable urban transitions.

Keywords: eco-innovation; sustainable development; urban policy.

Category of the paper: Conceptual paper.

1. Introduction

1.1. Environmental challenges and the need for sustainable urban development

Modern cities are facing increasingly complex and interconnected challenges, resulting from both growing demographic pressure and deepening environmental, infrastructural and economic problems. On the one hand, there is a systematic increase in the urban population, which is the result of urbanization processes and internal migrations, leading to an increased concentration of population in the largest centers. On the other hand, many European societies – including Poland – are experiencing an ageing population, which forces urban infrastructure, public services and social space to adapt to the needs of older people (Główny Urząd Statystyczny, 2023; United Nations, Department of Economic and Social Affairs, 2019).

The increase in the number of people in cities directly translates into increased demand for energy, water, transport and other natural resources. This phenomenon is accompanied by a growing level of consumption, which leads to an increase in pollutant emissions, environmental degradation and an increase in social and infrastructural problems (European Environment Agency, 2020). In particular, this applies to phenomena such as air pollution, traffic noise, limited access to green spaces, as well as the growing costs and difficulties associated with the management of municipal waste and wastewater. At the same time, many cities are struggling with ageing infrastructure, the modernisation of which faces numerous technical, legal and financial barriers inherent in public funds management systems. The housing deficit, public transport congestion and the increasing burden on energy systems also remain significant problems (Ministerstwo Funduszy i Polityki Regionalnej, 2021; Instytut Rozwoju Miast i Regionów, 2022). Today, cities act as key nodes of concentration of financial, population and cultural flows, becoming the main centers for generating economic growth. In the conditions of dynamic and inevitable technological, social and economic changes, it is precisely those centers that are able to effectively implement innovations that gain an advantage in attracting human capital, creating new jobs and shaping sustainable and competitive urban communities.

In this context, eco-innovations – defined as any type of technological, organisational or social innovation that contributes to the improvement of the state of the natural environment and increasing the efficiency of resource use (Organisation for Economic Co-operation and Development, 2011) – are of particular importance. Their role in the transformation of cities is fundamental – they support the transition towards low-carbon, resource-efficient and future-proof systems. The aim of eco-innovation is not only to reduce energy consumption and consumption of raw materials, but also to reduce the emission of harmful substances, improve the quality of life of residents and stimulate economic development in accordance with the principles of sustainable development (United Nations Environment Programme, 2011).

According to data from the Central Statistical Office, in June 2023, 22.4 million people lived in Polish cities, which accounted for 60% of the country's total population. The scale of urbanization will increase steadily in the coming decades – forecasts indicate that by 2050 two-thirds of the world's population will live in cities. A high concentration of population means not only economic potential, but also enormous pressure on the environment, resulting from, among m.in example, pollutant emissions, excessive energy consumption and limited availability of natural resources. For this reason, cities are becoming spaces with special potential – but also responsibility – in the field of implementing innovative environmental solutions.

Eco-innovations, as innovative technologies, organizational models and social practices, support the reduction of the negative impact of human activity on the environment, improve the efficiency of resource management and increase the quality of life of residents (Szymańska, 2016). The literature on the subject emphasizes that eco-innovation is not only an element of sustainable development, but also a factor increasing the competitiveness of cities. Motivations for the implementation of eco-innovations result not only from legal regulations and cost pressures, but also from a wide set of supply conditions, such as the availability of technological resources, organizational specificity of entities, innovations in management, conditions of competition and consumer expectations (Horbach, 2008).

Urban transformation based on eco-innovation requires not only the right technologies, but also friendly institutional, legal and financial conditions. In recent years, a number of instruments have been implemented at both EU and national level to support this process. These include, m.in example, green public procurement (GPP), environmental technology verification systems (ETVs) or environmental certificates such as Blue Angel, EU Ecolabel or Nordic Swan (European Commission, 2021; European Commission – Joint Research Centre, 2018; Umweltbundesamt, 2021).

Despite the availability of these tools, the level of implementation of eco-innovations in organizational units of Polish cities remains low. Research points to a number of barriers: lack of competence and knowledge among decision-makers, complicated administrative procedures and difficulties in obtaining funding (Instytut Ochrony Środowiska – Państwowy Instytut Badawczy, 2020). This shows that it is crucial not only to develop technology, but also to strengthen institutional trust, build environmental awareness and create a stable political and financial framework.

In the face of the intensifying climate crisis and the growing importance of cities as centres of socio-economic transformation, it is necessary to develop effective strategies to enable their sustainable development. Poland, as a country that is intensively urbanizing, is facing the challenge of rapid urban transformation in line with the assumptions of the European Green Deal. There is an urgent need to identify specific barriers and drivers for the implementation of eco-innovations that can act as a catalyst for this transformation. The article responds to the

current demand of policymakers, scientists and practitioners for knowledge that supports the development of climate-neutral urban policies.

The research problem posed by the authors concerns the answer to the question: *What institutional, financial and social factors have the greatest impact on the effectiveness of the implementation of eco-innovations in Polish cities?* In the study, the authors attempted to show that the integration of institutional instruments, appropriate financial mechanisms and activities to increase social awareness contributes to a significant acceleration of the implementation of eco-innovations in urban units in Poland. The authors are of the opinion that the identification and analysis of key institutional, financial and social factors allows for a better understanding of the conditions in which Polish cities function. This makes it possible to develop more effective strategies for implementing eco-innovations that will be adapted to local realities. A clear identification of barriers and opportunities fosters sound investment and organisational decisions, as well as the creation of a stable policy framework to support the green transition. As a result, such identification can significantly accelerate the pace of implementation of eco-innovative solutions and increase their effectiveness in practice.

The originality of this paper lies in its interdisciplinary approach, combining perspectives from urban management, architecture, and data analysis to explain the mechanisms that determine the effectiveness of eco-innovation in Polish cities. Unlike previous studies that focused mainly on the technological or environmental dimensions, this research integrates institutional, financial, and social aspects, providing an empirical framework for understanding governance-based eco-innovation as a new model of urban sustainability in Central Europe. The paper contributes to the literature by linking national policy instruments with local implementation practices, offering insights relevant to both academic research and urban policy.

To sum up, the main objective of this article is to analyze institutional, financial and social factors influencing the implementation of eco-innovations in Polish cities. The authors review the literature and national and EU strategic documents, identifying existing barriers and good practices. The article provides recommendations for local governments, decision-makers and urban practitioners that can support the process of green transition towards sustainable, low-carbon urban development.

2. Methods

The research presented in this article was conducted based on the method of triangulation of sources, which consists in combining the analysis of scientific literature, strategic documents and case studies of the implementation of eco-innovations in Polish and European cities. The use of this method allowed for more comprehensive and reliable results by collating data

from different sources and perspectives. The literature analysis included publications in the field of:

- theory of sustainable development,
- Smart Cities *concept*,
- green transition,
- adaptation of cities to climate change,
- and environmental and eco-innovation.

The criteria for selecting sources were: scientific value (indexed journals, recognized authors), topicality (mainly publications from the last 10 years), and a direct thematic connection with the issues of urban policy, technology implementation and design aimed at the needs of residents.

In addition, as part of the work presented in the article, the:

- national and EU strategic policies (including m.in. the European Green Deal, the National Urban Policy 2030, the Responsible Development Strategy),
- reports and expert opinions of public institutions and international organizations (e.g. European Commission, OECD, UN-Habitat),
- legal acts on waste management, energy efficiency and green public procurement in Poland.

The third phase of the research was the analysis of selected case studies, in particular those using *living labs* to test innovative environmental solutions and disseminate new technologies. These included:

- eco-innovation projects implemented in Polish cities: Warszawa, Krakow, Łódź, Wrocław, Rzeszów and Gliwice,
- selected foreign examples.

The criteria for selecting cases were: belonging to the space of Polish or European cities, the variety of implementation instruments used (e.g. technological, organizational, legislative) and the diverse scale of action (from pilot projects to urban projects of a systemic nature).

At the last stage, a comparative analysis was carried out, which included:

- a review of good practices in the implementation of eco-innovations in Europe, including particular emphasis on the activities undertaken by Polish cities,
- identification of the main barriers and factors conducive to the implementation of eco-innovation in the urban context,
- assessing the potential of institutional and technological tools that can support the sustainable transformation of cities.

The aim of such a selected and applied methodology was not only to map existing practices, but also to identify patterns and conditions for the effective implementation of eco-innovations that can be replicated in other cities in Poland. The next steps of the presented methodology allow for:

- reducing interpretation errors and increasing the reliability of conclusions,
- deep understanding of the implementation context and the specifics of local conditions,
- understanding the basis for assessing the consistency of the strategy with real actions.

The analysed data covered the period from 2015 to 2024, which allowed to capture both the beginnings and the effects of the implementation of the latest instruments supporting eco-innovation.

3. Literature review

3.1. Definitions of eco-innovation (EU, OECD, National)

The concept of *eco-innovation* does not have a single, universally binding definition, which results from the interdisciplinary nature of this phenomenon and its dynamic development in various sectors of the economy and public policy. In the literature on the subject and strategic documents, there are a number of definitional approaches that take into account various aspects of eco-innovation – from technological to organizational and social.

One of the most frequently cited definitions comes from a report by the European Commission (2007), which defines eco-innovation as: *all forms of innovation that lead to significant and observable progress in achieving environmental objectives by reducing environmental impact or using natural resources more efficiently* (Eco-Innovation Action Plan, 2007).

A similar approach is proposed by the OECD, which defines eco-innovation as *the process of developing new products and services that contribute to sustainable development by reducing the negative environmental impacts of economic activity* (OECD, 2009).

In Polish strategic documents, such as the "National Smart Specialization" (KIS), eco-innovations are understood as activities that lead to the development and implementation of new or significantly improved products, processes, services and business models aimed at reducing pressure on the environment and promoting sustainable development.

In turn, the scientific literature indicates that eco-innovations include not only the technological aspect (e.g. energy-efficient devices), but also:

- organisational innovations (e.g. new models of management in waste management),
- social (e.g. changes in consumer lifestyles),
- systemic (e.g. transformations in spatial planning and urban mobility).

Horbach (2008) emphasizes that eco-innovation can be motivated by both external factors (legal regulations, social pressure) and internal factors (the need to reduce costs, increase efficiency, competitive advantage). Thus, eco-innovation is the result of synergy between technological possibilities, institutional conditions and changing social expectations. Selected

definitions of eco-innovation together with an analysis of the key elements of a given approach are shown in Tab. 1.

Definitions of eco-innovation differ by emphasis on technological, institutional, or social dimensions. Table 1 summarizes the most common definitions proposed by key international organizations.

Table 1.
Comparison of eco-innovation definitions

Source	Key elements
European Commission (2007)	Innovation reducing environmental impact and improving resource efficiency.
OECD (2009)	New products and services contributing to sustainable development.
National Environmental Policy 2030 (Poland)	Environmental technologies adding value throughout the product life cycle.
Fussler, James (1996)	Market value creation combined with reduced environmental footprint.

Source: own study.

To conclude the review, eco-innovation should be understood as an inherently interdisciplinary construct encompassing technological, organisational, social, and institutional change. There is broad agreement that its core purpose is to reduce environmental impacts and improve resource efficiency. The main differences between definitions lie in scope and emphasis—whether prioritising technology-driven advances, systemic transformations, or societal change. Policy documents adopt a pragmatic stance, whereas scholarly work aims for conceptual precision and completeness. Overall, eco-innovation emerges as a multidimensional, evolving framework that connects policy and scholarship and guides practice toward verifiable environmental improvements.

3.2. Typology of eco-innovation

Eco-innovation represents a crucial dimension of sustainable development, aiming to mitigate the negative environmental effects of urbanisation and promote more efficient resource use. In Europe, its development has been strongly driven by the transformation processes linked to the **European Green Deal** (EC, 2019) and related policy challenges such as climate-change adaptation, energy decarbonisation, circular-economy business models, and the introduction of zero-emission and waste-free production systems.

Eco-innovations can be classified according to different criteria and analytical perspectives, indicating that their emergence depends on the interaction between technology, public policy, and market dynamics (Rennings, 2000; Horbach et al., 2012; Hojnik, Ruzzier, 2016). Table 2 presents a condensed typology commonly used in urban sustainability research.

Table 2.
Typology of eco-innovation

Type of eco-innovation	Main Focus and examples
Technological	New or improved products and processes reducing emissions and resource use (e.g., renewable energy, energy-efficient lighting, wastewater treatment).
Organisational	Management and logistics models improving environmental performance (e.g., ISO 14001, sustainable supply chains).
Social	Behavioural and community innovations promoting sustainable practices (e.g., sharing economy, city bikes, community gardens).
Policy-driven	Innovations introduced through regulation or incentives (e.g., green public procurement, emission standards).

Source: own elaboration based on Rennings (2000), Horbach et al. (2012), and Hojnik, Ruzzier (2016).

Rennings (2000) proposed a further distinction between *innovations by effect*—those that generate positive environmental outcomes indirectly—and *innovations with intent*, explicitly designed for environmental improvement. This approach helps distinguish between solutions consciously aimed at improving the quality of the environment and those that produce ecological benefits as secondary effects. Such differentiation is especially relevant for urban management, where both deliberate environmental strategies and incidental benefits can support sustainable development.

The sources of eco-innovation are generally divided into *technology push*, *regulatory pull*, and *market pull* mechanisms (Rennings, 2000). Technology push stems from advances in science and industry, regulatory pull arises from legal and policy frameworks, and market pull reflects consumer and competitive pressures. Empirical studies indicate that the diffusion of eco-innovation depends on the interplay among these factors, supported by environmental standards, certification systems, and fiscal incentives (Chaudhuri, Mukhopadhyay, 2013).

The typology of eco-innovation highlights the interdependence of technological, organisational, social, and policy dimensions. Understanding these relationships allows policymakers and urban practitioners to identify effective mechanisms that foster the green transformation of cities and to integrate innovation processes into comprehensive sustainable-development strategies.

3.3. Urban Eco-Innovations

Cities, as the main centers of resource consumption and pollutant emissions, are key arenas for testing and implementing eco-innovations. Within the urban context, these innovations aim to improve air quality, reduce CO₂ emissions, increase the energy efficiency of buildings and infrastructure, and strengthen systems for water and waste management. They also promote sustainable mobility, climate adaptation through green and blue infrastructure, and civic participation in environmental education (United Nations Human Settlements Programme, 2020).

For the purposes of this study, **urban eco-innovation** is defined as new or improved products, services, processes, or technologies implemented in cities that effectively reduce the negative environmental impact of urban activities, enhance resource efficiency, and improve residents' quality of life. Their distinguishing feature lies in their ability to generate both ecological and socio-institutional value by integrating technological solutions into planning, infrastructure, and decision-making processes. Local governments—through public procurement, spatial planning, transport, education, and municipal management—play a decisive role in creating a favorable regulatory, financial, and organizational framework (European Commission, 2019).

Cities can act as 'urban living labs', where innovative solutions are tested in real-world conditions, with the active participation of citizens and stakeholders. These are spaces where environmental innovations are tested in real urban conditions, with the active participation of residents, local governments, the private sector, science and non-governmental organizations. Urban Living labs combine scientific research with urban practice, allowing you to quickly test the effectiveness of new solutions through micro-scale experimentation before the solutions are implemented at the city-wide level. It is very important that this way of introducing innovations promotes social participation. Residents are not only recipients of innovations, but also co-creators.

Examples of leading European urban living labs are presented in **Table 3**, showing different approaches to integrating eco-innovation into sustainable city management.

Table 3.
Typology of eco-innovation

City / Initiative	Main focus areas	Key outcomes / lessons
Amsterdam – Amsterdam Smart City	<i>Energy efficiency in buildings, electric mobility, shared transport, smart street lighting</i>	Integration of digital technologies and citizen participation in sustainable urban management
Copenhagen – Climate Neutral Strategy	Green and blue infrastructure, innovative bicycle transport, air-quality monitoring	Climate adaptation and data-driven management of urban systems
Vienna – Smarter Together (Horizon 2020)	<i>Energy-efficient housing retrofits, electromobility, creation of social spaces</i>	Collaborative innovation through EU-funded pilot projects and social inclusion

Source: own elaboration based on Amsterdam Smart City (2020), City of Copenhagen (2021), and Smarter Together Vienna (2020).

These examples demonstrate that urban living labs accelerate the testing and implementation of eco-innovations, strengthen interdisciplinary cooperation, and increase public acceptance of environmental projects. They also reveal the importance of linking technological, social, and institutional innovation in urban-development strategies, creating a foundation for the long-term transition toward climate-neutral cities.

As shown in Figure 1, the main determinants of urban eco-innovation include technological factors, social demand, regulatory frameworks, and urban strategies.

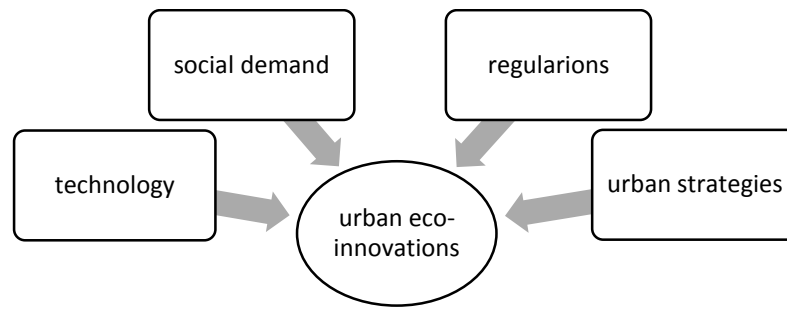


Figure 1. Determinants of urban eco-innovation.

Source: own elaboration based on Horbach, Rammer, Rennings (2012).

According to the literature, the main determinants of eco-innovation are technology, market forces, regulations, and company strategies (Horbach, Rammer, Rennings, 2012). In the urban context, these factors can be translated into:

- technologies that include modern infrastructure and digital systems such as smart energy grids, air-quality sensors, sustainable public transport, waste management systems, and energy-efficient construction;
- social demand arising from residents' expectations for sustainable services and public spaces;
- regulations concerning environmental protection, building standards, low-emission zones, and financial incentives;
- urban strategies defining development visions, cooperation programmes, and strategic goals (e.g., *smart city*, *resilient city*). Together, these components create the institutional and market framework for eco-innovation and determine its pace and scale.

Social and institutional capital are key factors in the generation and implementation of eco-innovations. They reflect the ability to build cooperation, trust, and partnership among urban actors. High social capital strengthens innovation processes through coordination, knowledge exchange, and resource mobilisation. Residents play a major role as co-creators of innovation: their attitudes and behaviours stimulate demand for eco-friendly solutions such as community gardens, zero-waste initiatives, and participation in public consultations. Shared services like car-sharing or city bikes also foster environmental awareness. Analyses of urban case studies confirm that citizen engagement increases both the acceptance and sustainability of implemented projects.

Non-governmental organisations and public institutions have a crucial role in implementing eco-innovations. NGOs, acting as intermediaries between communities and city authorities, mobilise residents for environmental activities and education. Municipal governments coordinate and regulate implementation processes, providing legal, financial, and organisational frameworks. Promoting cross-sectoral cooperation through participatory tools—such as citizens' budgets, sustainability councils, and civic panels—helps scale successful pilot projects into strategic programmes, fostering the *diffusion of innovation*.

The greatest effects are achieved when residents, NGOs, and public institutions cooperate. Such collaboration combines expert and local knowledge, enables better adaptation of solutions to social needs, and ensures legitimacy and social acceptance of innovation. Examples include local energy plans (*Amsterdam Energy Transition*), participatory spatial planning with citizens' panels in Vienna, and Warsaw's citizens' budget supporting ecological micro-innovations like green stops and community gardens.

The success of eco-innovation also depends on the cultural dimension, which shapes social acceptance and readiness to use new solutions. Environmental education and cooperation with research centres play a crucial role. High environmental awareness fosters faster adaptation of shared transport, waste segregation, and circular-economy systems. Scandinavian countries exemplify this approach, where a culture of simplicity, thrift, and closeness to nature encourages public support for innovation. Similarly, Japan's tradition of recycling and reusing resources facilitates the implementation of circular-economy practices.

A decisive factor for effective eco-innovation is **financial management**, ensuring access to capital and reducing investment risk. Proper financial instruments enable infrastructure projects, experimentation, and technology scaling. Across Europe and Poland, the EU's Structural and Investment Funds, the Cohesion Fund, Horizon Europe, and LIFE Programme support energy efficiency, circular economy, and low-emission mobility. At the national level, the *National Fund for Environmental Protection and Water Management (NFEP&GW)* and regional funds co-finance local projects. Other instruments include *green bonds*—used by cities such as Paris and Gothenburg to finance public transport modernisation and green infrastructure—and *public-private partnerships (PPPs)* that share costs and risks while accelerating innovation.

Table 4.
Financial instruments supporting urban eco-innovation

Instrument/Mechanism	Main purpose and examples	Key benefits
EU Structural and Investment Funds (Cohesion Fund, Horizon Europe, LIFE)	Financing projects in energy efficiency, circular economy, and low-emission mobility across EU member states.	Long-term, stable funding; supports large-scale infrastructure and research projects.
National and regional funds (<i>NFEP&GW</i> , regional environmental funds)	Co-financing local-government initiatives such as renewable energy, waste-management systems, and sustainable transport.	Facilitates municipal participation; complements EU programmes.
Green bonds (e.g., Paris, Gothenburg))	Bonds issued by cities to fund pro-environmental projects such as public-transport modernisation or green infrastructure	Attracts private investors; promotes transparency and accountability.
Public-private partnerships (PPPs)	Shared investments in renewable energy, energy-efficient buildings, or water and sewage systems.	Distributes risks and costs; accelerates implementation of innovative solutions.

Source: own elaboration based on European Commission (2023), NFEP&GW (2024).

These instruments together create a diversified and complementary funding ecosystem. By combining EU, national, and local sources with private-sector participation, cities can accelerate innovation, lower financial risk, and enhance long-term sustainability.

Urban eco-innovation integrates technological, institutional, financial, and social dimensions of sustainability. Its success depends not only on advanced technologies but also on civic participation, effective governance, cultural readiness, and well-designed financial frameworks. Understanding these interconnections enables policymakers to design adaptive, inclusive, and resilient strategies for sustainable urban transformation.

4. Examples of good practices for implementing eco-innovations in Polish cities

4.1. Building urban competences

In Poland, a significant shift in large-city management priorities is visible — from traditional infrastructural approaches to strategies focused on adaptive capacity, environmental awareness, and inclusiveness. In 2022, ten Polish cities joined the EU Mission: Climate-Neutral and Smart Cities, aiming to achieve climate neutrality. By 2023, five of them — Warszawa, Kraków, Łódź, Wrocław, and Rzeszów — received the EU Cities Mission Label after expert evaluation. In 2024, these cities gained access to the Capital Hub platform, which offers technical, financial, and advisory support for climate adaptation projects.

Building urban competences in eco-innovation management is one of the main conditions for successful implementation. Cities must strengthen technical and organisational skills, develop cross-sectoral cooperation capacities, and improve social communication and environmental education. Competence development should include strategic planning, fundraising, project management, and monitoring technological innovations. Recommended activities involve training programmes for public officials, partnerships with universities and research institutes, establishing *urban living labs*, and creating platforms for knowledge exchange and pilot projects testing innovative solutions.

Strengthening administrative and social competences enhances the adaptive capacity of cities, enabling effective collaboration between residents, academia, business, and public institutions — a prerequisite for sustainable transformation.

4.1.1. Warszawa

Warszawa actively implements eco-innovations aimed at climate adaptation and improving residents' quality of life. Its actions combine infrastructural investments and community programmes. The city greens public spaces, revitalises water reservoirs, and greens tram tracks to enhance air quality and increase rainwater retention. These initiatives support flood protection and sustainable water management.

As shown in Figure 2, the *Czajka Wastewater Treatment Plant* represents a key eco-innovation in energy-efficient water processing.



Figure 2. Czajka Wastewater Treatment Plant in Warsaw - an example of eco-innovation.

Source: Wodociągi Warszawskie. (2025, September 21). *Zakład "Czajka"*. Retrieved September 21, 2025, from <https://www.mpwik.com.pl/view/zaklad-czajka>

Warszawa involves residents in eco-innovation through subsidy programmes for local environmental projects and the publication of the *Warsaw Environmental Decision* guide promoting green building and low-emission standards. Selected districts, such as Praga Południe and Ursynów, operate as *urban living labs*, where advanced environmental technologies are tested before wider implementation.

Warszawa integrates technological, social, and spatial eco-innovations, using pilot districts as testing grounds for scalable environmental solutions.

4.1.2. *Kraków*

Kraków participates in the EU NetZeroCities initiative and focuses on reducing greenhouse gas emissions, particularly in the building sector. The *NEEST Project* aims to improve energy efficiency through large-scale retrofitting of 1970s residential blocks (see Figure 3).

Kraków collaborates with the National Centre for Research and Development (NCBR), Energy Forum, and National Centre for Nuclear Research (NCBJ) to integrate scientific knowledge with practical experience. This cooperation has led to the creation of a digital tool supporting deep thermal modernisation planning for residential and public buildings. Eco-innovations implemented in Kraków include advanced construction technologies, green investment models, revitalisation of urban spaces, and citizen engagement in the energy transition.

Kraków demonstrates how institutional partnerships and digital tools enhance the efficiency of eco-innovation implementation, particularly in climate-oriented projects.



Figure 3. NEEST project - modernization of blocks from the 70s - an example of eco-innovation.

Source: Wodociągi Warszawskie. (2025, September 21). *Zakład "Czajka"*. Retrieved September 21, 2025, from <https://www.mpwik.com.pl/view/zaklad-czajka>

4.1.3. Łódź

Łódź addresses environmental degradation and high energy consumption while capitalising on its industrial heritage and research potential. Its priorities include expanding green areas, improving water retention, and adapting to climate change through green–blue infrastructure that cools urban areas and reduces flooding.

As shown in **Figure 4**, projects such as the greening of tram tracks illustrate this strategy.



Figure 4. Greening of tram in Łódź.

Source: Sztuka Krajobrazu. (2025, September 21). *Zielona rewolucja w Łodzi w 2025 r.* Retrieved September 21, 2025, from <https://sztuka-krajobrazu.pl/5750/arttykul/zielona-rewolucja-w-lodzi-w-2025-r>

The city modernises residential and public buildings, integrating renewable energy technologies such as photovoltaic systems and heat pumps. It also invests in low-emission public transport, cycling infrastructure, and shared mobility. Digital innovations include smart lighting, air-quality monitoring, and platforms supporting urban planning and citizen communication. *Urban Living Labs* enable cooperation between residents, universities, and private companies.

Łódź combines adaptive infrastructure with digital tools and participatory mechanisms, creating an integrated model of sustainable urban governance.

4.1.4. Wrocław

Wrocław, one of Poland's largest urban centres, faces the challenge of balancing dynamic development with environmental protection. The city has long invested in **green–blue infrastructure** to counteract heat waves and flooding, including the construction of rainwater retention systems, new reservoirs, and riverbank revitalisation. Urban greenery—parks, rain gardens, and green stops—plays a key role in improving air quality and comfort.

Figure 5 presents an example of visible architectural greening supporting Wrocław's green city vision.



Figure 5. The green façade of the Municipal Office building at Świdnicka Street.

Source: Wrocław.pl. (n.d.). *Zielona Stolica Europy – Wrocław na zielono*. Retrieved from <https://www.wroclaw.pl/zielony-wroclaw/wroclaw-zielona-stolica-europy-parki-kieszonkowe-zielone-sciany-parklety-woonerfy>

Wrocław also modernises public buildings through energy retrofits and PV installations, supports prosumer energy, and develops low-emission transport. Smart-city tools (air-quality monitoring, traffic optimisation, and smart lighting) are integrated with *Urban Living Labs*, where residents and universities test solutions in real conditions.

Wrocław links infrastructure renewal with social innovation and digital transformation, illustrating a holistic model of climate-neutral urban development.

4.1.5. Rzeszów

Rzeszów, one of five Polish cities with the **EU Cities Mission Label (2023)**, invests in renewable energy and smart technologies. The city promotes photovoltaic systems on public buildings, heat pumps, and energy storage, supporting prosumer investments through subsidies and partnerships.

Figure 6 illustrates one of Rzeszów's flagship smart-city projects.



Figure 6. Smart waste bins.

Source: MZBM Rzeszów. (n.d.). *Rzeszów testuje inteligentne pojemniki na odpady – innowacja na terenie zarządzanym przez MZBM Rzeszów*. Retrieved from <https://mzbm.rzeszow.pl/rzeszow-testuje-inteligentne-pojemniki-na-odpady-innowacja-na-terenie-zarzadzany-przez-mzbm-rzeszow/>

4.1.6. Gliwice

Gliwice, a leading city in the Upper Silesia–Zagłębie Metropolis, integrates innovation with academic collaboration. Many eco-innovations result from cooperation with the Silesian University of Technology, enabling the development of advanced green technologies.

The upcoming *Green Energy Park*—a combined heat and power facility—will generate energy from residual municipal waste starting in 2028. The city also piloted the BB-1 autonomous electric minibus project (Figure 8.) developed jointly with the Silesian University of Technology and the University of Silesia. The prototype, tested in 2023 under the *Urban Living Lab* model, carried over 3000 passengers and received positive public feedback.



Figure 7. Green Energy Park.

Source: gov.pl. (n.d.). *Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej – NFOŚiGW przeznaczy ponad 270 mln zł na Park Zielonej Energii w Gliwicach*. Retrieved from <https://www.gov.pl/web/nfosigw/nfosigw-przeznaczy-ponad-270-mln-zl-na-park-zielonej-energii-w-gliwicach>

Gliwice continues to expand e-mobility, traffic-management systems, and urban greening, counteracting heat islands and improving public-space aesthetics. Collaboration between academia, the city, and private industry supports the diffusion of eco-innovation and the development of smart solutions in energy, transport, and planning.



Figure 8. BB-1 Autonomous Electric Minibus.

Source: Dzisiaj w Gliwicach. <https://dzisiajwgliwiczach.pl/przyszlosc-jest-tu-i-teraz-stworzony-w-gliwicach-minibus-rusza-w-droge-bez-kierowcy/?cn-reloaded=1>

Gliwice exemplifies successful science–city partnerships that turn innovation into practical, resident-oriented eco-solutions.

4.2. Eco-innovations in cities – sector analysis

The examples of Polish analysed above show that contemporary urban policy increasingly integrates technological innovation with social participation and sustainable spatial development. Eco-innovation is no longer viewed merely as a set of technological projects but as a systemic process that transforms the way cities function, manage resources, and engage residents. This evolution responds to the rapidly changing expectations of urban communities, shaped by digitalisation, climate awareness, and new models of participatory governance.

Urban eco-innovation reflects a multidimensional transformation linking environmental performance, technological progress, and social well-being. The main directions of this transformation include the implementation of green and blue infrastructure improving microclimate and biodiversity (Warszawa, Łódź, Wrocław), energy-efficient construction and retrofits contributing to urban decarbonisation (Kraków’s NEEST project), and integration of technology in public space through solar benches, environmental sensors, and other smart solutions (Warszawa, Rzeszów). The spread of IoT-based systems enables dynamic management of energy, transport, and waste (Gliwice, Rzeszów), while augmented reality (AR) increasingly supports environmental education and civic engagement.

According to the literature, cities can be analysed by their dominant economic sectors—agriculture, industry, and services—each defining a distinct pathway of sustainable transformation.

- **Agro-technological cities**, such as *Almería (Spain)*, combine precision agriculture with renewable energy and technological services. Although agriculture plays a minor role in large Polish cities, its principles inform peri-urban planning and local food resilience strategies.

- **Industrial cities**, including *Łódź* and *Gliwice*, use eco-innovation to revitalise degraded post-industrial areas, transforming them into mixed-use districts focused on education, culture, and circular production. This mirrors European trends linking industrial regeneration with the circular economy.
- **Service-oriented cities**, such as *Warszawa*, *Kraków*, and *Wrocław*, prioritise digitalisation, smart mobility, and citizen-centred innovations, demonstrating how eco-innovation can serve as a governance tool that improves quality of life and environmental resilience.

European experiences complement these patterns. *Bergen (Norway)* integrates landscape and climate neutrality in spatial policy, while *Almería (Spain)* represents the synergy between agriculture, technology, and sustainability. Together, they show that effective eco-innovation depends on aligning environmental goals with local economic and institutional contexts.

A summary of the sector analysis is provided in Table 5.

Table 5.

Selected typologies of eco-innovation

Urban area	Physical Elements/ Infrastructure	Digital/ Smart Elements	Design Notes
Transport and mobility	Hybrid Electric Vehicles, EV Charging Stations, City Bike & Bike Stations, Smart Stops/Shelters, Parking Lots with EV Spaces	Traffic Control Systems, Car-Sharing / Bicycle Mobile Apps, Traffic Monitoring	Places for chargers, bicycle stops and stations, space for EV parking lots, integration with the Smart City system should be provided
Energy and buildings	Passive/Energy Efficient Buildings, Photovoltaic Panels, Solar Benches & Solar Lighting, Smart LED Street Lights	Energy Management Systems (EMS), Energy Consumption Monitoring and Network Load Optimization	Plan PV panel spaces, grid access, and easy equipment maintenance
Water and water and sewage management	Retention Reservoirs & Ponds, Green Area Irrigation Systems, Water Treatment Plants	Water Quality Monitoring, Irrigation Control Systems, Weather Data and Water Consumption Analysis	Provide land reserves for reservoirs and rainwater, integration with the Smart City system for optimization
Greenery and public space	Community gardens, green roofs and walls, Benches and pergolas with solar function, Eco-friendly playgrounds	Soil moisture and planting monitoring systems, Intelligent management of public space	Provide space for solar benches and gardens, integration with other systems (energy, water)
Infrastruktura IT / Smart City	Wi-Fi Points, Smart Air, Noise, Motion Sensors, Telemetry Stations & Local Servers	Urban Data Integration (IoT) Systems, Analytics & Prediction Platforms, Citizen Applications	Necessary network infrastructure, space for sensors and nodes, compatibility with other urban systems
Education and environmental awareness	Information boards in public spaces, Interactive ecopoints in parks and schools	Educational mobile apps, Energy/water monitoring platforms for residents	Placement of points in accessible locations, integration with educational programs
Health and quality of life	Urban greenery, recreational areas, Air filters in sensitive places, Bicycle and pedestrian paths	Air quality monitoring, Smog or excessive noise warning systems	Design with accessibility and security in mind, integration with Smart City systems

Source: own elaboration based on municipal and European smart-city strategies (2019-2025).

5. Factors conducive to the implementation of eco-innovations in cities in Poland

Building upon the preceding discussion on good practices and the development of urban competences that facilitate eco-innovation, this section explores the broader set of factors that enable their effective implementation in Polish cities. It aims to identify and analyse the institutional, social, economic, and environmental determinants that create favourable conditions for the diffusion of eco-innovative solutions. By examining these interrelated dimensions, the section provides a deeper understanding of the systemic foundations that underpin the successful transformation of Polish cities towards sustainability.

5.1. Institutional and legal instruments

5.1.1. National and EU regulations supporting sustainable development

Legal frameworks at both EU and national levels form the foundation for implementing sustainable development policies and creating conditions for eco-innovation. The European Green Deal (2019) establishes a roadmap toward climate neutrality by 2050, operationalised through instruments such as the Fit for 55 package, the EU Taxonomy, and sectoral directives on energy efficiency (2012/27/EU), renewable energy (RED II, RED III), and the circular economy. These are reinforced by financial mechanisms such as the Just Transition Fund and Horizon Europe, which stimulate innovation and environmental protection.

In Poland, the Environmental Policy of the State 2030 defines national priorities, linking environmental goals with socio-economic development. It is complemented by key sectoral acts, including the *Environmental Protection Law* (2001), the *National Energy and Climate Plan 2021-2030*, the *Renewable Energy Sources Act* (2015), and the *Circular Economy Strategy 2030*. Together, these documents form a coherent policy framework promoting energy efficiency, resource management, and biodiversity conservation.

However, their practical impact is constrained by uneven enforcement and weak coordination between national, regional, and municipal levels. Although Polish legislation aligns with EU objectives, implementation delays and limited administrative capacity often reduce the effectiveness of these frameworks at the city level.

5.1.2. Green Public Procurement Policy

Green Public Procurement (GPP) is one of the most effective instruments for stimulating eco-innovation through market demand. As the public sector accounts for nearly 14% of EU GDP (European Commission, 2016), local governments can significantly influence innovation pathways by integrating environmental criteria into tenders.

Polish cities have begun applying GPP in transport, construction, and waste management — for instance, purchasing electric buses, LED street lighting, or certified sustainable buildings (BREEAM, LEED). However, despite the strong regulatory base, adoption remains fragmented

and inconsistent. Barriers include low awareness among procurement officers, lack of training, fear of litigation when using restrictive criteria, and limited availability of certified products.

GPP's potential to drive innovation is thus underutilised: it remains more a policy ambition than a systemic practice. A stronger institutional culture, clearer national guidelines, and incentives for municipalities are necessary to unlock its transformative potential.

5.2. Technology certification and verification mechanisms

5.2.1. Environmental Technology Verification (ETV)

Environmental Technology Verification (ETV), established under ISO 14034, serves as a vital mechanism for building credibility and trust in eco-innovation. It provides independent verification of manufacturers' claims regarding technological performance, confirming their validity under real operating conditions. Unlike traditional certification systems based on uniform criteria, ETV enables the selection of verification parameters suited to innovative solutions that often exceed regulatory standards or fall outside conventional assessment methods. Introduced by the European Commission in 2012 within the Eco-Innovation Action Plan (EcoAP), the programme significantly supported the market entry of new environmental technologies and reduced investment uncertainty, particularly for small and medium-sized enterprises.

Although the EU-level initiative concluded in 2022, the ETV framework continues to operate through internationally harmonized standards. The ISO 14034: *Environmental Management – Verification of Environmental Technologies* standard, adopted in Europe in 2019, ensures methodological consistency, transparency, and reliability of results. Accredited Verification Bodies (ISO 17020) and laboratories (ISO 17025) safeguard quality and impartiality, while verification statements issued by independent entities confirm both the technological and environmental performance of innovations. This, in turn, strengthens market confidence, lowers investment risk, and promotes wider adoption of eco-innovative solutions across urban and industrial contexts.

5.2.2. Environmental Certifications

Eco-labelling and certification systems such as the *EU Ecolabel*, *Blue Angel*, and *Nordic Swan* play a dual role as both market mechanisms and regulatory tools. They encourage producers to adopt environmentally friendly technologies and help consumers and public institutions make informed choices.

In urban contexts, certifications are widely used in GPP procedures — for example, as selection criteria for sustainable construction materials or energy-efficient equipment. Beyond procurement, certification schemes raise awareness among residents and promote a culture of sustainability and innovation. However, their voluntary character and lack of enforcement mechanisms reduce their systemic impact.

To increase their effectiveness, certifications should be more closely tied to fiscal incentives, funding criteria, and urban management standards, turning them from symbolic recognitions into practical drivers of transformation.

5.3. Financial support and grant programs

5.3.1. EU and national funds supporting urban eco-innovation

The development of eco-innovations in the urban environment would not be possible without adequate financial resources, which enable both research on new technologies and their practical implementation in the urban space. In this context, EU and national funds are of particular importance, as they are a basic tool for supporting the transformation of cities towards sustainable development.

One of the most important sources of funding at the national level is the European Fund for Infrastructure, Climate and Environment (FEnIKS), which replaced the previous Infrastructure and Environment Programme (OPliŚ). This programme supports investments aimed at improving energy efficiency, developing low-emission transport, protecting environmental resources and adapting to climate change. In the urban area, FEnIKS enables the financing of projects such as the modernization of heating networks, the development of renewable energy sources or the introduction of innovative solutions in waste management.

At the EU level, the LIFE Programme plays a key role, being the only financial instrument of the European Union entirely dedicated to environmental protection and climate action. This program supports demonstration and pilot projects that test new solutions in the field of natural resource protection, reduction of greenhouse gas emissions, improvement of air quality or resource efficiency. Climate change adaptation measures such as green-blue infrastructure, rainwater retention systems and low-emission public transport are particularly important for cities.

An equally important instrument is the Horizon Europe research and innovation programme (2021-2027), one of the pillars of which focuses on supporting research and innovation related to the European Green Deal. This program enables financing of projects related to the energy transition, digitization of urban infrastructure, implementation of intelligent transport management systems or the development of the circular economy.

It is worth noting that EU funds are often supplemented by national instruments, such as the support offered by the National Fund for Environmental Protection and Water Management (NFOŚiGW), which finances projects related to improving energy efficiency, the use of RES, air protection and modern waste management. Coordination of activities between the national and EU levels increases the capacity of cities to obtain funds for the implementation of innovative environmental projects.

Thanks to national and EU funds, it is possible not only to finance costly infrastructure investments, but also to support research, testing of new solutions and their dissemination in urban practice. As a result, these mechanisms are the basis for the implementation of sustainable

development policies and the effective implementation of the European Green Deal at the local level.

As a discussion and critical remarks one should underline strong framework with gaps in enforcement. The legal and institutional frameworks at both EU and national levels provide a comprehensive foundation for the implementation of eco-innovations in Polish cities. Instruments like the European Green Deal, the Fit for 55 package, and Poland's Environmental Policy of the State 2030 present clear targets and strategic directions.

However, the effectiveness of these instruments is often undermined by implementation challenges. Despite the existence of progressive legal mechanisms, Poland has frequently been criticized for delays in adopting EU directives and inconsistent enforcement of environmental regulations. Additionally, the coordination between different levels of government (national–regional–local) can be fragmented, which reduces the practical impact of these policies on urban innovation.

Green Public Procurement (GPP) is presented as a powerful catalyst for eco-innovation. Its strategic importance is undeniable, especially considering the public sector's purchasing power. Yet in practice, Polish cities still struggle to systematically implement GPP policies. Barriers include:

- low awareness among procurement officers,
- insufficient training or guidance,
- fear of legal disputes when environmental criteria limit competition,
- limited availability of certified green products/services.

Thus, while the legal basis exists, GPP in Poland remains more of a policy ambition than a widespread practice.

Environmental Technology Verification (ETV) and eco-labels undoubtedly help increase transparency, reduce investment risk, and encourage consumer and institutional trust in green solutions. These mechanisms are especially important for SMEs developing new environmental technologies. However:

- the voluntary nature of these certifications reduces their penetration,
- lack of incentives or regulatory mandates to prioritize certified technologies weakens their market impact,
- the termination of the EU ETV pilot programme in 2022 may further reduce visibility and interest in verification systems unless a strong replacement is implemented.

EU and national funds such as FEnIKS, LIFE, Horizon Europe, and NFOŚiGW programmes represent robust financial foundations for urban eco-innovation in Poland. These programmes support both infrastructure modernisation and innovation development.

It should be stressed that critical issues remain:

- administrative complexity and bureaucratic hurdles can discourage smaller municipalities,
- competition for funding is high, favouring larger, better-prepared cities,

- monitoring and evaluation mechanisms of funded projects are not always rigorous, leading to a gap between declared outcomes and real environmental impacts.

Eco-innovation in Polish cities is supported by a broad and well-developed system of instruments across regulatory, procurement, verification, and financial dimensions. However, a recurring pattern emerges: excellent strategic frameworks but uneven implementation.

Table 6.
Strengths and challenges of eco-innovation in Poland

Strengths	Challenges
• Alignment with EU green policy (Green Deal, Fit for 55, taxonomy). • Access to diversified financial support • Growing awareness of the role of public procurement and certification. • National strategies linking sustainability with economic development.	• Weak enforcement and regulatory compliance. • Low uptake and institutional resistance to GPP. • Limited penetration of technology verification tools. • Complex and competitive grant application procedures.

To effectively transition to a sustainable and innovative urban model, Polish cities must not only rely on existing instruments but also:

- strengthen local administrative capacity,
- increase institutional cooperation,
- simplify access to support programmes,
- promote mandatory or incentivised use of green criteria and certifications.

Without addressing these systemic issues, the implementation of eco-innovations risks remaining fragmented and insufficient, despite solid legal and financial foundations. It is also very important that eco-innovation is not only about technologies but also about the systems, governance, and culture that enable them to thrive.

6. Barriers to eco-innovation in Polish cities

The implementation of eco-innovations in the urban environment is also associated with challenges, such as: fragmentation of competences, financial shortages, cultural barriers and social resistance to change. Therefore, an integrated and long-term approach that combines technological innovation with educational, institutional, and participatory activities is crucial (Instytut Rozwoju Miast i Regionów, 2022).

In view of increasingly strict EU environmental standards — particularly those stemming from the Europe 2030 Strategy — Poland must align its environmental performance with that of other Member States. This poses a significant challenge, as it requires catching up on decades of underinvestment in environmental protection (Piotrowska, 2012). According to the State of the Environment in Poland 2022 report, *Expenditures on environmental protection and water*

management remain at a very low level relative to GDP (Główny Inspektorat Ochrony Środowiska, 2022).

Since 2010, Poland has been among the countries with the lowest eco-innovation index in the Ecoinnovation Scoreboard, which contains a comparative assessment of European Union Member States in the field of research and innovation (European Commission, 2023). Compared to all countries, this result is significantly below the average. What is the main barrier, apart from the lack of public sector funding? *The Eco-Innovation Country Profile 2022 report* identifies key barriers to the introduction of eco-innovation in Poland.

From the consumer perspective, *greenwashing* remains a major issue, leading to distrust in environmentally friendly products and making it difficult to distinguish genuine innovation from marketing. Price sensitivity also limits the demand for ecological goods, while a lack of awareness of the circular economy concept slows the adoption of sustainable consumption patterns.

For enterprises, the main obstacles include late notification of legislative changes, ambiguities in legal provisions, and a lack of financial incentives to invest in innovation. Entrepreneurs point to complex and inconsistent regulations that complicate adaptation and increase uncertainty. Many companies also note that administrative procedures and overly restrictive interpretations of environmental law can discourage experimentation and innovation.

At the strategic level, the *Environmental Policy of the State 2030 – Development Strategy in the Area of Environment and Water Management* (Republic of Poland, 2019) identifies barriers such as low expenditure on R+D+I (Research, Development, Innovation), fragmented programmes with differing goals and operators, and a lack of measurable environmental indicators. The document also highlights the absence of a national database of environmental technologies, which could provide reliable information on available and emerging innovations. This information gap weakens coordination between research, industry, and public policy.

Despite eco-innovation being one of the most dynamically developing global markets — even surpassing ICT and pharmaceuticals in growth — the Polish capital market remains only moderately interested in financing environmental technologies (Republic of Poland, 2023). As noted by Burzyńska & Hajdys (2021), most companies engaged in eco-innovation concentrate on technological aspects, neglecting organisational changes, knowledge management, and human capital development — elements that are equally essential for sustainable innovation.

7. Discussion

The findings presented in this paper confirm that the effective implementation of eco-innovations in Polish cities depends on the integration of institutional, financial, and social factors. This result is consistent with the conclusions of Horbach, Rammer and Rennings (2012), who emphasized the complementary role of regulatory push/pull and market demand in shaping environmental innovation. Similarly, Szymańska (2016) pointed out that urban eco-innovation requires coordinated actions across governance, funding, and citizen engagement. However, the present study extends these frameworks by demonstrating that institutional capacity and administrative competence at the local level remain the decisive variables in the Polish context.

In comparison to other studies (Hojnik & Ruzzier, 2016; OECD, 2011; UN-Habitat, 2020), the results show that while the policy environment in Poland aligns with the European Green Deal, there is still a significant implementation gap. This confirms the observation made by the European Commission (2023) in the *Eco-Innovation Scoreboard*, where Poland ranked below the EU average. Our research identifies that this gap arises not only from financial constraints but also from fragmented governance and low awareness among decision-makers.

Compared with earlier works that focused mainly on technological or environmental determinants, this study contributes new empirical knowledge by linking eco-innovation with governance capacity and local participation. This perspective highlights the importance of cities as learning systems, where institutional learning is combined with social experimentation. The case studies from Warszawa, Kraków, Wrocław, Łódź, Rzeszów, and Gliwice illustrate that eco-innovations become effective only when local governments integrate technology deployment with participatory approaches and long-term planning. This finding extends the conceptual framework of urban eco-innovation beyond the technological dimension toward a socio-institutional model.

Our analyses provide an integrated view of eco-innovation processes in Polish cities and show their broader implications for urban development and sustainability governance. In general, the results confirm the initial hypothesis that institutional integration and social awareness are key drivers of eco-innovation. However, the study also reveals that Poland's urban policies remain overly centralized, which slows down the diffusion of innovation. Decentralization of decision-making, combined with stronger financial incentives for municipalities, could significantly enhance the practical implementation of eco-innovations.

In relation to previous research, the novelty of this study lies in identifying governance-based eco-innovation as an emerging model of urban sustainability in Central Europe. While previous studies by Horbach et al. (2012) and Hojnik & Ruzzier (2016) analysed primarily the technological and economic dimensions, this paper demonstrates the interdependence between institutional capacity, civic participation, and adaptive management. The results also expand

the theoretical framework of eco-innovation by including urban governance, planning, and data-driven management as central determinants of success.

Furthermore, this study shows that eco-innovation should be considered not merely a technological process but a systemic transformation linking public policy, economy, and society. Similar conclusions were reached by Caragliu, Del Bo & Nijkamp (2011) and Batty et al. (2012) in the context of smart and sustainable cities. Polish cities follow this trend, albeit at a slower pace, gradually shifting from compliance-based policy models to adaptive and participatory governance frameworks.

The significance of this analysis lies in its interdisciplinary approach, combining perspectives from management, architecture, and data analysis. From the management perspective, eco-innovation requires coherent governance and institutional learning. From the perspective of urban design, cities act as physical laboratories where green infrastructure, compact spatial planning, and energy-efficient buildings demonstrate measurable benefits. Finally, from the data analytics perspective, smart systems, AI tools, and urban platforms enhance monitoring and decision-making, supporting long-term sustainability.

The study has certain limitations. The data were mainly derived from secondary sources and desk research, which may limit the precision of quantitative assessment. The case studies focused on large cities; smaller municipalities may face different institutional and financial conditions. Therefore, future research should include comparative quantitative analysis across cities of different sizes and governance capacities, combining GIS tools, data science, and social research methods.

In conclusion, the findings indicate that Poland's path toward sustainable urban transformation through eco-innovation is evolutionary rather than revolutionary. The effectiveness of eco-innovation depends less on technological advancement itself than on the ability to build coherent, participatory, and data-informed governance systems. This result confirms that the hypothesis formulated at the beginning of the study was correct and highlights the importance of integrating diverse disciplinary and sectoral perspectives to strengthen the adaptive capacity of cities.

8. Conclusions

Eco-innovations are most effective when implemented at the level of districts or entire cities, as this allows for scale and systemic impact. It is crucial to involve multiple stakeholder groups – residents, local authorities, scientific institutions and the private sector – in order to implement a coherent sustainability strategy. Educating the public is particularly important, as technology alone is not enough to achieve sustainable environmental effects. It is also necessary to change attitudes, habits and increase environmental awareness. In order for the

local community to really want to get involved, appropriate incentives are needed – both informative and financial. Financing models should be flexible and adapted to local realities and the level of acceptable risk, which increases their effectiveness and scalability.

Poland has a significant potential in the implementation of eco-innovations, both due to the scale of urbanization and the growing activity of local governments and civil society. There is also an increasing emphasis on climate education, the development of renewable energy sources, improving the energy efficiency of buildings and the modernization of public transport. These activities, supported by EU funds and local strategies, indicate a positive direction and growing readiness of Polish cities to implement comprehensive eco-innovations.

The determinants of urban eco-innovation are not a static category – their importance and nature can evolve with global technological, social and environmental trends. In the perspective of the coming decades, three megatrends will be of particular importance: digitization and artificial intelligence, climate and energy crises, and demographic change.

It should be emphasized that the development of digitalisation and artificial intelligence (AI)-based tools is radically changing the way eco-innovations are designed, monitored and implemented in cities. Intelligent energy management systems based on AI algorithms allow for real-time optimization of resource consumption by integrating renewable energy sources, energy storage and transport infrastructure. Thanks to the use of big data technology and the Internet of Things (IoT), it is possible to diagnose environmental problems more accurately – from air quality to effective waste management. The data collected from city sensors is the basis for better informed public policy decisions.

Another factor changing the face of eco-innovation is artificial intelligence, which is used, among other things, in modelling and predicting the effects of climate change, enabling the creation of spatial planning tools adapted to future threat scenarios. As a result, one of the key determinants of the development of eco-innovation is the city's ability to integrate digital solutions with technical infrastructure, public services and management systems. Cities that can effectively combine data, technology and spatial policy will be able to implement sustainable and efficient green solutions faster. In the face of increasing extreme events, such as droughts, floods or heatwaves, cities will need to prioritise innovations that increase the resilience of infrastructure and the ability to adapt to climate change. At the same time, global and regional energy crises will accelerate the transition towards autonomous, distributed energy systems, based on local renewable sources and energy storage.

The importance of eco-innovations in the area of energy efficiency of buildings, transport and municipal services will grow steadily, as they will be treated not only as a tool for environmental protection, but also as an element of energy security. In this context, crisis pressure will become a determinant of the implementation of eco-innovations, cities will be forced to accelerate the introduction of new technologies not only for ecological reasons, but also to ensure the continuity of infrastructure and the safety of residents.

Demographic changes, such as population ageing and increased internal and international migration, are becoming another factor influencing the direction of eco-innovation. An ageing population will force the design of solutions that support the accessibility and inclusiveness of urban space – from energy-efficient, ergonomic buildings adapted to the needs of older people to environmentally friendly forms of public transport that provide mobility for seniors. Migration, in turn, will increase pressure on urban infrastructure and municipal service systems, but at the same time create the potential for the development of eco-innovations that integrate diverse cultural and social needs. In multicultural cities, there will be a need to introduce social eco-innovations that support the integration of migrants and promote pro-ecological attitudes in diverse communities.

As a result, the ability of local governments to adapt green solutions to the needs of different social groups will become a determinant of eco-innovation in cities, which requires flexible planning, social dialogue and an inclusive approach to sustainable development. To sum up, the development of eco-innovation in cities in the coming years will be determined by three interdependent processes: digitization and the development of artificial intelligence, pressure resulting from the climate and energy crises, and demographic and social changes. What they have in common is the need for flexibility, adaptation and integration of technology into public policies. The cities of the future will not only be technologically smart, but also socially sustainable and environmentally resilient.

Beyond these practical implications, this research also contributes to the broader academic debate on sustainable urban transformation. It highlights that eco-innovation is not merely a technological trend but a governance paradigm linking environmental, economic, and social dimensions of urban development. The study offers a conceptual and empirical framework that can be used for comparative analyses across different European regions and governance systems.

Critically, the research recognises its own limitations. The findings are based mainly on qualitative analysis and secondary data, and further empirical studies – including quantitative evaluation, stakeholder surveys, and longitudinal monitoring – are necessary to assess the long-term effectiveness of eco-innovation policies.

Nevertheless, the lessons learned from the Polish context can inform both policy and practice across the EU. The results may support the refinement of cohesion policy instruments, inspire city-level strategies within programmes such as *Krajowa Polityka Miejska 2030* or *EU Mission: Climate-Neutral and Smart Cities*, and guide local authorities in designing flexible, data-informed, and inclusive innovation systems.

Ultimately, the research underscores the importance of adaptive governance – the ability of cities to learn, experiment, and evolve in response to environmental and social challenges. The knowledge generated in this study provides a foundation for further research and action, offering a roadmap for transforming eco-innovation from individual initiatives into an integrated mechanism for achieving long-term urban sustainability.

References

1. Burzyńska, D., Hajdys, D. (2021). *Determinants and sources of financing eco-innovation in Polish enterprises. Folia Oeconomica. Acta Universitatis Lodziensis*. Łódź: University of Łódź.
2. Council of Ministers (2023). *Environmental Policy of the State 2030 – Development Strategy in the Area of Environment and Water Management*. Retrieved from: <https://www.gov.pl/web/srodowisko/polityka-ekologiczna-panstwa-polityka-ekologiczna-panstwa-2030>
3. *Dzisiaj w Gliwicach*. <https://dzisiajwgliwicach.pl/przyszlosc-jest-tu-i-teraz-stworzony-w-gliwicach-minibus-rusza-w-droge-bez-kierowcy/?cn-reloaded=1>
4. European Commission – Joint Research Centre (2018). *ETV – Environmental technology verification as a tool to support green innovation*. Retrieved from: <https://ec.europa.eu/jrc/en/publication/etv-environmental-technology-verification>
5. European Commission (2016). *Buying Green! A Handbook on Green Public Procurement*. Brussels: European Commission.
6. European Commission (2019). *The European Green Deal (COM(2019) 640 final)*. Brussels: European Commission.
7. European Commission (2021). *Public procurement for a better environment – Green Public Procurement (GPP)*. Retrieved from https://ec.europa.eu/environment/gpp/index_en.htm
8. European Commission (2023, July 30). *European Innovation Scoreboard 2023 and Regional Innovation Scoreboard 2023*. Retrieved from: <https://ec.europa.eu/research-and-innovation/en/statistics/performance-indicators/european-innovation-scoreboard/eis>
9. European Environment Agency (EEA) (2020). *Urban sustainability in Europe – What is driving cities' environmental performance?* Copenhagen: EEA.
10. Famielec, J., Stępień, B. (2018). Instrumenty ekonomiczne w ochronie środowiska w Polsce. *Ekonomia i Środowisko*, 1(64), 8-27.
11. Główny Inspektorat Ochrony Środowiska (2022). *Stan środowiska w Polsce. Raport 2022*. Warszawa: Biblioteka Monitoringu Środowiska. Retrieved from: <https://www.gios.gov.pl>
12. Główny Urząd Statystyczny (2023). *Ludność. Stan i struktura oraz ruch naturalny w przekroju terytorialnym*. Warszawa: Główny Urząd Statystyczny.
13. Gov.pl (n.d.). *Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej – NFOŚiGW przeznaczy ponad 270 mln zł na Park Zielonej Energii w Gliwicach*. Retrieved from: <https://www.gov.pl/web/nfosigw/nfosigw-przeznaczy-ponad-270-mln-zl-na-park-zielonej-energii-w-gliwicach>
14. Hojnik, J., Ruzzier, M. (2016). What drives eco-innovation? A review of an emerging literature. *Environmental Innovation and Societal Transitions*, 19, 31-41. <https://doi.org/10.1016/j.eist.2015.09.006>

15. Horbach, J., Rammer, C., Rennings, K. (2012). Determinants of eco-innovations by type of environmental impact: The role of regulatory push/pull, technology push and market pull. *Ecological Economics*, 78, 112-122. <https://doi.org/10.1016/j.ecolecon.2012.04.005>
16. Instytut Ochrony Środowiska – Państwowy Instytut Badawczy (2020). *Raport o stanie środowiska w Polsce 2020*. Retrieved from: <https://ios.edu.pl>
17. Instytut Rozwoju Miast i Regionów (2022). *Diagnoza stanu polskich miast w kontekście wyzwań środowiskowych*. Warszawa: Instytut Rozwoju Miast i Regionów.
18. Instytut Rozwoju Miast i Regionów (2022). *Miejskie eko-innowacje w praktyce – bariery i rekomendacje*. Warszawa: Instytut Rozwoju Miast i Regionów.
19. Jasińska, A. (2022). *Eco-Innovation Country Profile 2022: Poland*. Retrieved from: <https://circabc.europa.eu/ui/group/96ccdecdec-11b4-4a35-a046-30e01459ea9e/library/>
20. Kassenberg, A., Śniegocki, A. (2012). *Zrównoważony rozwój miast w Polsce – kierunki i instrumenty*. Warszawa: Instytut na rzecz Ekorozwoju.
21. Ministerstwo Funduszy i Polityki Regionalnej (2021). *Krajowa Polityka Miejska 2030*. Warszawa: Ministerstwo Funduszy i Polityki Regionalnej.
22. MZBM Rzeszów (n.d.). *Rzeszów testuje inteligentne pojemniki na odpady – innowacja na terenie zarządzanym przez MZBM Rzeszów*. Retrieved from: <https://mzbm.rzeszow.pl/rzeszow-testuje-inteligentne-pojemniki-na-odpady-innowacja-na-terenie-zarzadzany-przez-mzbm-rzeszow/>
23. Organisation for Economic Co-operation and Development (OECD) (2011). *Fostering Innovation for Green Growth*. Paris: OECD Publishing.
24. Organisation for Economic Co-operation and Development (OECD) (2015). *Going Green: Best Practices for Green Procurement*. Paris: OECD Publishing.
25. Piotrowska, J. (2012). Ekoinnowacje – wyzwanie dla polskiej gospodarki. *Studies and Works of the Faculty of Economic Sciences and Management*, 28, 93-104.
26. Rennings, K. (2000). Redefining innovation: Eco-innovation research and the contribution from ecological economics. *Ecological Economics*, 32(2), 319-332. [https://doi.org/10.1016/S0921-8009\(99\)00112-3](https://doi.org/10.1016/S0921-8009(99)00112-3)
27. Republic of Poland, Interoperability and Architecture Portal (2023, August 16). *Ecological Policy of the State 2030 (PEP2030)*. Retrieved from: <https://www.gov.pl/web/ia/polityka-ekologiczna-panstwa-2030-pep2030>
28. Sobala-Gwosdz, A., Czakon, P., Gwosdz, K., Hetmańczyk, K. (2024). *Innowacyjność i kreatywność ośrodków miejskich. Badania Obserwatorium Polityki Miejskiej*. Warszawa/Kraków: Instytut Rozwoju Miast i Regionów. <https://doi.org/10.51733/opm.2023.24>
29. Sztuka Krajobrazu (2025, September 21). *Zielona rewolucja w Łodzi w 2025 r.* Retrieved from: <https://sztuka-krajobrazu.pl/5750/artykul/zielona-rewolucja-w-lodzi-w-2025-r>
30. Szymańska, D. (2016). *Eco-innovations in urban development*. Toruń: Nicolaus Copernicus University Press.

31. Thidell, Å. (2009). Ecolabelling and product development. In: P. Del Rio Gonzalez (Ed.), *Environmental Innovation and Societal Transitions*. Springer.
32. UBA (Federal Environment Agency, Germany) (2021). *Blue Angel – The German Ecolabel*. Retrieved from: <https://www.blauer-engel.de/en>
33. UNEP (2011). *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*. Nairobi: United Nations Environment Programme.
34. United Nations Human Settlements Programme (UN-Habitat) (2020). *World Cities Report 2020: The Value of Sustainable Urbanization*. Nairobi: UN-Habitat.
35. United Nations, Department of Economic and Social Affairs (2019). *World Urbanization Prospects: The 2018 Revision*. New York: United Nations.
36. Wodociągi Warszawskie (2025, September 21). *Zakład „Czajka”*. Retrieved from: <https://www.mpwik.com.pl/view/zaklad-czajka>
37. Wroclaw.pl (n.d.). *Zielona Stolica Europy – Wrocław na zielono*. Retrieved from: <https://www.wroclaw.pl/zielony-wroclaw/wroclaw-zielona-stolica-europy-parki-kieszonkowe-zielone-scianny-parklety-woonerfy>

INTEGRATING THE THEORY OF CONSTRAINTS AND A FLOW BALANCING APPROACH INTO INTRALOGISTICS OPERATIONS

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Purpose: The aim of this paper is to improve intralogistics efficiency by identifying and eliminating constraints in a medical device sterilization process. The study applies the Theory of Constraints (TOC) and flow balancing to address a real-world bottleneck in healthcare production.

Design/methodology/approach: A single case study was conducted in a sterilization unit handling medical device trays. The TOC Five Focusing Steps were used to identify and resolve the main constraint. Performance indicators were analyzed, and process observation, time measurement, as well as equipment redesign supported the flow-balancing approach in reducing inefficiencies.

Findings: The unloading station emerged as the main constraint. Improvements such as redesigning the tray-handling robot, optimizing buffer usage, and enhancing gripper capacity reduced cycle times and increased throughput. Eliminating delays and improving synchronization across process stages enhanced flow efficiency, shortened waiting times, and improved resource utilization.

Research limitations/implications: As the study is limited to one sterilization unit and organizational context, results may not be directly generalizable. Further research should include multi-case studies and longitudinal analysis to test long-term sustainability and broader applicability.

Practical implications: The study shows how TOC can effectively identify bottlenecks and improve intralogistics performance. Similar methods can help organizations unlock hidden capacity, reduce waste, and synchronize flow without major investments. These improvements strengthen resilience and support demanding production targets in regulated healthcare environments.

Social implications: By improving efficiency and reliability in sterilization processes, the study indirectly contributes to patient safety and healthcare quality. Enhanced flow also promotes responsible resource use and supports broader sustainability goals.

Originality/value: This paper demonstrates the integration of TOC and flow balancing in a real-world healthcare production context. It offers a structured approach to intralogistics challenges and provides actionable insights for production engineers, healthcare logistics managers, and continuous improvement specialists.

Keywords: robotization of logistics processes, waste, Theory of Constraints (TOC), flow balancing, cycle time, organizational improvement.

Category of the paper: Case study.

1. Introduction

In today's business environment, companies must go beyond offering basic products by carefully identifying and addressing unspoken customer needs, providing strong value propositions, supporting and valuing their employees, reducing their environmental footprint, and continually improving production processes and overall efficiency. A consistent focus on improvement is essential for maintaining long-term success, which constitutes the primary objective of any enterprise (Hamrol, 2018). However, achieving this success necessitates the systematic identification and resolution of factors that constrain a system's performance. Within a business context, such a limiting factor is termed a constraint - any element that hinders the system from attaining its optimal operational capacity (Goldratt, Cox, 2016).

This study investigates disruptions affecting the Medical Device Tray Handler during sterilization. Utilizing a focused case study to analyze the real-world process flow and applying the Theory of Constraints (TOC), the research aims to identify opportunities for process improvement to enhance efficiency, reduce waste, and pinpoint the system's bottleneck for targeted improvements based on TOC principles.

The chosen approach enables a detailed analysis of the material flow within a sterilization unit and supports the identification of mechanisms that generate inefficiencies.

Accordingly, the study is guided by the following research questions:

- RQ1: What is the primary constraint that limits the efficiency of the medical device sterilization process?
- RQ2: How can the Theory of Constraints and flow balancing be applied to mitigate this constraint and improve system throughput?
- RQ3: What practical lessons can be derived from this case that may be transferable to other intralogistics contexts?

The novelty of this research lies in integrating the Theory of Constraints with a flow-balancing approach in the context of medical device sterilization, an area where such applications remain underexplored. The results contribute to the ongoing discussion on how intralogistics processes in healthcare can be optimized without major capital investment, thereby offering both theoretical and practical significance.

2. Literature review

E.M. Goldratt, a visionary management expert, conceptualized the Theory of Constraints (TOC) in his influential book, 'The Goal: Excellence In Manufacturing', published in 1984. This pioneering work established the fundamental principles and practices of TOC, providing a comprehensive framework for enhancing production management (Trojanowska, Dostatni, 2017).

The Theory of Constraints (TOC) emerged from an earlier methodology known as OPT (Optimized Production Technology) (Rogowska, 2023). Originally, OPT aimed to improve performance in production systems by identifying and managing bottlenecks. As the approach developed, TOC expanded its applications beyond manufacturing, evolving into a systems-oriented management philosophy.

Over time, TOC came to be applied in fields such as project management (through the Critical Chain method), logistics, sales, marketing, strategic planning, and organizational change (Ikeziri et al., 2019; Knop, 2024). Key developments included the articulation of the Five Focusing Steps for continuous improvement and the introduction of TOC's logical thinking processes for problem analysis and decision-making (Cyplik et al., 2012; Kosieradzka et al., 2022). Thus, TOC evolved from a production optimization tool into a comprehensive management philosophy focused on systematically identifying and eliminating constraints to maximize value flow across the entire organization (Bilinovics-Sipos, Reicher, 2023; Lewandowska-Ciszek et al., 2024; Mabin, Balderstone, 2003; Tokarski, Łuczak, 2023).

Organizational structures generally comprise networks of interdependent elements, often likened to interconnected chains. Consequently, similar to a chain, the overall strength of a system is determined by its weakest link, commonly referred to as the bottleneck. In response to this dynamic, the Theory of Constraints (TOC) is centered on the identification, management, and elimination of such limitations by aligning the flow of materials, products, information, and human resources with the system's overall capacity (Hamrol et al., 2015; Moore, Scheinkopf, 1998).

Building on this foundation, a core principle of TOC posits that efforts should be directed towards the point of greatest leverage within the system. Notably, this critical point is not necessarily confined to a single, specific area; rather, it may encompass any factor that significantly influences the constraint (Lewandowska-Ciszek, 2018). Therefore, a comprehensive understanding of the system's interdependencies is crucial for effectively enhancing performance and achieving sustained success (Lewandowska-Ciszek, 2022, 2025b).

The Theory of Constraints utilizes the Five Focusing Steps (Figure 1), a systematic methodology that involves: identifying the primary bottleneck; determining the optimal way to leverage this constraint; aligning all other processes with this decision; improving the capacity of the constraint; and iteratively restarting the process if the constraint is no longer the limiting

factor (Ashlag, 2014; Bicheno, Holweg, 2016; Corbett, 1998; Goldratt, 2003; Hadaś et al., 2012; Koliński et al., 2010; Lewandowska-Ciszek, 2025a; Moore, Scheinkopf, 1998; Trojanowska et al., 2011, 2017; Trojanowska, Dostatni, 2017; Trojanowska, Pająk, 2010; Woepfel, 2000).

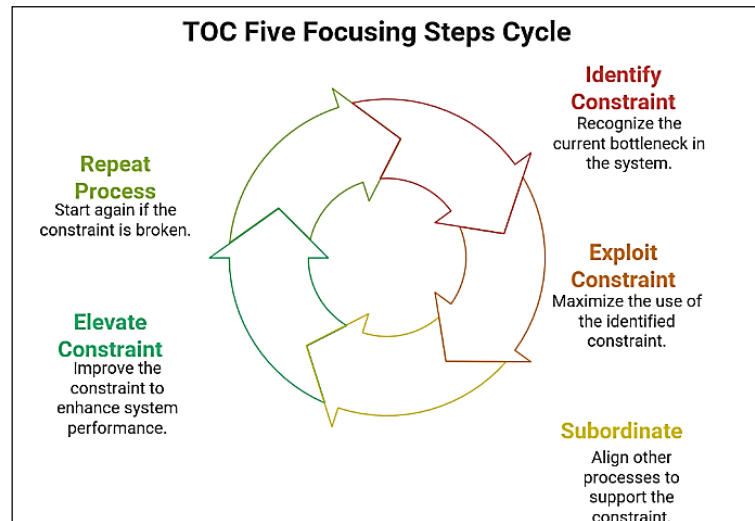


Figure 1. TOC Five Focusing Steps Cycle.

TOC was applied across diverse industries, including aerospace, semiconductors, furniture, and automotive. Most implementations were partial, targeting specific production processes or bottlenecks (Panizzolo, 2016).

The Theory of Constraints (TOC) significantly enhances manufacturing efficiency by systematically identifying and resolving process bottlenecks, leading to substantial reductions in lead times and inventory, as well as increased production throughput. Empirical evidence, such as the research conducted by Mabin and Balderstone, corroborates these benefits (Mabin, Balderstone, 2003). Their analysis of organizations adopting TOC revealed significant performance improvements, including an average decrease of 70% in order-to-delivery lead time and 65% in manufacturing cycle time, accompanied by a 49% mean reduction in inventory. Moreover, Mabin and Balderstone's (2003) findings indicated that TOC implementation resulted in an average increase of 65% in throughput or revenue and a 44% average improvement in meeting due dates.

3. Methodology

This study adopts a single case study methodology, a well-established approach in logistics research known for its depth and versatility. Case studies enable in-depth exploration of complex, real-world phenomena and can uncover underlying mechanisms within logistics activities (Aastrup, Halldórsson, 2008). They accommodate both qualitative and quantitative

approaches, making them suitable for exploring, validating, or extending existing theories (Dinwoodie, Xu, 2008; Hakkinen, Hilmola, 2005). Furthermore, case studies offer high construct validity and can facilitate the discovery of new variables or hypotheses (Bennett, 2004).

The case was selected because the sterilization unit represented a critical stage in medical device production where intralogistics inefficiencies had a direct impact on throughput and compliance with strict healthcare regulations. The research was conducted in 2024 in Germany, providing a real-world context for analyzing time-sensitive and safety-critical processes.

The single case study methodology proves particularly effective for tracking and analyzing material flow processes in industrial manufacturing contexts. Various methodological tools support this approach, including software-based workplace visualization (Dulina et al., 2024), value stream mapping, and lean performance metrics (Domingo et al., 2007). Material flow is assessed at both micro and macro levels (Kósi, Torma, 2005), often within structured improvement frameworks such as Toyota's 8-Step Process. Tools like time studies, SMED (Single-Minute Exchange of Die), and 5-Why analysis are utilized to identify inefficiencies (Halim et al., 2013).

Data collection combined quantitative and qualitative techniques. Quantitative measures included takt time, cycle time, throughput, buffer utilization, and Total Machine Efficiency. These were recorded through direct time measurements and equipment monitoring. Qualitative observations of machine behavior were also collected to capture contextual factors influencing process performance.

These indicators were systematically recorded before the improvement actions, establishing a clear pre-intervention benchmark for quantifying post-intervention performance gains.

The methodology typically unfolds in several phases: assessing the current state of material flow, developing detailed internal transport and logistics programs, and identifying opportunities for rationalization and optimization (Królczyk et al., 2014). Production flow analysis supports optimized cell layouts and more efficient material handling (Modrák, 2009).

In this research, a single in-depth case study approach is employed to analyze real-world challenges in intralogistics operations within a sterilization unit. The study applies the Theory of Constraints (TOC) Five Focusing Steps to systematically identify the primary constraint in the process flow and evaluate targeted improvement strategies. Key performance indicators such as takt time and cycle time are used to assess system behavior and optimize overall throughput.

4. Process description prior to improvement

The scope of this project includes the equipment specifications, design, installation, and testing of the Medical Device Tray Handler, which performs the following steps:

- unloads medical devices from the upstream machine,
- transports them overhead to the Tray Handler,
- places them horizontally onto trays,
- stacks loaded trays to form a full stack,
- conveys full stacks to the Autoclave,
- unloads stacks from the Autoclave,
- unstacks the trays for medical device unloading and places them into an output conveyor,
- returns empty trays back to be loaded,
- has a flip station with camera/vision inspection system and tray ejector with not fully unloaded materials.

The Tray Handler is a machine that is fully integrated into a manufacturing line, which includes inspection stations, medical device handling systems, and automation systems.

This project is designed to help new medical device manufacturing operations and to make it possible to expand the line in the future to meet manufacturing and sales needs.

Essential operating conditions are clearly specified and must be followed exactly as described below. The machine must be able to load, unload, and process 400 products per minute with a yield of at least 99.5%. Yield is measured as the number of products successfully offloaded into the output conveyor divided by the number of products delivered by the input conveyor. Scrapped items impacting yield include product defects caused by machine handling, and dropped or misplaced products. Total machine efficiency must be at least 97%. Yield loss must not exceed 0.5% of the total number of products presented to the input conveyor. Downtime must not exceed 3.0% of available run time.

The Total Machine Efficiency can be calculated as follows:

$$TME = \left(\frac{[ER \times (ERT - DT)] - MP}{ER \times ERT} \right) \times 100 \quad (1)$$

where:

TME – Total Machine Efficiency [%],

ER – Expected Rate [ppm],

ERT – Expected Run Time [min],

DT – Downtime [min],

MP – Mishandled Parts [parts].

The Yield Loss can be calculated as follows:

$$YL = \frac{MP}{(ER \times (ERT - DT))} \times 100 \quad (2)$$

where: YL – Yield Loss [%].

The Total Machine Downtime can be calculated as follows:

$$TMD = \frac{DT}{ERT} \times 100 \quad (3)$$

where: TMD – Total Machine Downtime [%].

For example, a 2-hour production run at 400 parts per minute is expected to produce 48,000 parts. However, if the machine is down for 4 minutes during the run, it will only produce 46,400 parts. Additionally, if 200 products are lost within the equipment and not successfully unloaded, the machine's overall efficiency will be reduced.

Total Machine Efficiency:

$$\frac{(400 \times (120 - 4)) - 200}{(400 \times 120)} \times 100 = 96.25\%$$

The following would be the Yield Loss:

$$\frac{200}{(400 \times (120 - 4))} \times 100 = 0.43\%$$

The following would be the Total Machine Downtime:

$$\frac{4}{120} \times 100 = 3.33\%$$

Stages of the designed process (Figure 2, Figure 3).

The first stage of the process is the infeed conveyor. This conveyor transports medical devices from the upstream machine to the Tray Handler at a rate of 400 parts per minute. The Tray Handler then loads the medical devices onto trays, which contain 7 horizontal rows of 40 pieces each, for a total of 280 pieces per tray.

The Tray Loading Robot loads medical devices onto trays. Empty trays are delivered to the loading area on a closed loop conveyor. The robot places products into the trays until they are full, and is able to load trays at a rate of at least 400 parts per minute to support the overall operating speed of the Tray Handler.

Once a tray is full of products, it is inspected to make sure that all of the products are in the correct position. If the tray is acceptable, it is transferred to the stacking cell and added to the stack in progress. If the tray is not acceptable, it is separated from the production line and moved to a location where an operator can be alerted to manually correct the tray. After an operator corrects the loading, it is put back into the production stream at the next available opportunity. As each tray is filled, it is added to the stack. The stack is complete when it has 41 filled trays and one base tray at the bottom. The base tray provides a stable platform for stacking the trays and transporting the stack to and from the Autoclave. The completed stack is then conveyed to a queue of stacks waiting to be sterilized. While the completed stack is being sterilized, new trays are being filled and a new stack is being built.

The Tray Handler communicates with the Autoclave to load trays. When the Autoclave is ready to accept a new load of three stacks, an operator instructs the Autoclave to open its inlet door. Once all three stacks have been transferred into the Autoclave, the operator closes the door and starts the sterilization cycle. Autoclave loading happens independently of tray loading and unloading, and does not affect the speed or timing of these functions.

The Tray Handler communicates with the Autoclave to unload trays. When the Autoclave has completed a cycle and met all required sterilization parameters, it sends a message to the Tray Handler. The operator then instructs the Autoclave to open its outlet door and starts the unloading process.

When the stack arrives at the unstacking station, it is lifted off of the base. The base is then moved to the stacking station, where it is prepared to receive a new stack. Trays are removed from the stack and transferred to the unloading robot, where the products are removed.

When the tray reaches the unloading station, the robot picks up the products and places them on an output conveyor until the tray is empty. The unloading operation can process products at a rate of 400 parts per minute to maintain the overall balance of the line.

The output conveyor transports products to the inspection system. After the tray has been unloaded, any remaining products are removed as scrap and the tray is presented for vision inspection. The inspection verifies that the tray is completely empty and no products are left on it. If the inspection is successful, the empty tray is accumulated in the empty tray buffer and staged for further loading of unprocessed products by the loading side of the Tray Handler. If the inspection fails, the tray is redirected to the inspection drawer for manual operator removal. After the operator confirms that the tray has been cleared, the vision system inspects the tray again. If the inspection is successful, the tray is moved to the empty tray buffer. This process continues until the entire stack is emptied of products.

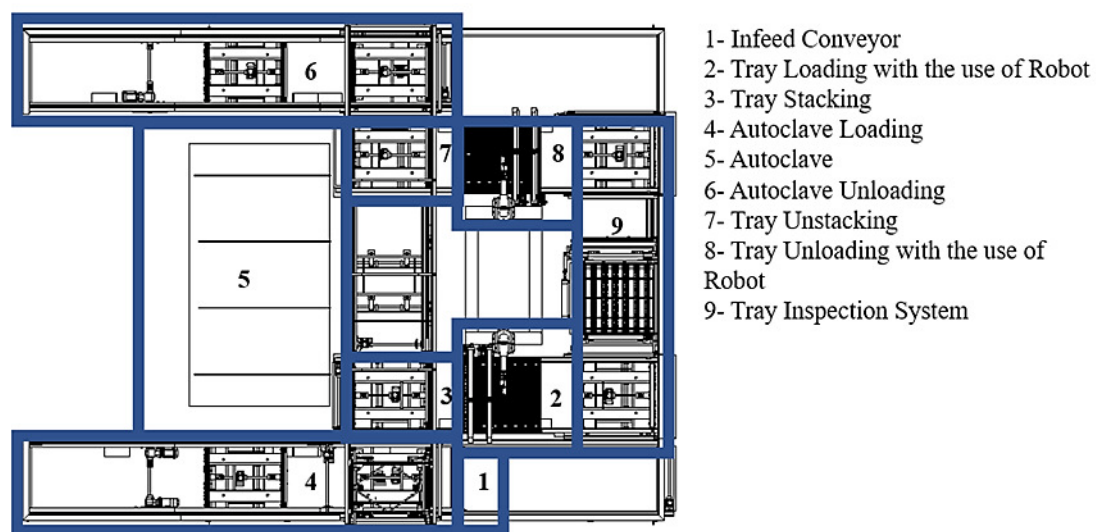


Figure 2. The defined stages of the process.

5. Process improvement

Applying the Theory of Constraints to the case under study, the unloading station was identified as the constraint in the sterilization process. This means that the rate at which customer orders can be fulfilled at this station limits the rate at which materials can flow through the entire system.

The Theory of Constraints shows that the most important factor in managing the flow of materials is to focus all of the enterprise's efforts on the part of the process where the most impact can be made (Bozarth, Handfield, 2008). This could be a constraint, or an area that has a significant impact on the constraint's performance.

Even though the unloading operation is the bottleneck in the material flow in the case study, it is important to make significant changes to the operations that are close to and have a big impact on the unloading operation. These operations are the biggest sources of waste in the company, and improving their efficiency will have the biggest impact on the unloading phase.

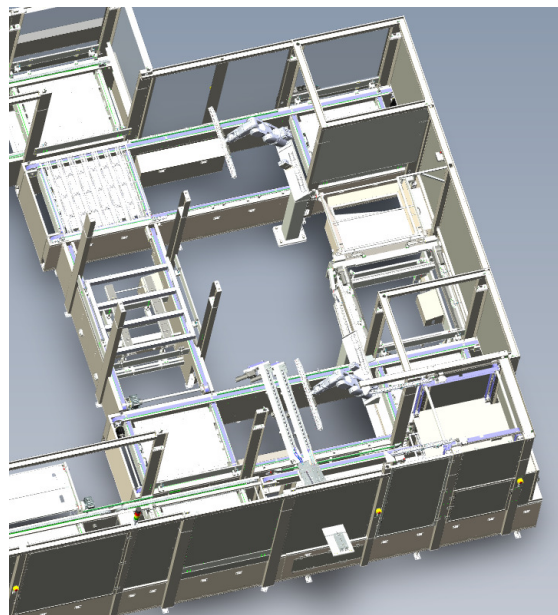


Figure 3. A process model under study.

The Tray Stacking area has three sources of waste:

- 2 seconds of delay until the base frame starts moving from the base tray accumulator to the waiting position on the conveyor with trays,
- 4.25 seconds of base frame waiting time until moving from the waiting position on the conveyor with trays to the stacker,
- 7 seconds of waiting time until the tray with the product moves to the waiting position on the conveyor with trays due to destacking delay from the loading tray buffer.

In summary, eliminating the 13.25 seconds of actual waiting time would reduce the loading waiting time of the entire batch by about 40 seconds.

To compensate the passing of the top tray, Robot in Tray Loading must reach a speed of 267 product in addition to the 400 pieces per minute within each stack. This would result in a cycle time of 41 seconds per tray, which is equivalent to 410 pieces per minute.

After implementing the above improvements, with a particular focus on step 3 of the Theory of Constraints (subordination), the cycle time was reduced. Unfortunately it was still longer than the takt time. Further research showed that there are places in the system that have a direct impact on the upstream and an indirect impact on the downstream.

It has been noted that product delivery can be accelerated on infeed. For this purpose, the power of the drive controlling the product feeding screw has been increased. This made it possible for the robot to pick up the product faster, which ultimately further shortened the time needed for the robot to place products on the tray. After accelerating the tray loading time, it turned out that the waiting time for the next empty tray was too long, which resulted in the cycle time not being shortened. The process of delivering empty trays to the infeed needed to be looked at. Knowing that process runs in a closed loop, the rate at which empty trays are received depends on the rate at which the product trays are emptied. Therefore, attention was focused on the stand: Flip station with camera inspection and tray ejector.

The inspection verifies that the tray is completely empty and no products left on the tray. Once accepted by the inspection, the empty tray is now accumulated in the empty tray buffer and staged for further loading of unprocessed products by the loading side of the Tray Handler.

The process of verifying empty trays is time-consuming and critical to the overall process. By emptying product trays faster, a buffer of empty trays can be created, eliminating wait time in the process. To achieve this, the gripper on the robot used to unload product from trays was modified from a 20-piece gripper to a 40-piece gripper. This reduced the unloading time of product trays by approximately 40% and protected the buffer of empty trays. As a result, products could be processed at a rate of 440 pieces per minute.

6. Discussion and summary

The biggest problem was that the average unit production time needed to meet customer demand was lower than the cycle time of the analyzed process. It means that the system was unable to meet customer demand due to the fact that the utilization of the process step (cycle time divided by takt time) amounted to above 100%.

In the above mentioned case study a downstream process step was highly-utilized simultaneously decreasing the utilization of all upstream process steps as the pace of the material flow was limited by the capacity of the bottleneck. By observing the flow of material through a system, it was possible to determine the bottlenecks. A system's throughput was limited by a constraint. Only by increasing flow through the constraint could overall throughput

be increased. Bottlenecks were easy to identify because of the ability to see how stockpiles formed queues in front of overloaded processes stage. This continuous increase in inventory indicated that the next stage of the process was not able to fulfil customer demand.

Our finding that the analyzed process was unable to meet customer demand due to a bottleneck with utilization above 100% is consistent with the observations of Bilinovics-Sipos and Reicher (2023), who emphasized that bottlenecks constrain overall throughput and manifest through growing inventories in front of overloaded stages. Similar to the results reported by Mabin and Balderstone (2003), our study confirms that addressing the identified constraint is the only effective way to increase system-wide performance. Moreover, the evidence from Lewandowska-Ciszek et al. (2024) and Tokarski and Łuczak (2023) aligns with our findings by demonstrating that targeted process improvements and flow simulations can enhance efficiency, reduce waste, and strengthen organizational resilience. While these studies validate our results, the specific application to sterilization processes in healthcare has remained underexplored, which underlines the novelty and practical relevance of our contribution.

Building on these insights, further analysis of the material flow in our case study highlights how interdependencies between process stages shaped system performance. When items moved through the system, the operations undertaken in one part of the system were strictly connected to the other parts. Product processing was only possible when product availability allowed. The aforementioned made it possible to contrast value-adding and non-value-adding activities. Any developments being proposed to eliminate different sources of waste were implemented with greater confidence by exploring the system's dynamics rather than just its static aspects.

This research investigated disruptions affecting the Medical Device Tray Handler during the sterilization process and demonstrated how takt time analysis and process improvements can enhance efficiency and reduce waste. However, as the study focuses on a single case within a unique organizational and operational context, its findings may have limited generalizability. Conducting longitudinal studies would be beneficial to evaluate the long-term sustainability of the improvements achieved.

The comparison of pre- and post-intervention KPIs confirmed measurable performance gains, as reductions in cycle time and increases in throughput were observed directly against the established baseline.

In summary, the study confirmed that eliminating the unloading station bottleneck through targeted improvements enhanced intralogistics flow and overall process efficiency. These results demonstrate the practical value of combining the Theory of Constraints with flow balancing in healthcare operations, while also highlighting the methodological limitation of a single case study. In addition, by improving the efficiency of sterilization processes, the study indirectly contributes to higher patient safety and resource sustainability in healthcare logistics. Future research should therefore validate these findings through multi-case and longitudinal analyses to strengthen their generalizability and long-term applicability.

References

1. Aastrup, J., Halldórsson, Á. (2008). Epistemological role of case studies in logistics. *International Journal of Physical Distribution & Logistics Management*, 38(10), 746-763. <https://doi.org/10.1108/09600030810926475>
2. Ashlag, Y. (2014). *TOC Thinking: Removing Constraints for Business Growth*. North River Press. <https://books.google.pl/books?id=TMWvoAEACAAJ>
3. Bennett, A. (2004). Case Study Methods: Design, Use, and Comparative Advantages. In: D.F. Sprinz, Y. Wolinsky-Nahmias (Eds.), *Models, Numbers, and Cases: Methods for Studying International Relations* (pp. 19-55). University of Michigan Press.
4. Bicheno, J., Holweg, M. (2016). *The Lean Toolbox, 5th edition. A handbook for lean transformation*. PICSIE Books.
5. Bilinovics-Sipos, J., Reicher, R. (2023). Overview of the concepts of bottleneck in the operation process. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 55-67. <https://doi.org/10.29119/1641-3466.2023.170.3>
6. Bozarth, C.C., Handfield, R.B. (2008). *Introduction To Operations and Supply Chain Management*. Pearson Education International.
7. Corbett, T. (1998). *Throughput Accounting: TOC's Management Accounting System*. North River Press. <https://books.google.pl/books?id=IQEBAAAACAAJ>
8. Cyplik, P., Adamczak, M., Hadas, Ł. (2012). Critical Chain Project Management and Drum-Buffer-Rope Tools Integration in Construction Industry - Case Study. *Scientific Journal of Logistics*, 8(1).
9. Cyplik, P., Hadaś, Ł., Domański, R. (2009). Implementation of The Theory of Constraints in The Area of Stock Management Within The Supply Chain-A Case Study. *Electronic Scientific Journal of Logistics*, 5(3).
10. Dinwoodie, J., Xu, J. (2008). Case studies in logistics: a review and tentative taxonomy. *International Journal of Logistics Research and Applications*, 11(5), 393-408. <https://doi.org/10.1080/13675560802389130>
11. Domingo, R., Alvarez, R., Melodía Peña, M., Calvo, R. (2007). Materials flow improvement in a lean assembly line: a case study. *Assembly Automation*, 27(2), 141-147. <https://doi.org/10.1108/01445150710733379>
12. Dulina, L., Zuzik, J., Furmannova, B., Kukla, S. (2024). Improving Material Flows in an Industrial Enterprise: A Comprehensive Case Study Analysis. *Machines*, 12(5), 308. <https://doi.org/10.3390/machines12050308>
13. Goldratt, E.M. (2003). *Production the TOC Way with Simulator*. North River Press.
14. Goldratt, E.M., Cox, J. (2016). *The goal: a process of ongoing improvement*. Routledge.
15. Hadaś, Ł., Fertsch, M., Cyplik, P. (2012). *Planowanie i sterowanie produkcją*. Wydawnictwo Politechniki Poznańskiej.

16. Hakkinen, L., Hilmola, O.-P. (2005). Methodological pluralism in case study research: an analysis of contemporary operations management and logistics research. *International Journal of Services and Operations Management*, 1(3), 239. <https://doi.org/10.1504/ijssom.2005.006576>
17. Halim, N.H.A., Jaffar, A., Noriah, Y., Naufal, A.A. (2013). Case Study: The Methodology of Lean Manufacturing Implementation. *Applied Mechanics and Materials*, 393, 3-8. <https://doi.org/10.4028/www.scientific.net/amm.393.3>
18. Hamrol, A. (2018). A new look at some aspects of maintenance and improvement of production processes. *Management and Production Engineering Review*, 9(1). <https://doi.org/10.24425/119398>
19. Hamrol, A., Gawlik, J., Skołud, B. (2015). *Strategies and practices of efficient operation. Lean, Six Sigma, and other (methods)*. PWN.
20. Ikeziri, L.M., Souza, F.B. de, Gupta, M.C., de Camargo Fiorini, P. (2019). Theory of constraints: review and bibliometric analysis. *International Journal of Production Research*, Vol. 57, Iss. 15-16. <https://doi.org/10.1080/00207543.2018.1518602>
21. Knop, K. (2024). Using the theory of constraints thinking process tools to solve critical problems in the organization. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 197, 305-331. <https://doi.org/10.29119/1641-3466.2024.197.18>
22. Koliński, A., Trojanowska, J., Pająk, E. (2010). Theory of constraints as supporting element of logistics controlling. In: E. Badzińska (Ed.), *Sources of Competitive Advantage for Enterprises* (pp. 71-84). Publishing House of Poznan University of Technology.
23. Kósi, K., Torma, A. (2005). Tracing material flows on industrial sites. *Periodica Polytechnica Social and Management Sciences*, 13(2), 133-149.
24. Kosieradzka, A., Węgrzyk, J., Smętek, W., Strzelec, P. (2022). Maximising performance of a hospital's HBOT laboratory using the theory of constraints. *Scientific Papers of Silesian University of Technology Organization and Management Series*, 155, 187-208. <https://doi.org/10.29119/1641-3466.2022.155.13>
25. Królczyk, G., Legutko, S., Królczyk, J., Tama, E. (2014). Materials Flow Analysis in the Production Process - Case Study. *Applied Mechanics and Materials*, 474, 97-102. <https://doi.org/10.4028/www.scientific.net/amm.474.97>
26. Lewandowska-Ciszek, A. (2018). Theory of constraints as a stimulus towards warehouse transformation process on the example of the distribution center. *Management and Production Engineering Review*, 9(4). <https://doi.org/10.24425/119550>
27. Lewandowska-Ciszek, A. (2022). The Lean Industry 4.0 approach on the example of an automated line for dosing loose raw materials. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 163, 343-356. <https://doi.org/10.29119/1641-3466.2022.163.20>

28. Lewandowska-Ciszek, A. (2025a). Achieving End-of-Line Efficiency Through Automated and Robotic Logistics: A Simulation-Driven Approach. In: A. Burduk, M.A. Xavier, J.M. Machado, S. Butdee, K. Krot, P. Srikhumsuk, D. Lapczynska (Eds.), *Intelligent Systems in Production Engineering and Maintenance, IV. Vol. 1: Mechanical Engineering*. (pp. 214-228). Springer. https://doi.org/10.1007/978-3-031-99159-2_16
29. Lewandowska-Ciszek, A. (2025b). Znaczenie symulacji procesów biznesowych dla projektowania odpornych łańcuchów dostaw. In: *Logistyka i zarządzanie łańcuchem dostaw w czasach turbulencji, zakłóceń i niestabilnej gospodarki* (pp. 141-159). Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu. <https://doi.org/10.18559/978-83-8211-251-1/8>
30. Lewandowska-Ciszek, A., Szczypa, P., Szymkowiak, M., Grabański, S. (2024). Navigating hyper-individualization: building resilience systems through process simulation. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 209, 229-247. <https://doi.org/10.29119/1641-3466.2024.209.13>
31. Mabin, V.J., Balderstone, S.J. (2003). The performance of the theory of constraints methodology: Analysis and discussion of successful TOC applications. *International Journal of Operations and Production Management*, 23(5-6). <https://doi.org/10.1108/01443570310476636>
32. Modrák, V. (2009). *Case on Manufacturing Cell Formation Using Production Flow Analysis*.
33. Moore, R., Scheinkopf, L. (1998). Theory of constraints and lean manufacturing: friends or foes. *Chesapeake Consulting Inc*.
34. Panizzolo, R. (2016). Theory of constraints (TOC) production and manufacturing performance. *International Journal of Industrial Engineering and Management*, 7(1). <https://doi.org/10.24867/ijiem-2016-1-103>
35. Rogowska, P. (2023). Process cycle time as a base of constraint identification in TOC application to a printing production system. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 177, 529-541. <https://doi.org/10.29119/1641-3466.2023.177.30>
36. Tokarski, D., Łuczak, Ł. (2023). Optimization of logistics processes in the sustainable development of manufacturing enterprises. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 178, 683-692. <https://doi.org/10.29119/1641-3466.2023.178.37>
37. Trojanowska, J., Dostatni, E. (2017). Application of the theory of constraints for project management. *Management and Production Engineering Review*, 8(3). <https://doi.org/10.1515/mper-2017-0031>
38. Trojanowska, J., Koliński, A., Kolińska, K. (2011). Using of throughout accounting in manufacturing companies – case studies. *Management and Production Engineering Review, Vol. 1*, 58-65.

39. Trojanowska, J., Kolinski, A., Varela, M.L.R., Machado, J. (2017). The use of theory of constraints to improve production efficiency – Industrial practice and research results. *24th International Conference on Production Research, ICPR 2017*. <https://doi.org/10.12783/dtetr/icpr2017/17667>
40. Trojanowska, J., Pająk, E. (2010). Using the theory of constraints to production processes improvement. *Proceedings of the International Conference of DAAAM Baltic*.
41. Woeppel, M. (2000). Manufacturer's Guide to Implementing the Theory of Constraints. In: *Manufacturer's Guide to Implementing the Theory of Constraints*. <https://doi.org/10.1201/9781420025712>

DIGITAL COMPETENCIES IN SUPPLY CHAINS IN THE ERA OF INDUSTRY 5.0

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Purpose: The purpose of this article is to identify and assess the key digital AND technical competencies necessary for effective supply chain management in the realities of Industry 5.0. under conditions of accelerated digitization.

Research methodology: the study was conducted using a diagnostic survey method, based on a CAWI questionnaire addressed to a purposively selected group of 34 senior managers - directors of logistics, purchasing and owners of companies operating in Poland and abroad. Competencies were assessed using a three-point Likert scale.

Results: The most frequently indicated competency was the ability to solve problems in a digital environment, considered a basic requirement for effective leadership. This included analytical, interpersonal and strategic skills. The importance of complex thinking, projective planning, general technological knowledge, and data and information analysis was particularly strongly emphasized. Both Polish and foreign market managers emphasized the need to develop competencies that allow them to operate efficiently in a complex and rapidly changing environment.

Research limitations/implications: The limitation of the study remains the small, purposefully selected sample of respondents, which limits the possibility of fully generalizing the results. However, the results obtained can serve as a starting point for further quantitative and qualitative research, taking into account industry and cultural differences.

Practical implications: The results of the survey can support HR departments and managers responsible for talent development in planning training programs to improve the skills of managers. Particular attention should be paid to developing digital skills linked to supply chain management in an integrated technology environment.

Social implications: The study emphasizes that the development of digital competencies must go hand in hand with social skills, supporting the human-centric nature of Industry 5.0. This approach can foster a sustainable work environment.

Originality/value: The article brings a new perspective to the issue of managerial competencies, highlighting their digital dimension in supply chain management in the medical equipment industry. It provides a valuable contribution to academia, business practitioners and HR departments.

Keywords: digital competencies, managers, supply chain, Industry 5.0, medical equipment sector, digital transformation.

Category of the paper: research paper.

1. Introduction

Supply chains are facing increasing complexity, are increasingly global in scope and are increasingly vulnerable to disruption. In this context, the skills to efficiently use digital technologies and tools that support decision-making and operational and strategic management to a high degree are becoming increasingly important. The purpose of this paper is to identify and assess the digital competencies necessary to gain a competitive advantage in supply chain management in today's reality of rapidly changing conditions in the global economy.

Industry 5.0, dubbed the next industrial revolution, is a paradigm that places the interaction of humans and technology at the center. What was at the heart of Industry 4.0, i.e. automation and increased operational efficiency, is giving way to three new assumptions: technologies are to support employees and thus streamline processes and increase productivity, (human at the center), all activities are to foster environmental protection and technologies are to increase the positive impact on society (sustainability and social responsibility), and building production stability and security by designing processes and systems that are resistant to disruptions such as pandemics, conflicts. In this context, digital competencies become the foundation for realizing the potential of modern technologies. The topics raised, and especially the research conducted, fill the research gap on the role of digital and technical competencies in Industry 5.0. To date, no research has been conducted on the importance of digital and technical competencies in the context of Industry 5.0. Therefore, it is reasonable to ask, what is the importance of the identified technical and digital competencies in the era of digitization, supporting the human-centered approach in Industry 5.0? The structure of the article meets the need to justify the research gap. Digital competencies in supply chains were characterized, along with a relevant literature review of the Industry 5.0 era. This was followed by a literature review based on the identified research gap and a proposal of its own set of competencies for Industry 5.0. The next step was to present the characteristics of the research and the industry in which it was conducted, and to identify the importance of the selected medical equipment industry. The article concludes with a discussion and conclusions and recommendations that clearly indicate the importance of digital and technical competencies in Industry 5.0.

2. Literature review

Supply chain management needs not only digitization-related tools, but also new skills dictated by the economy's transformation to Industry 5.0. While Industry 5.0 offers a promising framework for human-centered, sustainable and resilient supply chains, its full potential has yet to be realized. As organizations seek to implement advanced technologies, they must also

address the challenges of workforce adaptation and the ethical implications of digital industrialization. They must incorporate social considerations into their operational strategies by ensuring a balance between technological advances and human-centered practices (Gladysz et al., 2023; Shi et al., 2023). The emergence of new responsibilities, tasks, as well as roles, e.g., working with robots, equipment, algorithms, so that employees effectively interact with new technologies requires time and preparation. Digital competencies in particular can have a significant impact on supply chain optimization and efficiency, transparency and resilience. Although the concept of Industry 5.0 focuses primarily on the high-tech manufacturing environment, management competence in this aspect seems equally significant.

2.1. Digital transformation of the supply chain in the context of Industry 5.0

At the center of the dynamic changes associated with digitization is a human-centered approach, where technology does not replace humans, but enhances their capabilities and supports their potential and intelligence (Chidozie et al., 2024). A separate issue is the consideration of the most important factor in this transformation, i.e. people, employees at various levels and their approach to transformation and digitization in organizations (Tabrizi et al., 2019)

Digitization is the technological basis for change in organizations. Digital transformation in a broad sense has many definitions and figures reporting on various aspects of human activity, not necessarily related to industry and business (Kraus et al., 2021). Digital transformation is not limited to changing information into a digital format. In a sense, it can be defined as a fundamental rethinking of how organizations operate and deliver value using digital technologies and data-driven strategies (Kraus et al., 2021). Digital transformation in supply chains, on the other hand, can be linked to fundamental change that significantly alters business processes, structures and organizational culture between supply network partners as well.

Innovative technologies serve as building blocks for transformation and supply chain management practices to achieve sustainability and resilience in the face of changing challenges and disruptions (Agrawal et al., 2024).

The term Industry 5.0 can be seen as an umbrella term for the modern use of intelligent automation, data exchange and processing and manufacturing technologies, although the phenomenon is developing in parallel with the Industry 4.0 paradigm (Gladysz et al., 2023). Key digital tools relevant to supply chain digitization include (Chidozie et al., 2024; Madsen et al., 2023; Shi et al., 2023; Zouari et al., 2021):

- Internet of Things (IoT): IoT devices, embedded with sensors and connectivity, enable the collection of real-time data throughout the supply chain; this includes, for example, inventory levels or conditions during transportation.

- Big Data Analytics: big data analytics tools enable real-time processing of information to predict, for example, fluctuations in demand, supply shortages, advanced analytics allows to predict disruptions in the supply chain in time and respond to them more effectively, monitor inventory or track shipments.
- Blockchain technology: blockchain involves recording transactions throughout the supply chain, increases transparency, security, providing a verifiable history of products and processes.
- Artificial Intelligence (AI) and Machine Learning (ML): artificial intelligence (AI) and ML algorithms enable automation of repetitive tasks, optimization of complex processes. Technology improves demand forecasting or route optimization.
- Cloud computing: Cloud computing is "a model for enabling ubiquitous, convenient on-demand network access to a shared pool of configurable computing resources that can be quickly shared and released".
- Digitization facilitates faster order processing, precise delivery tracking and personalized interactions with customers. This leads to greater customer satisfaction and loyalty by meeting customer expectations for speed and transparency.

Digitization of the supply chain is emerging in an era where real-time communication and coordination is taking place (Zouari et al., 2021) .

Using advanced technologies, companies can analyze massive amounts of data to predict customer preferences, optimize delivery routes in real time and personalize interactions with customers. For example, artificial intelligence-based algorithms can adapt to changing demand patterns, ensuring efficient allocation of resources during peak hours (Gładysz et al., 2023).

Industry 5.0 is characterized by digital transformation and digital integration with an emphasis on technologies redesigned for human-centeredness, connectivity, sustainability and resilience (Durugbo, 2025).

The 5.0 paradigm places a strong emphasis on environmental and social sustainability. For supply chains, this translates into operational processes that minimize environmental impact, promote ethical sourcing and contribute to social well-being (Agrawal et al., 2024).

Three pillars on which Industry 5.0 is based (Breque et al., 2021; Coelho et al., 2023):

- Human-machine collaboration and human-centricity, which can lead to more efficient processes, enhanced collaboration and improved decision-making.
- Sustainability and social benefits, where Industry 5.0 can contribute to the development of environmentally friendly practices, the social impact of technological advances.
- Resilience, which many legacy manufacturing processes have lacked and making them resilient to any disruption (such as pandemic or conflict) is one of the pillars of Industry 5.0.

The most studied issue related to Industry 5.0 in a systematic review of the literature has recognized technologies such as artificial intelligence, big data, the Internet of Things, blockchain and cyber-physical systems (Madsen et al., 2023). Technologies such as are also mentioned (Chidozie et al., 2024; Shi et al., 2023).

Cobots, robots that collaborate with humans to help with tasks that require precision, improving productivity and safety in warehouses and manufacturing plants.

Digital Twins: digital twins, or virtual replicas of physical assets, processes and supply chains, are tasked with real-time monitoring, simulation and optimization.

Augmented (AR) and Virtual Reality (VR): These technologies are bringing significant changes to training and supply chain logistics. AR allows employees to access additional, contextual information, while VR allows for realistic training simulations.

AI-based decision support systems: The development of AI is leading to increasingly sophisticated analytical tools that, by leveraging massive data sets, support accurate decision-making and facilitate the management of complex processes in supply networks.

Research on Industry 5.0 highlights the growing importance of automation and robotics emphasizing the human-robot relationship (Coelho et al., 2023; Demir et al., 2019; Pizoń, Gola, 2023). A cyber-physical system today can take the form of autonomous production using human intelligence (Nahavandi, 2019). With the importance of cyber-physical systems knowledge and supervision in addition to supporting human-machine interaction (Grabowska et al., 2022). These technologies significantly affect supply chain processes and operations.

The literature emphasizes that in the next industrial revolution, the most important change is the shift in focus from technology-based progress (IoT, AI, digital twins, robotics, augmented reality, etc.) to worker-based progress. It is the industry to adapt to human needs, not humans to adapt to ever-evolving technology (Xu et al., 2021; Gladysz et al., 2023).

EC documents talking about the transformation of the European economy towards Industry 5.0. primarily emphasize the importance of human capital. Technology is there to serve people (Breque et al., 2021; European Commission et al., 2021).

To deepen our understanding of the changing landscape in the context of digital transformation and the ongoing transformation of the economy towards Industry 5.0, it is necessary to highlight the key digital and technical competencies needed to manage supply chains.

2.2. Digital competencies in supply chains in the reality of economy 5.0

The main obstacle to the digital transformation is the lack of an adequately prepared workforce, with an increase in the number of workers who are unskilled or have competencies that are not suited to the requirements of the modern economy. The world, which is gradually overcoming the problem of illiteracy, is now facing the challenge of more intensive education and the need for re-education (Wincewicz-Bosy, Lupicka, Stawiarska, 2017). An analysis of past studies by researchers and practitioners indicates a certain lack in the demands related to

digital and technical competencies related to humanocentricity, sustainability, and the resilience of businesses and supply chains to changing economic conditions. The shift away from the key tenets of Industry 4.0 in favor of digitization processes is increasingly apparent. As a result of a review of available scientific publications, reports and book studies, a new, more precise catalog of digital competencies corresponding to the challenges of the Industry 5.0 era is emerging. The modern manager, in order to meet the demands of building organizational resilience, should flexibly develop and adapt the skills he or she possesses. This means applying different sets of competencies depending on the context and specifics of the situation (Łupicka-Fietz, Jeszka, 2024).

Based on a review of the literature (European Commission et al., 2021; McLaren, 2021; Audrey, Paksi, 2021; Dwivedi et al., 2023; Song et al., 2021; Knut, Balaji, 2013; Gartner, 2023; APICS, 2014; Hoffman et al., 2005; Relich, 2015; Joerres, McAuliffe, 2016; Winter, Heindl, 2016; Davis et al., 2011; Bauer et al., 2015; Störmer et al., 2014; Pompa, 2015) identified the 16 most commonly identified digital and technical competencies relating to the operation of supply chains in the reality of Economy 5.0.

General digital skills

Basic digital skills and knowledge of software are essential for operating in the digital economy. General IT skills can be defined as the ability to use information and communication technologies and move freely in a digitized environment. General IT skills can include operating computer hardware, which involves running, configuring and basic maintenance of devices such as a computer, laptop or smartphone, using operating systems, including Windows and Linux, as well as managing files and folders (Majewski, 2018). We can also include creating and editing text documents, spreadsheets and multimedia presentations, as well as searching for information, assessing the reliability of sources, using email, video conferencing and instant messaging (Szeliga, 2020).

Of course, digital security is not insignificant, consisting of knowing how to protect data, using passwords and recognizing phishing or malware threats (Castells, 2010; Szeliga, 2020). When discussing basic digital skills, it is worth noting the ability to solve simple technical problems, such as restoring an Internet connection or changing device settings (European Union Agency for Cybersecurity [ENISA], 2021).

General IT skills are a "must have" for any adult. They are compared to the ability to write or read - they are essential competencies for both work and everyday life. General IT skills are basic abilities related to the use of information and communication technologies (ICT), including both the operation of computer hardware and the use of popular office applications, web browsers and basic communication tools. These competencies enable the user to function efficiently in the digital environment, and provide a foundation for developing more advanced digital skills.

Managing knowledge regarding the use and harm of digital technologies to the environment

Organizations are committed to operating in a sustainable manner. Knowledge of digital technology use and harm is the same as corporate social responsibility. Competencies include recognizing the negative impacts of technologies (e.g., CO₂ emissions, e-waste, energy intensity of data centers) and positive uses (environmental monitoring, closed-loop economy) (Malmodin, Lundén, 2018). Among other relevant issues related to this competency, it is worth mentioning awareness of the life cycle of digital devices (Forti, Baldé, Kuehr, Bel, 2020) and promoting digital sustainability by improving communication skills and educating employees and communities about the green aspects of technology (European Commission, 2022). Having this competency means being able to make environmentally friendly digital decisions, implement measures to reduce energy consumption, streamline business processes with minimal environmental impact, and foster a culture of environmental responsibility.

Data and information processing and analytics

Data science and analytics are among the most sought-after and rapidly growing disciplines. However, because the field crosses the boundaries of many disciplines and its skills are still evolving, it is often difficult to define its specific set of skills and competencies. This competency consists of the ability to acquire, collect, process, analyze and interpret data and information in order to make informed decisions and add value in various areas of activity. It includes both technical skills (analytical tools and methods) and a critical approach to data quality and reliability. This competency can include data acquisition and organization as the ability to search, select and collect data from various sources (internal and external), including big data (big data) (Kitchin, 2014). In addition, it is worth mentioning data processing, analysis, interpretation and visualization, presenting the results in a clear and useful way, using data visualization tools (e.g., dashboards, infographics) (Few, 2012; James et al., 2021). The practical application of this competency is evident in the use of data analytics to optimize processes, support business, scientific or administrative decisions (Davenport, Harris, 2007). Possession of this competency enables effective use of data for decision-making, enhancing innovation and competitiveness, identifying trends, and supporting transparency of evidence-based activities.

General knowledge of technologies

General knowledge of technologies refers to a basic understanding and knowledge of technologies used in the modern world, both in daily life and in professional activities. It includes awareness of the operation, capabilities and limitations of various technological solutions, as well as their impact on society, the economy and the environment. The scope of competence includes knowledge of the general mechanisms of digital, communication, production, transportation and energy technologies (Volti, 2017), awareness of their applications in various sectors, such as medicine, education, industry or administration (Volti, 2017), orientation to the development trends of modern technologies, such as artificial

intelligence, the Internet of Things, biotechnology and robotics, among others (Schwab, 2016), the ability to critically analyze the benefits and risks of technology, including ethical and environmental aspects (Mitcham, 1994), as well as an understanding of their impact on the labor market, communications, lifestyles and social relations (Castells, 2010).

General knowledge about organizations

General knowledge of organizations involves understanding the fundamental principles of organizations, including their goals, formal and informal structures, and management processes (Scott, 2015). It includes the ability to analyze key areas of operation, such as human resource management, financial management and operational processes, as well as an orientation to various types of organizations, whether commercial, public or non-profit (Daft, 2021; Mintzberg, 1993). This competency also includes knowledge of decision-making processes and information flow within the organization, awareness of the impact of the market, social, legal and technological environment on organizational operations, and the basic principles of adapting organizations to change and implementing innovations (Burnes, 2017; Hatch, 2018; Robbins, Judge, 2019).

Specialized and up-to-date knowledge of technologies and organizations

The competence of specialized and up-to-date knowledge of technologies and organizations consists of an in-depth knowledge of modern technological solutions and contemporary organizational structures and processes, enabling an understanding of development trends, assessment of the effects of innovations and their impact on organizational performance and the environment (Arthur, 2009; Daft, 2021; Schwab, 2016; Scott, 2015). It includes advanced technological knowledge of digital, information, production, energy and communication systems, including their capabilities, limitations and integration into organizational processes (Arthur, 2009; Schwab, 2016), as well as up-to-date knowledge of organizations, including contemporary structures, management models, decision-making processes, communication, and adaptation to change and the impact of the external environment (Daft, 2021; Scott, 2015). This competency also includes awareness of the direction of technology and management methods, and knowledge of potential benefits and risks, including ethical, environmental and social aspects (Burnes, 2017; Mitcham, 1994).

Statistical skills

Statistical skills are an important component of modern workforce competencies, as they refer to the ability to collect, compile, analyze, interpret and present data in such a way as to enable reliable conclusions and fact-based decision-making. They are defined in various ways in the literature. Moore, McCabe and Craig (2017) define statistics as the field that deals with the collection, analysis and interpretation of data, emphasizing that statistical competence boils down to the use of its methods in the decision-making process. Rumsey (2016) points out that they mean the ability to understand data and its variability, interpret results, and evaluate the quality of analyses. The American Statistical Association (2016) emphasizes the importance of so-called statistical literacy, understood as the ability to critically perceive statistical

information and put it to practical use in both professional work and everyday life. Utts (2003), on the other hand, emphasizes that statistical literacy includes the ability to analyze data under conditions of uncertainty and to draw conclusions using quantitative methods.

Ability to interact with modern interfaces

The ability to interact with modern interfaces is a competence that denotes the ability to effectively and consciously use various forms of human-computer communication. It refers to both classic graphical interfaces (GUIs) and newer developments such as touch screens, voice recognition systems, gesture-based interfaces, as well as augmented and virtual reality (AR/VR) technologies or conversational interfaces such as chatbots and voice assistants. An important component of this competence is the ability to adapt to new forms of interaction, to critically evaluate their functionality and to be able to use them in everyday life and work, especially in environments that require the use of advanced IT systems or tools to support business processes. There are a number of definitions in the literature that converge. Norman (2013) emphasizes that modern user interfaces should be viewed as tools that support human activities through intuitiveness, simplicity and the ability to minimize cognitive load. Hassenzahl and Tractinsky (2006) emphasize that an important aspect of this competence is the user's ability to experience the interface as useful, friendly and aesthetically pleasing, which influences the satisfaction and effectiveness of the interaction. On the other hand, Dix, Finlay, Abowd and Beale (2004) point out that interacting with interfaces involves mastering input/output techniques, understanding interaction models, and adapting to a variety of human-system communication modes.

Complex thinking

Complex thinking is the ability to translate vast amounts of data into abstract concepts that allow one to see and understand the nature and significance of change. It involves analyzing and solving problems of high complexity, ambiguity and variability. It involves identifying connections between multiple elements of a system, studying their interrelationships, and predicting the effects of decisions over the long term. This ability requires not only critical reflection and analytical thinking, but also creativity, flexibility and the ability to integrate information from different areas. The OECD (2018) defines complex thinking as the ability to solve problems in a dynamically changing environment that is characterized by multidimensionality and uncertainty. Senge (2006) points out that complex thinking is closely related to systems thinking, which means the ability to grasp the whole by understanding the relationships and feedbacks between system elements. Csapó and Funke (2017), on the other hand, emphasize that it encompasses the ability to deal with problems that require understanding and controlling dynamic systems and anticipating the consequences of actions in the long term.

Cognitive load management

Cognitive load management is the ability to consciously direct and regulate one's mental resources in such a way as to effectively receive, process and use information in the process of learning, working or making decisions. It includes matching task complexity to cognitive

capacity, reducing distractions and optimally using working memory. Paas and Van Merriënboer (1994) emphasize the role of metacognitive strategies that enable control over the thinking process and better management of cognitive resources. Kirschner, Ayres and Chandler (2011) add that cognitive load management is particularly important in education and environments where rapid decision-making is required, and supports the development of digital skills.

Knowledge of various business and operational processes

This knowledge refers to the ability to recognize, understand and interpret the principles by which a business operates. It includes an awareness of core business areas - such as planning, production, logistics, marketing or finance - and recognizing their interrelationships and impact on organizational effectiveness (Hammer, Champy, 1993). Davenport (1993) stresses that it helps identify the stages of operational activities and identify ways to improve them. Porter (1985) points to its importance for competitive advantage, and Hammer (2010) and Davenport and Short (1990) link it to modern management methods such as business process reengineering.

Projective thinking

Projective thinking is the ability to anticipate potential events and possible developments, as well as to plan activities in a forward-looking perspective. Voros (2003) describes it as the process of foresight, which involves analyzing trends and creating scenarios. Miller (2007) emphasizes the role of data interpretation skills and imagination in creating alternative visions of the future. Sardar (2010) emphasizes that projective thinking plays an important role in adapting to uncertainty, and Slaughter (1995) sees it as a principle that shapes cultural resilience. Candy and Dunagan (2017) point to the importance of projective thinking in designing scenarios and preparing for future challenges.

Knowledge of new media

New media literacy refers to the ability to critically evaluate and use modern communication tools, such as social media, streaming platforms, websites and mobile applications (Jenkins, 2006). Livingstone (2009) emphasizes that it also includes understanding the impact of media on culture and social life. Castells (2009) emphasizes the multidirectional nature of communication in the digital environment. Buckingham (2003) points out that new media literacy involves building an informed online presence, recognizing risks and actively participating in digital culture.

Specialized digital skills

This competency includes advanced knowledge and practical skills in developing, implementing and maintaining information systems. Pressman (2014) describes it in the context of software engineering. Stallings (2017) emphasizes the importance of IT security, and Laudon and Laudon (2020) point to their role in information management. Sommerville (2016) adds that they also require knowledge of design methods such as Agile and DevOps.

Basic risk management knowledge

Basic risk management knowledge means understanding the principles of identifying, analyzing, assessing and evaluating, as well as controlling and monitoring risks to an organization. Risk management uses methods such as HAZOP, BowTie analysis or FMEA, among others.

Basic knowledge of business continuity management

This competency refers to knowing how to plan and implement processes that allow an organization to function despite disruptions. Herbane (2010) points to the need for a crisis approach, ISO (2019) sets standards in this area, and Bhamra, Dani and Burnard (2011) emphasize the importance of resilience and the ability to recover. The essence of business continuity management is the creation of contingency and so-called "Recovery" plans that will allow the organization to return to normal operations in a short period of time.

3. Research methodology

To carry out the research, the authors used a survey method, directing a questionnaire to a purposively selected group of respondents. The research sample included senior managers responsible for logistics and supply chains in manufacturing companies (including directors of logistics and purchasing departments), as well as owners and CEOs of companies in the medical device sector. The selection of participants, although it limited the sample size and did not allow it to be representative, ensured a high level of substantive responses due to their knowledge, professional experience and international perspective on team management.

A total of 34 responses were obtained, including 20 from Poland and 13 from foreign markets. Only top executives were qualified to participate in the survey, and the sample size was due to organizational constraints. The questionnaire was preceded by direct e-mail or telephone contact with potential respondents, during which the purpose of the survey, the manner in which it was to be conducted and the importance of the issue under study were presented. At the same time, detailed substantive and technical guidance was provided to participants.

The questions in the questionnaire were developed on the basis of a review of the literature on the subject and the results of pilot studies conducted in 2017 and 2018 (Lupicka, Grzybowska, 2017, 2018), which made it possible to verify the existing set of competencies and expand it to include the new digital and technical competencies currently required. Based on them, the existing survey tools were modified, expanding them to include issues of digital competencies in the context of Industry 5.0. The survey covered companies located in Europe, North America and East Asia, operating in the medical device manufacturing sector.

The survey was conducted in June 2023. The questionnaire was prepared electronically and distributed via email. The method used was CAWI (Computer-Assisted Web Interview), which allows respondents to complete the questionnaire themselves in an online form. Respondents were guaranteed full anonymity. The survey tool was based on a three-stage Likert scale, where 1 meant the lack of relevance of a given competence, 2 - no clear opinion, and 3 - relevance of the competence. The choice of a three-level scale allowed not only to assess the importance of the studied characteristics, but also to capture neutrality in the responses.

The research process was carried out in accordance with the ethical principles set forth in the *Code of Ethics for Research Employees* (Committee on Ethics in Science, 2020) and with the applicable data protection regulations (RODO).

4. Industry characteristics

The medical device industry is a key component of the global health care system, covering a wide range of products used in the diagnosis, therapy, monitoring and prevention of disease. According to the World Health Organization (WHO), there are about 2 million different types of devices on the market, categorized into more than 7,000 general groups - from simple tools such as bandages or syringes to high-tech devices including pacemakers and MRI machines (WHO, 2023).

The data states that the medical device market reached \$542.21 billion in 2024, and could grow to \$886.68 billion by 2032 (Fortune Business Insights, 2024). The sector's growth is determined primarily by demographic and epidemiological factors, such as aging populations, population growth, and the increasing number of lifestyle diseases, including diabetes, obesity, cardiovascular disease and cancer. Currently, there are more than 400 million people with diabetes worldwide, and this number could increase by half in the next few years, with an estimated 200 million diabetics in China and India alone (PARP, 2021).

Demographic factors play a special role in shaping the future of the market. In the near future, senior citizens will make up about 20% of the European Union's population, and in Japan up to a third of the population. The global population is also projected to increase by about a billion by 2030, reaching 8.6 billion, and nearly 10 billion by mid-century (PARP, 2021). At the same time, there is a growing demand for technological solutions to compensate for the limitations of aging and often outdated hospital infrastructure, especially in Europe and the United States. Implementing modern digital solutions is becoming a key way to improve the quality, accessibility and cost-effectiveness of health care systems (BCC Research, 2023).

5. Results

Analyzing the table below, it can be seen that for domestic respondents the most important digital and technical competencies are data and information processing and analytics, and complex thinking. In contrast, for foreign respondents, the most important competencies are cognitive load management and projective thinking. Common to both groups of respondents is the competency of projective thinking. On the other hand, as for the competencies rated lowest, there were similar indications in both groups, concerning statistical skills and knowledge of new media.

Table 1.
Digital and technical competencies in light of the survey

Digital and technical competencies	Domestic respondents		Foreign respondents	
	Mean	Standard deviation	Mean	Standard deviation
Knowledge management regarding the use and harmfulness of digital technologies to the environment	1,9	5,85	2,5	3,21
Data and information processing and analytics	3,0	11,54	2,5	5,13
General knowledge of technologies	2,2	6,50	2,8	5,77
General knowledge of organizations	2,3	6,50	2,6	5,77
Specialized and up-to-date knowledge of technologies and organizations	2,1	2,51	2,6	4,93
Statistical skills	2,1	2,51	2,2	4,04
Ability to interact with modern interfaces	2,1	5,13	2,5	4,16
Complex thinking	2,9	10,69	2,9	6,65
Management of cognitive load	2,4	7,02	2,9	6,65
Knowledge of various business and operational processes in the organization	2,7	9,07	2,5	4,04
Projective thinking	2,5	6,65	2,9	6,65
Knowledge of new media	1,9	4,16	2,0	1,15
Specialized IT skills	1,6	4,61	2,3	2,30
Basic knowledge of risk management disruptions	2,7	9,07	2,5	4,16
Basic knowledge of business continuity management operations	2,6	8,32	2,7	5,85
General computer skills	2,5	6,65	2,5	4,16

Source: own elaboration based on surveys.

Slight differences are also apparent in the case of the competence of knowledge management regarding the use and harm of digital technologies to the environment. Here, domestic respondents showed that this is not a significant competence, while for foreign respondents it is already more important. The same is true of the competence concerning general knowledge of technologies. Foreign respondents considered this skill to be quite significant, while domestic respondents did not report a high degree of importance for this competence.

Similar indications of the average degree of importance of the competencies in question for both groups were for basic knowledge of disruption risk management or basic knowledge of business continuity management. Summarizing the table, it can be noted that domestic respondents generally rated most competencies lower compared to foreign respondents.

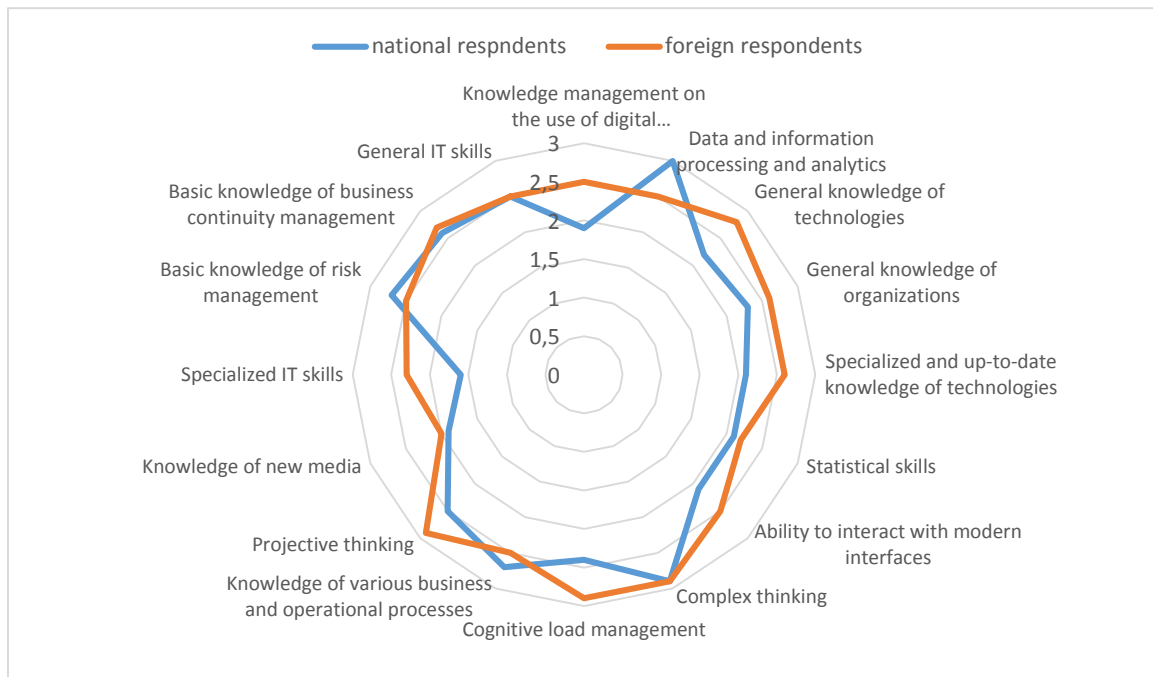


Figure 1. Digital competencies in the era of Industry 5.0.

Source: own elaboration based on the survey.

Analysis of the standard deviation results reveals mostly small differences in the distribution of responses between the Polish and foreign markets. The standard deviation (SD) determines the degree of dispersion of values in a data set, usually in relation to the mean of that group (Foltynowicz, Lupicka, Jeszka, 2024). In simple terms, the standard deviation indicates how much the values of a given quantity spread around the mean. The smaller the value of the deviation, the more the observations cluster around the mean. In the case of the "data and information processing and analysis" competence, a significant difference in the standard deviation becomes apparent - domestic respondents were more decisive in marking the same answer than foreign respondents. The situation is similar for the "complex thinking" competence. Despite the same mean, the standard deviation is incomparable. It can be seen that domestic respondents were also in this case more determined to mark the same answer than their foreign counterparts.

6. Discussion

Public reluctance towards artificial intelligence, including the use of IT expertise, stems from fears of new solutions to streamline processes and, above all, the feeling that these technologies limit traditional human work (Wincewicz-Bosy, Lupicka, Stawiarska, 2017). CEOs - the authors and implementers of these technologies - indicate that the development of AI-based systems and machines is unlimited. They intend to further improve functionalities,

introduce new analytical tools, especially in machine learning and advanced event processing. A variety of data will be used for this purpose, both from networks, supply chains and from individual actors involved in business processes.

Both customers implementing AI and those who are just considering its implementation, as well as their employees, the scientific and business communities - despite appreciating the benefits of artificial intelligence - express concerns about its risks, as strongly revealed by the results of surveys conducted, especially among domestic respondents. The indicated barriers and recommendations for its development were assigned to political-legal, economic, technological and socio-cultural categories (Wincewicz-Bosy, Lupicka, Stawiarska, 2017). Companies that have not yet decided to implement AI are looking for economic arguments. The difficulty is that it is still unclear how long the proposed solutions will last or how to accurately estimate the return on investment - especially in the absence of clear data on the savings generated by self-learning applications.

As a result, a development gap is emerging between companies that lack adequate information resources and large corporations, where artificial intelligence and digital competencies are becoming part of key decision-making structures, even at the board level (Wincewicz-Bosy, Lupicka, Stawiarska, 2017). This approach raises the question of whether new challenges will arise in the area of supply chain management and logistics, and what digital and technical competencies will be necessary to make sound decisions about the development of organizations and supply networks in the context of the transformation of the economy towards Industry 5.0.

In the reality of Economy 5.0, where the accent is on simultaneous economic, social and environmental development, as well as on improving technological skills and risk management competencies, human collaboration - a key capability in management, including in the area of supply chains - is becoming particularly important again.

Awareness of currently required skills, which should be included in personnel development policies, creates a need among employees for training, continuing education and upskilling, i.e. reskilling and upskilling activities. This challenge falls largely on Human Resources departments. Referring to the results of the survey, it is clear that the awareness of foreign respondents regarding the role of digital competencies is far greater than that of domestic respondents. This could be due to a number of reasons. One of them may be the higher level of development of foreign companies compared to Polish ones.

Referring to the DESI (2022) report, one can see the difference in the level of digitization of Poland compared to Europe. Our foreign colleagues see the need to integrate man and machine as an important challenge of managing non-collar workforce teams. Its key problem is the establishment of dependency vectors in joint (human-robot) decision-making and the related transparency of these decisions. Another reason is the continued lack of funding for Polish companies and opportunities to implement innovations. Entrepreneurs in the Polish market are struggling with problems such as the continuous increase in the minimum wage,

which results in the profits generated being used for salaries rather than for company development.

7. Conclusions

Based on the research, it can be concluded that in the face of constant and dynamic economic and technological changes, and especially in the context of the transformation towards Industry 5.0, digital and technical competencies are becoming increasingly important. This includes analytical, interpersonal and strategic skills. Respondents particularly emphasized the importance of such competencies as complex thinking, projective planning skills, general technological knowledge and data and information analysis.

Both Polish and foreign survey participants emphasized the need to develop competencies that enable them to function efficiently in a complex and rapidly evolving work environment. Differences in responses between groups may have been due to cultural differences or varying levels of digital maturity of individual organizations.

From the point of view of management practice, the results indicate the need to integrate the development of digital competencies into organizational strategies, especially in highly regulated and technologically advanced sectors, such as the medical device industry. They also underscore the importance of the interaction of technology and human capital, as without this synergy the implementation of the Industry 5.0 concept will not be possible.

It seems reasonable to conduct further research in this area. It is worth considering cross-industry analysis, in-depth qualitative research on the competencies of the future, as well as evaluation of the effectiveness of programs to develop digital and technical competencies in the context of the transformation of supply chains towards Industry 5.0.

The development of modern technologies is associated with the simultaneous emergence of new opportunities and challenges, especially in the context of its impact on the labor market and the difficulty of assessing the viability of deployments. Industry 5.0 accentuates the need to combine digital, technical and social competencies, as well as to systematically develop employees' skills. The results of the research show clear differences between Poland and countries with a higher degree of digitization, which is due, among other things, to limited funding opportunities for innovation and structural conditions of the labor market. Further implications for in-depth research may include:

1. the impact of digital competencies on the finances of supply chains in Industry 5.0,
2. the development of digital competencies based on informal connections that result in a willingness to share experience and acquired knowledge,
3. the impact of digital competence development on knowledge conversion in Industry 5.0 supply chains.

The above considerations and implications for further research will advance the understanding of the role played by digital competencies in supply chains in the era of Industry 5.0.

References

1. Agrawal, S., Agrawal, R., Kumar, A., Luthra, S., Garza-Reyes, J.A. (2024). Can industry 5.0 technologies overcome supply chain disruptions? A perspective study on pandemics, war, and climate change issues. *Operations Management Research*, 17(2), 453-468. <https://doi.org/10.1007/s12063-023-00410-y>
2. American Statistical Association (2016). *Guidelines for assessment and instruction in statistics education (GAISE) college report 2016*. American Statistical Association.
3. APICS (2014). *APICS Operations Management Body of Knowledge (OMBOK) Framework* (3rd ed.). APICS.
4. Arthur, W.B. (2009). *The nature of technology: What it is and how it evolves*. Free Press.
5. Audrey, A., Paksi, C. (2021). *Industry 5.0: A human-centric solution*. Springer.
6. Bauer, W., Hämmerle, M., Schlund, S., Vocke, C. (2015). Transforming to a hyper-connected society and economy - Towards an "Industry 4.0". *Procedia Manufacturing*, 3, 417-424. <https://doi.org/10.1016/j.promfg.2015.07.200>
7. BCC Research (2023). *The medical device market is booming in the future*. <https://blog.bccresearch.com/the-medical-device-market-is-booming-in-the-future>
8. Bhamra, R., Dani, S., Burnard, K. (2011). Resilience: The concept, a literature review and future directions. *International Journal of Production Research*, 49(18), 5375-5393.
9. Buckingham, D. (2003). *Media education: Literacy, learning and contemporary culture*. Polity Press.
10. Burnes, B. (2017). *Managing change*. Pearson Education.
11. Candy, S., Dunagan, J. (2017). Designing an experiential scenario: The people who vanished. *Futures*, 86, 136-153.
12. Castells, M. (2009). *Communication power*. Oxford University Press.
13. Castells, M. (2010). *The rise of the network society* (2nd ed.). Wiley-Blackwell.
14. Chidozie, B., Ramos, A., Ferreira, J., Ferreira, L.P. (2024). The Importance of Digital Transformation (5.0) in Supply Chain Optimization: An Empirical Study. *Production Engineering Archives*, 30(1), 127-135. <https://doi.org/10.30657/pea.2024.30.12>
15. Coelho, P., Bessa, C., Landeck, J., Silva, C. (2023). Industry 5.0: The Arising of a Concept. *Procedia Computer Science*, 217, 1137-1144. <https://doi.org/10.1016/j.procs.2022.12.312>
16. Csapó, B., Funke, J. (Eds.) (2017). *The nature of problem solving: Using research to inspire 21st century learning*. OECD Publishing.

17. Daft, R.L. (2021). *Organization theory and design* (13th ed.). Cengage Learning.
18. Davenport, T.H. (1993). *Process innovation: Reengineering work through information technology*. Harvard Business School Press.
19. Davenport, T.H., Harris, J.G. (2007). *Competing on analytics: The new science of winning*. Harvard Business School Press.
20. Davenport, T.H., Short, J.E. (1990). The new industrial engineering: Information technology and business process redesign. *Sloan Management Review*, 31(4), 11-27.
21. Davis, J., Edgar, T., Porter, J., Bernaden, J., Sarli, M. (2011). Smart manufacturing, manufacturing intelligence and demand-dynamic performance. *Computers & Chemical Engineering*, 47, 145-156. <https://doi.org/10.1016/j.compchemeng.2012.06.037>
22. Demir, K.A., Döven, G., Sezen, B. (2019). Industry 5.0 and Human-Robot Co-working. *Procedia Computer Science*, 158, 688-695. <https://doi.org/10.1016/j.procs.2019.09.104>
23. Dix, A., Finlay, J., Abowd, G.D., Beale, R. (2004). *Human-computer interaction*. Pearson.
24. Durugbo, C.M. (2025). Uncertainties of supply chain transition and integration for Industry 5.0: A review of operations management literature. *International Journal of Production Research*, 63(18), 6915-6937. <https://doi.org/10.1080/00207543.2025.2489039>
25. Dwivedi, Y.K., Hughes, L., Baabdullah, A., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M., Wamba, S. (2023). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management*, 71, 102642. <https://doi.org/10.1016/j.ijinfomgt.2023.102642>
26. ENISA (2021). *Cybersecurity skills framework*. European Union Agency for Cybersecurity. <https://www.enisa.europa.eu/publications/cybersecurity-skills-framework>
27. European Commission, Breque, M., De Nul, L., Petridis, A. (2021). *Industry 5.0: Towards a sustainable, human-centric and resilient European industry*. Publications Office of the European Union. <https://doi.org/10.2777/308407>
28. European Commission (2022). *The digital economy and society index (DESI) 2022*. Publications Office of the European Union. <https://doi.org/10.2759/709723>
29. Few, S. (2012). *Show me the numbers: Designing tables and graphs to enlighten* (2nd ed.). Analytics Press.
30. Foltynowicz, Z., Łupicka-Fietz, A., Jeszka, A.M., Kowalczyk, D. (2024). Evolution of social competencies in sustainable supply chains. *Sustainability*, 16(6), 2581. <https://doi.org/10.3390/su16062581>
31. Forti, V., Baldé, C.P., Kuehr, R., Bel, G. (2020). *The global e-waste monitor 2020: Quantities, flows and the circular economy potential*. United Nations University, United Nations Institute for Training and Research & International Telecommunication Union. <https://ewastemonitor.info/>

32. Fortune Business Insights (2024). *Medical devices market size, share & COVID-19 impact analysis*. <https://www.fortunebusinessinsights.com/industry-reports/medical-devices-market-100085>
33. Gartner (2023). *Future of supply chain: Building resilience in a digital-first world*. Gartner Research.
34. Gladysz, B., Tran, T., Romero, D., Erp, T. van, Abonyi, J., Ruppert, T. (2023). Current development on the Operator 4.0 and transition towards the Operator 5.0: A systematic literature review in light of Industry 5.0. *Journal of Manufacturing Systems*, 70, 160-185. <https://doi.org/10.1016/j.jmsy.2023.07.008>
35. Grabowska, S., Saniuk, S., Gajdzik, B. (2022). Industry 5.0: Improving humanization and sustainability of Industry 4.0. *Scientometrics*, Vol. 127, Iss. 6, pp. 3117-3144, doi: 10.1007/s11192-022-04370-1
36. Hammer, M. (2010). What is business process management? In: J. vom Brocke, M. Rosemann (Eds.), *Handbook on business process management*, 1 (pp. 3-16). Springer.
37. Hammer, M., Champy, J. (1993). *Reengineering the corporation: A manifesto for business revolution*. Harper Business.
38. Hassenzahl, M., Tractinsky, N. (2006). User experience - a research agenda. *Behaviour & Information Technology*, 25(2), 91-97.
39. Hatch, M.J. (2018). *Organization theory: Modern, symbolic, and postmodern perspectives* (4th ed.). Oxford University Press.
40. Herbane, B. (2010). Small business research: Time for a crisis-based view. *International Small Business Journal*, 28(1), 43-64.
41. Hillson, D. (2002). *Effective opportunity management for projects: Exploiting positive risk*. CRC Press.
42. Hoffman, K., Parejo, M., Bessant, J., Perren, L. (2005). Small firms, R&D, technology and innovation in the UK: A literature review. *Technovation*, 18(1), 39-55. [https://doi.org/10.1016/S0166-4972\(97\)00102-8](https://doi.org/10.1016/S0166-4972(97)00102-8)
43. International Organization for Standardization (ISO) (2019). *ISO 22301:2019 Security and resilience - Business continuity management systems - Requirements*. ISO.
44. James, G., Witten, D., Hastie, T., Tibshirani, R. (2021). *An introduction to statistical learning: With applications in R* (2nd ed.). Springer.
45. Jenkins, H. (2006). *Convergence culture: Where old and new media collide*. New York: University Press.
46. Joerres, J.A., McAuliffe, C. (2016). *The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution*. World Economic Forum.
47. Kirschner, P.A., Ayres, P., Chandler, P. (2011). Cognitive load theory. In: R. Mayer, P. Alexander (Eds.), *Handbook of research on learning and instruction* (pp. 97-113). Routledge.

48. Kitchin, R. (2014). *The data revolution: Big data, open data, data infrastructures and their consequences*. SAGE Publications.
49. Knut, H., Balaji, M. (2013). *Next-generation supply chains: Efficient, fast and tailored*. PwC.
50. Kraus, S., Jones, P., Kailer, N., Weinmann, A., Chaparro-Banegas, N., Roig-Tierno, N. (2021). Digital Transformation: An Overview of the Current State of the Art of Research. *Sage Open*, 11(3), 21582440211047576. <https://doi.org/10.1177/21582440211047576>
51. Laudon, K.C., Laudon, J.P. (2020). *Management information systems: Managing the digital firm*. Pearson.
52. Livingstone, S. (2009). *Children and the internet*. Polity Press.
53. Łupicka, A., Stawiarska, E., Wincewicz-Bosy, M. (2017). *Contemporary challenges of supply chains*. TEXTER. Warsaw.
54. Madsen, D.Ø., Berg, T., Di Nardo, M. (2023). Bibliometric Trends in Industry 5.0 Research: An Updated Overview. *Applied System Innovation*, 6(4), 63. <https://doi.org/10.3390/asi6040063>
55. Majewski, P. (2018). *Fundamentals of computer science: An introduction to information technology*. PWN.
56. Malmodin, J., Lundén, D. (2018). The energy and carbon footprint of the ICT and E&M sector in Sweden 1990-2015 and beyond. *Sustainability*, 10(9), 3027. <https://doi.org/10.3390/su10093027>
57. McLaren, D. (2021). Industry 5.0 and the rise of resilience in supply chain systems. *Journal of Manufacturing Systems*, 60, 755-767. <https://doi.org/10.1016/j.jmsy.2021.05.004>
58. Miller, R. (2007). Futures literacy: A hybrid strategic scenario method. *Futures*, 39(4), 341-362.
59. Mintzberg, H. (1993). *Structure in fives: Designing effective organizations*. Prentice Hall.
60. Mitcham, C. (1994). *Thinking through technology: The path between engineering and philosophy*. University of Chicago Press.
61. Moore, D.S., McCabe, G.P., Craig, B.A. (2017). *Introduction to the practice of statistics* (9th ed.). W.H. Freeman.
62. Nahavandi, S. (2019). Industry 5.0-A Human-Centric Solution. *Sustainability*, 11(16), 4371. <https://doi.org/10.3390/su11164371>
63. Norman, D.A. (2013). *The design of everyday things*. MIT Press.
64. OECD (2018). *The future of education and skills: Education 2030*. OECD Publishing.
65. Paas, F., Van Merriënboer, J.J. . (1994). Instructional control of cognitive load in the training of complex cognitive tasks. *Educational Psychology Review*, 6(4), 351-371.
66. Pizoń, J., Gola, A. (2023). Human-Machine Relationship-Perspective and Future Roadmap for Industry 5.0 Solutions. *Machines*, 11(2), 203. <https://doi.org/10.3390/machines11020203>

67. Polish Agency for Enterprise Development [PARP] (2021). *Report: the medical device industry in Poland*.
68. Polmed (2021). *Medical device sector in Poland - size, impact, importance*. <https://polmed.org.pl/raport-sektor-wyrobow-medycznych-w-polsce-wielkosc-oddzialywanie-znaczenie/>
69. Pompa, C. (2015). *Emerging trends in supply chain management*. McKinsey & Company.
70. Porter, M.E. (1985). *Competitive advantage: Creating and sustaining superior performance*. Free Press.
71. Pressman, R.S. (2014). *Software engineering: A practitioner's approach*. McGraw-Hill.
72. Relich, M. (2015). Knowledge acquisition for new product development with the use of an ontology. *Expert Systems with Applications*, 42(13), 6027-6041. <https://doi.org/10.1016/j.eswa.2015.03.017>
73. Robbins, S.P., Judge, T.A. (2019). *Organizational behavior* (18th ed.). Pearson.
74. Rumsey, D.J. (2016). *Statistics for dummies* (2nd ed.). Wiley.
75. Sardar, Z. (2010). The namesake: Futures; futures studies; futurology; futuristic; foresight- What's in a name? *Futures*, 42(3), 177-184.
76. Schwab, K. (2016). *The fourth industrial revolution*. World Economic Forum.
77. Scott, W.R. (2015). *Organizations and organizing: Rational, natural and open systems perspectives* (2nd ed.). Routledge.
78. Senge, P.M. (2006). *The fifth discipline: The art and practice of the learning organization*. Doubleday.
79. Shi, Y., Venkatesh, V.G., Venkatesh, M., Fosso Wamba, S., Wang, B. (2023). Guest editorial: Digital transformation in supply chains: challenges, strategies and implementations. *International Journal of Physical Distribution & Logistics Management*, 53(4), 381-386. <https://doi.org/10.1108/IJPDLM-05-2023-550>
80. Shneiderman, B., Plaisant, C., Cohen, M., Jacobs, S., Elmqvist, N., Diakopoulos, N. (2017). *Designing the user interface: Strategies for effective human-computer interaction*. Pearson.
81. Slaughter, R.A. (1995). *The foresight principle: Cultural recovery in the 21st century*. Praeger.
82. Sommerville, I. (2016). *Software engineering*. Pearson.
83. Song, M., Fisher, R., Kwoh, Y. (2021). Technological innovation and digital transformation for sustainability: Industry 5.0 and beyond. *Sustainability*, 13(16), 8854. <https://doi.org/10.3390/su13168854>
84. Stallings, W. (2017). *Effective cybersecurity: A guide to using best practices and standards*. Addison-Wesley.
85. Störmer, E., Patscha, C., Prendergast, J., Daheim, C., Rhisiart, M., Glover, P., Beck, H. (2014). *The future of work: Jobs and skills in 2030*. UK Commission for Employment and Skills.

86. Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, 12(2), 257-285.
87. Szeliga, M. (2020). *Information technology basics: A practical user's guide*. Helion Publishing House.
88. Tabrizi, B.N., Lam, E.Y., Girard, K., Irvin, V. (2019). *Digital Transformation Is Not About Technology*. <https://api.semanticscholar.org/CorpusID:251920900>
89. Utts, J.M. (2003). What educated citizens should know about statistics and probability. *The American Statistician*, 57(2), 74-79. <https://doi.org/10.1198/0003130031630>
90. Volti, R. (2017). *Society and technological change* (8th ed.). Worth Publishers.
91. Voros, J. (2003). A generic foresight process framework. *Foresight*, 5(3), 10-21.
92. Winter, J., Heindl, C. (2016). Digital transformation: How mature is your company? *Management Review Quarterly*, 66(2), 81-104. <https://doi.org/10.1007/s11301-016-0110-y>
93. World Health Organization [WHO] (2023). *Medical devices*. <https://www.who.int/health-topics/medical-devices>
94. Xu, X., Lu, Y., Vogel-Heuser, B., Wang, L. (2021). Industry 4.0 and Industry 5.0-Inception, conception and perception. *Journal of Manufacturing Systems*, 61, 530-535. <https://doi.org/10.1016/j.jmsy.2021.10.006>
95. Zouari, D., Ruel, S., Viale, L. (2021). Does digitalising the supply chain contribute to its resilience? *International Journal of Physical Distribution & Logistics Management*, 51(2), 149-180. <https://doi.org/10.1108/IJPDLM-01-2020-0038>

APPLICATION OF DIGITAL TOOLS IN ENTERPRISES IN THE CONTEXT OF COMMUNICATION MANAGEMENT

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Purpose: The purpose of the article is to identify the digital tools used and their role in enterprise communication management.

Design/methodology/approach: The paper uses a literature analysis method focusing on the identification and characterization of digital tools. A survey method was also used. The survey research conducted in 2024 was aimed at employees and managers of enterprises in the Silesian province. The analysis of the literature and the empirical research conducted in enterprises made it possible to achieve the stated purpose.

Findings: The empirical research conducted allowed the verification of four research hypotheses. Three of them were confirmed and one was falsified. The results of the research confirmed that most of the surveyed enterprises use digital tools for internal and external communication. The research also confirmed the positive impact of digital tools on communication in most of the surveyed enterprises.

Research limitations/implications: A limitation of the research conducted in the research process is the size of the research sample and the scope of the research limited to the Silesian province.

Practical implications: The research shows a number of practical implications that can significantly improve the efficiency of business processes and improve the competitiveness of companies. What is needed in this regard is further education of employees and investment in new technologies and tools, as well as the creation of standards and procedures for the use of these tools.

Social implications: The research has important social implications. The use of digital tools in companies can contribute to greater transparency in business operations, which can in turn have an impact on increasing the trust of various stakeholders. The introduction of more flexible work models, remote or hybrid work through the use of digital tools can increase employee satisfaction contributing to a better quality of life.

Originality/value: The issues raised concerning the application of digital tools in enterprises with a focus on communication is a timely and important topic in both scientific and practical layers. The results of the research can be of value to enterprise managers in particular.

Keywords: digital tools, communication, communication management, enterprises.

Category of the paper: Research paper.

1. Introduction

Digital tools are playing an increasingly important role in enterprise communications, offering a range of opportunities related to knowledge sharing, easier access to information, faster communication and strengthening social relationships, among others. As Szombathelyi K.M. et al. (2015) point out, the most important challenges for communication management are issues related to digital evolution, the development of communication instruments and networks and social media.

Communication in the modern world is of great value, it has become the basic foundation for the functioning of all organizations. Effective communication is a source of important information in the organizational and individual spheres (Drucker, 2009). It refers to the exchange of information, thoughts, opinions and feelings between the addressee and the recipient through a variety of channels and codes (Griffin et al., 2018). Communication is not only the transmission of information, but also the understanding of the intentions and emotions behind it. Communication, as defined, is the process of exchanging information, thoughts and emotions between individuals. Depending on its established goals, it can serve many different functions. It can be used to communicate results and rewards, establish cooperation, form trust, norms and values, mediate and negotiate, share experiences and ideas (Robbins, Judge, 2018). Communication can help coordinate activities, motivate employees, build relationships, create organizational culture, resolve conflicts and transfer knowledge (Ober et al., 2018). All of this underscores the importance of effective communication in our daily lives, both on a personal and professional levels. Regardless of its form, communication is crucial for understanding and cooperation between people. It provides a mechanism for creating and developing interpersonal relationships (Cooley, 1983).

In the 21st century, digitization has affected all fields, and many digital tools have been created and developed. They have also affected communication, which has undergone tremendous changes. These tools have significantly expanded the boundaries of information exchange, enabling it to spread on an unprecedented scale and communication has run beyond the boundaries of transmitted paper messages to their digital counterparts. However, the use of these tools also brings certain risks and challenges, such as potential privacy violations and the spread of misinformation. In order to fully realize the potential of digital tools for managing corporate communications, it is necessary to use them consciously and responsibly, taking into account possible risks and limitations.

The purpose of the article is to identify the digital tools used and their role in enterprise communication management.

2. Literature review - the role of digital tools in enterprise communications management

In the current era, dynamic advances in digital technology are having a significant impact on various aspects of daily and business life, including corporate communications management. It has changed various areas of human life on a global scale (Szadok-Bratun, Bratun, 2022). Effective communication in an enterprise is crucial to achieving organizational goals, improving cooperation among employees, and improving organizational performance. It is important for the organization itself as well as its environment (Klinowski, 2011). Communication in an enterprise can occur at different hierarchical levels, from horizontal, interpersonal communication between organizational members working at the same level, to vertical communication, which flows from management to employees and vice versa (Stoner, Freeman, Gilbert, 1999; Friedberg, 2019). Different forms of communication are used in an enterprise, including formal communication that takes place through official channels and procedures, and informal communication that takes place outside official channels (Sypniewska, 2013).

Nowadays where digitization dominates many aspects of life, communication takes a variety of forms using increasingly digital tools. The teleworking, in which digital tools play a large role, is becoming increasingly important (Clark et al., 2012; Smith et al., 2018). Modern digital tools, which are the result of technological advances, have the potential to optimize communication processes and contribute to achieving higher efficiency. Digital tools are one of the key success factors in an organization's communications, ceasing to be mere addons and becoming generating factors. The reason for their growing role is their effectiveness (Grandys, 2000). Nevertheless, adapting to innovative systems brings with it certain challenges, including the need for continuous education in new technologies.

The challenge is to match the right digital tools to the communication goals (Biesaga-Słomczewska, 2015). The choice of appropriate tools depends on the individual needs of the organization (Wojcik, Rybicka, 2013). Digital tools can include various technical means and methods that are necessary for the implementation of information systems. These include computer and communication hardware, system and application software, as well as data stored on electronic media (Grabowski et al., 2012). Popular digital tools used by companies include programs for creating and editing documents, such as Microsoft Office, Microsoft Outlook, Google Calendar and other scheduling and email software (Biesaga-Słomczewska, 2015). General uncategorized digital tools include the Internet and email, mobile devices such as tablets and smartphones, which, combined with the cloud and appropriate software, allow access to all company data. They make corporate communication easier and more efficient.

Digital technology tools can be divided into different types depending on their function and application. One of them is video conferencing tools that are communication platforms. Among these tools are Microsoft Teams, Zoom, Google Workspace, which are increasingly used by organizations for both internal and external communication (Dash et al., 2022). These platforms are used for real-time communication, enabling messaging, file sharing and simultaneous collaboration among multiple people in teams creating opportunities for employees to work together in a virtual environment. They enable video meetings, remote team collaboration. These tools are increasingly using artificial intelligence.

Communication, the better it is planned, the more effectively it works, the easier it is to conduct projects thanks to it, and it significantly affects the building of relationships between employees and external partners. Nowadays, many tools have been developed to support the area of project management. Among them we can mention tools such as Trello, or Jira (Clemente, Domingues, 2023).

In the era of modern digital economy, broadly applicable technologies have emerged that enhance, intensify and stimulate development. The literature distinguishes so-called intensifying technologies that can include cloud solutions, the Internet of things, artificial intelligence (AI), blockchain, among others (Śledziewska, Włoch, 2020). In the context of ever-evolving digital technologies, it is worth paying attention to cloud technologies, which allow organizations to manage communications more efficiently by using the right software (Shawish, Salama, 2014; Kopishynska et al., 2016). Cloud solutions are important in project management, among other things (Szydlowski, 2019). The Internet of Things (IoT), in turn, defined as a method of connectivity that allows data to be collected, transmitted and flowed between devices with or without human involvement over a network (Trzop, 2020; Guzowski et al., 2024). It plays a special role in the sphere of internal communication in companies. Thanks to its various functions, the Internet of Things supports communication by transmitting data on the availability of resources, the status of projects, allows control and monitoring of the working environment, the status of devices and infrastructure. This translates into a quick response to any irregularities making communication more efficient (Śledziewska, Włoch, 2020). The next intensifying technology that is finding increasing use is artificial intelligence (AI). It has a range of capabilities and functions that work well in situations where rapid communication is crucial. AI can be applied in areas such as speech recognition in voice systems, sharing records in real time, sorting messages, analyzing engaging content, translating speech into different languages, among others, which is invaluable in multinational companies (Makowski, 2023). One of the many functions of artificial intelligence is to manage, support and create so-called corporate communication channels. The development of artificial intelligence has resulted in the creation of chatbots, which can provide quick responses while relieving the burden on employees of the various departments of a given company (Makowski, 2023). In addition, they can also create their own content, text documents. Blockchain, in the context of internal communication, can be used to save documentation or messages that can be

transmitted internally using the platform (Kitsantas, Chytis, 2022). Another useful feature of this program is the ability to monitor the progress of work and report it in the current time so that all the stages of, for example, a project can be saved in it (Casey, Vigna, 2018).

Digital tools, play an extremely important role in communication, influencing all aspects of it. These tools have changed the way people establish and maintain connections, both in their personal and professional lives. Thanks to text and video communication applications, social media and online collaboration platforms, it is possible to transmit information instantly, significantly speeding up communication processes and eliminating geographical barriers. Digital tools used in social media that change the way we communicate are becoming increasingly important (Appel et al., 2020; Fraccastoro et al., 2021). Faraj, S., Jarvenpaa, S.L., and Majchrzak, A. (2015) argue that collaboration regarding knowledge sharing in online communities, which are a virtual organizational form, fundamentally changes the way members of an organization work together. The impact of social media applications on communication and improving corporate performance is also highlighted by Wang et al. (2016). Digital tools enable real-time communication, which is especially important in the business world, where a quick response can determine the success or failure of a venture. With platforms such as Zoom and Microsoft Teams, it is possible to hold meetings and collaborate with people from different parts of the world without being physically present. This global accessibility not only facilitates international business collaboration, but also supports the development of social relationships on an unprecedented scale.

The literature analysis conducted identified a research gap related to the paucity of studies on the application of digital tools in enterprise communication management.

3. Methods

The research problem focuses on finding an answer to the question: what is the role of digital tools in enterprise communications? It is important to understand which of the proposed tools are used for communication in companies and how they affect internal and external communication.

In order to solve the research problem and realize the formulated purpose of the paper, appropriate research methods were selected, such as literature analysis and survey method. The survey questionnaire consisted of closed questions and the answers were in scaled form. The collected data were analyzed using a Microsoft Excel spreadsheet.

Based on the literature analysis, the following research hypotheses were formulated:

- Hypothesis 1: Most of the surveyed companies use digital tools for communication.
- Hypothesis 2: Most of the surveyed employees use digital tools for internal and external communication like Zoom, Microsoft Teams, Slack.

- Hypothesis 3: The digital tools used have a positive impact on communication in most of the surveyed companies.
- Hypothesis 4: Artificial intelligence tools like Chat GPT are used in most of the surveyed companies.

The hypotheses were verified through quantitative research conducted using a survey questionnaire. Based on the data obtained, an analysis was conducted on the role of digital tools in enterprise communication.

The research used a random sampling method to select respondents from different companies operating in the Silesian province. This method made it possible to obtain a variety of opinions and experiences from employees working in different positions and in companies of different sizes. The largest group of respondents out of a total of 83 comes from small companies (33 people), which dominate the market, justifying their large representation in the sample. The second largest group is made up of people working in large enterprises (27). The smallest segment consists of medium-sized enterprises, with 23 responses. In terms of positions held, the sample consists mainly of employees (64 people), which is the vast majority, while a smaller percentage are middle managers (10 people) and top managers (9 people). This distribution of respondents makes it possible to analyze both the perspective of those who perform day-to-day tasks in companies and those who manage them, which allows a more complete view of the phenomenon under study.

4. Results and discussion

In order to verify the formulated hypotheses, research was conducted using a survey questionnaire.

As part of the survey, respondents were asked about the frequency of use of digital tools in the company. The results of the responses obtained are shown in Figure 1.

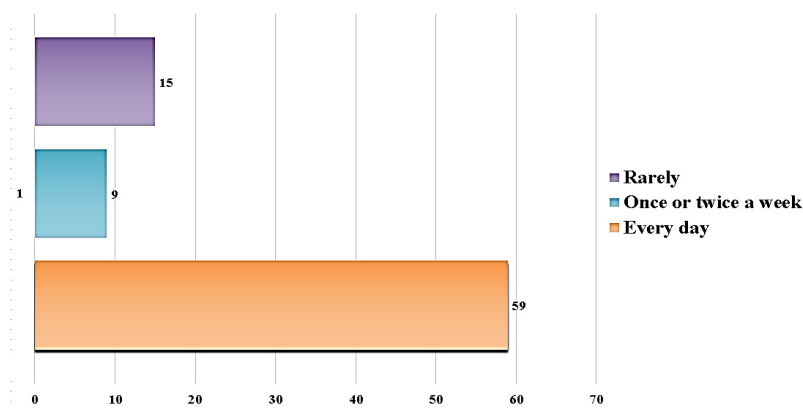


Figure 1. Frequency of use of digital tools in the company.

Source: own study based on research results.

The data presented in Figure 1 indicates that the majority of respondents—as many as 59 people - use digital tools daily. The least common response was using digital tools once or twice a week, marked by 9 respondents. Meanwhile, 15 respondents stated that they rarely use digital tools. Thus, the largest group are those who use digital tools frequently.

Project management tools, such as Trello, are playing an increasingly important role in both internal and external communication. The distribution of responses is illustrated in Figure 2.

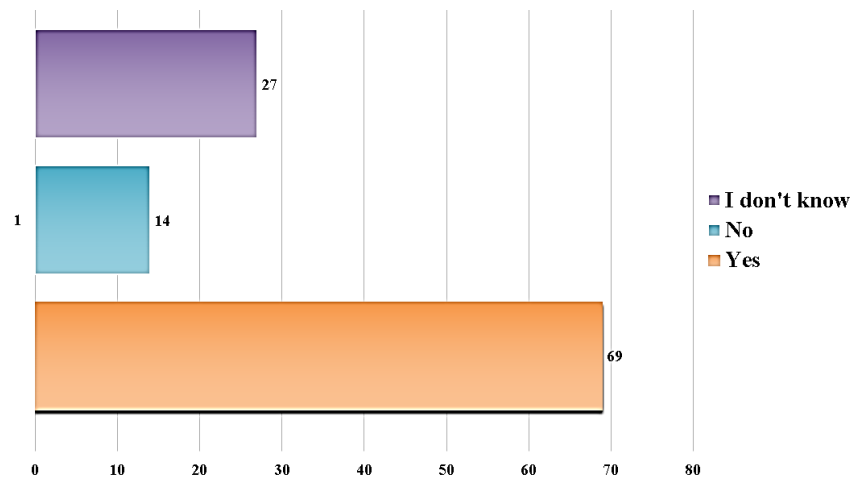


Figure 2. Using tools for project management e.g. type Trello.

Source: own study based on research results.

Figure 2 shows that 18 respondents use project management tools like Trello, while 38 respondents do not use such tools. Additionally, 27 respondents stated that they are unsure about their usage.

In the context of how digital tools impact team communication, respondents were asked whether digital tools facilitate communication within a team. The results are presented in Figure 3.

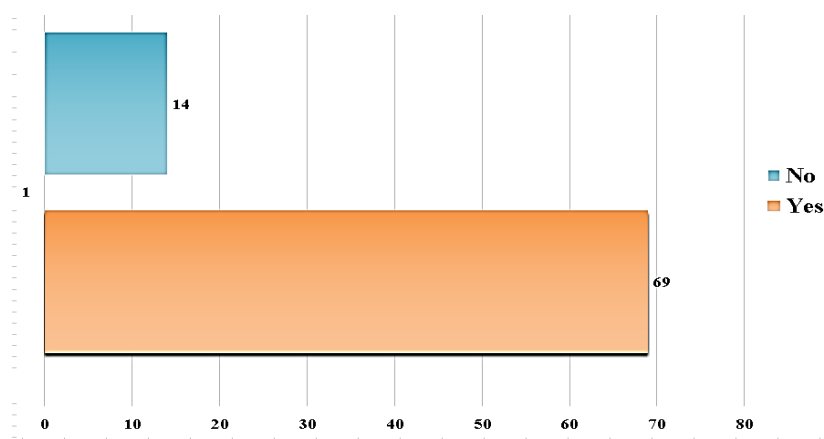


Figure 3. Impact of digital tools on team communication.

Source: own study based on research results.

As shown in Figure 3, 69 respondents indicated that digital tools help improve communication with other team members. Meanwhile, 14 respondents selected the answer "no". The presented data suggests that, for the majority of employees, digital tools make teamwork communication more efficient.

Digital tools such as Slack, Microsoft Teams, Workplace, and Zoom can be useful in both internal and external communication. Figures 4 and 5 illustrate the level of their utilization. Figure 4 presents the survey results regarding the use of digital tools like Slack, Microsoft Teams, Workplace, and Zoom among company employees.

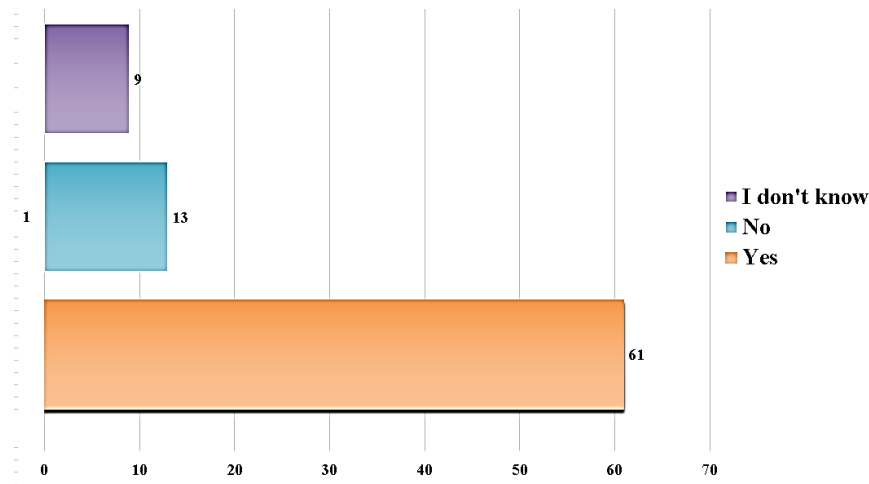


Figure 4. Using tools such as Slack, Microsoft Teams, Workplace, Zoom in internal communication between company employees.

Source: own study based on research results.

The data presented in Figure 4 shows that the vast majority of respondents—61 people—confirm that their company uses digital tools for communication between employees. In contrast, 13 respondents claim that such tools are not used in their company. The final group, consisting of 9 respondents, is unsure whether these tools are implemented in their organization. These findings suggest that the adoption of tools such as Slack, Microsoft Teams, Workplace, and Zoom in workplace communication is becoming increasingly popular due to their functionalities and benefits.

The use of digital tools such as Slack, Microsoft Teams, Workplace, and Zoom for external company communication is presented in Figure 5.

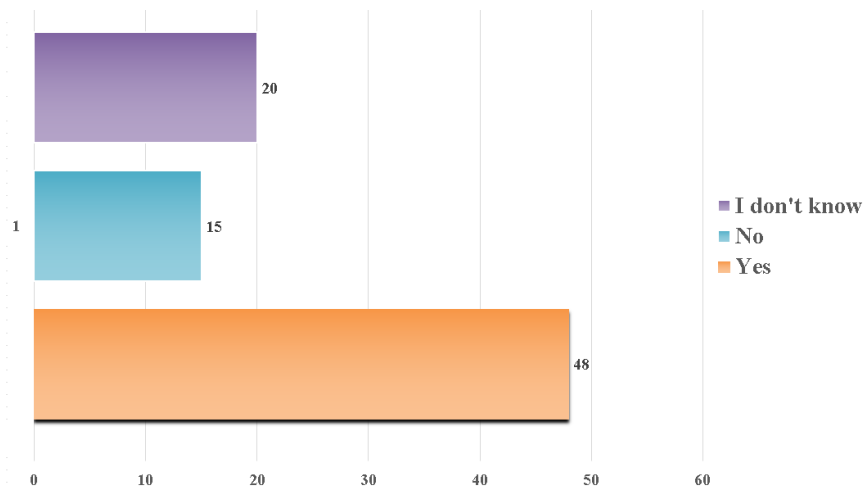


Figure 5. Using tools such as Slack, Microsoft Teams, Workplace, Zoom for external communication.
Source: own study based on research results.

The data presented in Figure 5 indicates that the majority of respondents (48 people) confirm the use of digital tools for communication with external partners, clients, and contractors. In contrast, 15 respondents state that such tools are not used in their company, while 20 respondents are unsure whether these tools are implemented. More than half of the employees therefore confirm the use of digital tools for external communication, which highlights the company's strong engagement in modern technologies to maintain relationships with clients and business partners.

As part of the study, respondents were also asked to evaluate the impact of digital tools on internal communication within the company. The results are presented in Figure 6.

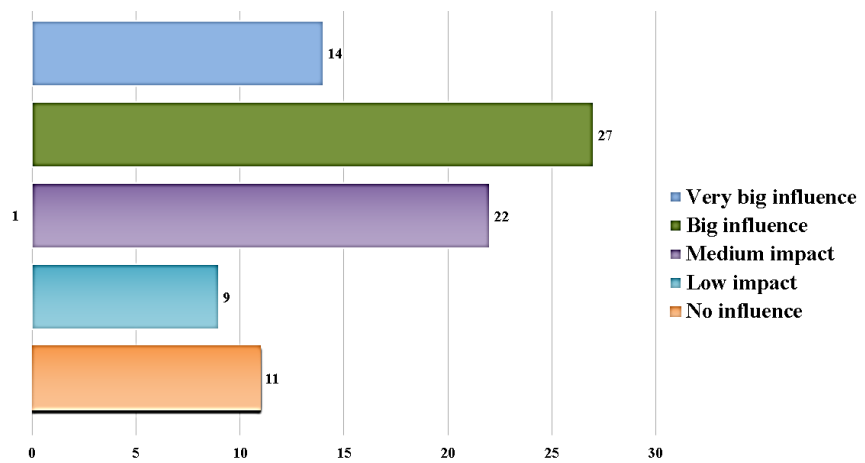


Figure 6. The degree of impact of digital tools on internal communication in the company.

Source: own study based on research results.

The largest group of respondents, 27 people, believes that digital tools have a significant impact on internal communication within the company. Another substantial group, 22 respondents, rated this impact as moderate, while 14 respondents consider it very significant. A smaller number of employees stated that digital tools have little impact (9 people) or no impact (11 people) on internal communication. The results suggest that digital tools

positively influence internal communication in the company. However, there is still room for further optimization and support to ensure their use is more consistent and effective across the organization.

Figure 7 presents the results regarding the use of artificial intelligence tools, such as ChatGPT.

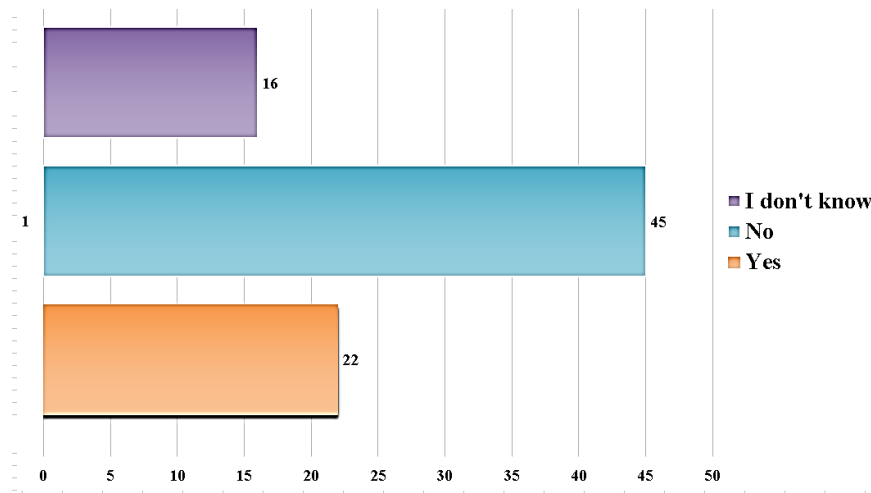


Figure 7. Use of AI tools in the company.

Source: own study based on research results.

The largest group of respondents, 45 people, stated that their company does not use AI tools. Meanwhile, 16 respondents are unsure whether such tools are in use, whereas 22 respondents confirmed that AI tools, such as ChatGPT, are used in their company. These results may suggest a lack of sufficient interest or awareness regarding the potential benefits of AI implementation in business processes.

The research conducted on the use of digital tools in the management of corporate communications allowed verification of the formulated research hypotheses. The results indicate that:

- Hypothesis 1 supposing that the majority of the surveyed companies use digital tools for communication has been verified and confirmed. 64 respondents out of 83 surveyed answered affirmatively to the question whether their company uses digital tools for communication between company employees.
- Hypothesis 2 supposing that most of the surveyed employees use digital tools for internal and external communication such as Zoom, Microsoft Teams, Slack was confirmed by more than half of the respondents who, when asked if their company uses digital tools for external and internal communication, answered that they use the above communicators. Moreover 61 respondents use the above tools to communicate among themselves, internally. 48 respondents use the same tools for external communication.
- Hypothesis 3 supposing that the digital tools used have a positive impact on communication in most of the surveyed companies was verified and confirmed. Respondents answered questions about the positive impact of internal and external

communication as follows: 54 respondents confirmed that the digital tools used in the company have a positive impact on both internal and external communication.

- Hypothesis 4, which assumes that artificial intelligence tools such as Chat GPT are used in most of the surveyed companies, was verified but not confirmed. This is because the majority, as many as 45 respondents, do not use AI tools of the Chat GPT type in their company.

The use of digital tools in the workplace can help make communication more effective, improving collaboration and information flow. Digital tools play an important role in both internal and external enterprise communications. Despite the increasing importance of artificial intelligence in both professional and everyday life, studies conducted indicate their use is not at the highest level. Given their scope and capabilities, their increasing use can be expected.

5. Conclusions

Contemporary enterprises in the era of an uncertain and dynamically changing environment must constantly adapt their communication strategy. Digital tools play a key role in this process, enabling effective management of enterprise communications. The use of digital tools can have a significant impact on increasing the efficiency and competitiveness of businesses. The use of tools such as Zoom, Microsoft Teams, Slack, real-time project management platforms in communication allows faster exchange of information within the organization and with external partners, better coordination and monitoring of the work of teams, faster decision-making. The use of digital tools also enables better management of interpersonal relationships, both with employees and customers.

Within the framework of the conducted research, some limitations can be pointed out related to the adopted scope of the research limited to the Silesian province and the size of the research sample. The research involved only quantitative research. In order to obtain the possibility of general inference, future research should focus on a larger research sample and a wider range covering enterprises in different countries and industries. Conducting also qualitative research, case studies could enrich the obtained results.

Research conducted confirms the growing impact of digital tools on communication management in companies, pointing to a number of social implications related to, among other things, improved quality of life for employees, greater satisfaction through the introduction of more flexible work models, such as hybrid, remote work. The results of a survey of 100 companies by H. Shahriar and B. Habibul (2024) showed the impact of digital tools on increasing employee satisfaction, collaboration and overall productivity. On the other hand, the results of a cross-sectional quantitative study conducted by K. Afridi et al. (2023) show that

digital communication tools have an impact on the performance of ongoing projects. Research by Marlow et al. (2017) finds a positive impact of platforms, digital tools for project management, among others, on communication and collaboration. Based on the findings of Ninye-Ranor et al. (2022), they recommend that employees and managers continuously improve their knowledge in the use of digital tools through various training and upskilling programs. More efficient communication processes through the use of digital tools can contribute to faster resolution of social problems. In addition, the integration of digital tools in the area of internal and external communication of companies can have an impact on greater transparency of business operations, which in the long perspective can increase the trust of society, customers in the company and lead to more responsible and sustainable practices. Companies can become more socially responsible.

Therefore, it is important to continuously improve the communication skills of employees while making wise use of available digital tools that can improve the efficiency of the communication processes carried out. It is also important for companies to invest in new technologies and digital tools that would support the integration of communication processes. In view of the risks posed by the use of digital tools, artificial intelligence, companies should also focus on developing and introducing standards and procedures for the use of these tools. It is also worthwhile to align the tools with an organization's communication strategy. As technology develops, the role of digital tools in communication will deepen and evolve, opening up new opportunities and posing new challenges for employees.

References

1. Afridi, K., Turi, J.A., Zaufishan, B., Rosak-Szyrocka, J. (2023). Impact of digital communications on project efficiency through ease of use and top management support. *Heliyon*, 9, e17941, <https://doi.org/10.1016/j.heliyon.2023.e17941>
2. Appel, G., Grewal, L., Hadi, R., Stephen, A.T. (2020). The future of social media in marketing. *Journal of the Academy of Marketing Science*, 48(1), pp. 79-95.
3. Biesaga-Słomczewska, E.J. (2015). Komunikacja wewnętrzna w erze cyfryzacji. *Ekonomiczne Problemy Usług*, No. 117.
4. Casey, M., Vigna, P. (2018). *The Truth Machine: The Blockchain and the Future of Everything*. New York: Harper Collins.
5. Clark, L., Karau, S., Michalisin, M. (2012). Telecommuting attitudes and the Big Five personality dimensions. *Journal of Management Policy and Practice*, 13, 31-46.
6. Clemente, M., Domingues, L. (2023). Analysis of Project Management Tools to support Knowledge Management. *Procedia Computer Science*, Vol. 219, pp. 1769-1776, <https://doi.org/10.1016/j.procs.2023.01.472>

7. Cooley, Ch. (1983). *Social Organization. A Study of the Larger Mind*. New York: Routledge.
8. Dash, S., Samadder, S., Srivastava, A., Meena, R., Ranjan, P. (2022). Review of Online Teaching Platforms in the Current Period of COVID-19 Pandemic. *Indian Journal of Surgery*, Vol. 84, pp. 12-17, <https://doi.org/10.1007/s12262-021-02962-4>
9. Drucker, P.F. (2009). *Zarządzanie XXI wieku – wyzwania*. MT Biznes.
10. Faraj, S., Jarvenpaa, S.L., Majchrzak, A. (2015). Knowledge collaboration in online communities. *Organization Science*, 22(5), 1224-1239.
11. Fraccastoro, S., Gabriellsson, M., Pullins, E.B. (2021). The integrated use of social media, digital, and traditional communication tools in the B2B sales process of international SMEs. *International Business Review*, Vol. 30, Iss. 4. <https://doi.org/10.1016/j.ibusrev.2020.101776>
12. Friedberg, A. (2019). Proces komunikacji interpersonalnej w środowisku pracy. *Zeszyty Naukowe Gdańskiej Szkoły Wyższej*, 22, pp. 151-158, <https://doi.org/10.24426/zngsw.v22i0.220>
13. Grabowski, M., Soja, P., Tadeusiewicz, R., Trąbka, J., Zając, A. (2012). *Systemy informacyjne zarządzania*. Kraków: Uniwersytet Ekonomiczny w Krakowie.
14. Grandys, A.J. (2000). *Marketing i technologia informacyjna: o związkach strategii marketingowych i strategii IT*. Łódź: Katedra Ekonomii i Marketingu Politechniki Łódzkiej.
15. Griffin, E., Ledbetter, A., Sparks, G. (2018). *A First Look at Communication Theory*. Tenth Edition. McGraw-Hill Education.
16. Guzowski, M., Aneszko, W., Giegiel, B., Szpilko, D. (2024). Zastosowanie Internetu Rzeczy w kontekście zrównoważonego rozwoju przedsiębiorstw z branży TSL. *Akademia Zarządzania*, 8(3), pp. 261-276, [10.24427/az-2024-0047](https://doi.org/10.24427/az-2024-0047)
17. Kitsantas, T., Chytis, E. (2022). Blockchain Technology as an Ecosystem: Trends and Perspectives in Accounting and Management. *Journal of Theoretical and Applied Electronic Commerce Research*, 17, pp. 1143-1161, <https://doi.org/10.3390/jtaer17030058>.
18. Klinowski, M. (2011). Controlling a różnice osobowości i komunikacja w projektach. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, Research Papers of Wrocław University of Economics*, No 188. Wrocław, pp. 41-49.
19. Kopishynska, O., Utkin, Y., Kalinichenko, A., Jelonek, D. (2016). Efficacy of the cloud computing technology in the management of communication and business processes of the companies. *Polish Journal of Management Studies*, Vol. 14, No. 2.
20. Makowski, M. (2023). Komunikacja z wykorzystaniem sztucznej inteligencji w turbulentnych warunkach rynkowych. *Media - Biznes - Kultura. Dziennikarstwo i komunikacja społeczna*, 1(14), pp. 87-109.
21. Marlow, J., Lacerenza, C.N., Salas, E. (2017). Communication in virtual teams: A conceptual framework and research agenda. *Human Resource Management Review*, 27(4), pp. 575-589.

22. Ninye-Ranor, L.C., Igbinedinon, V.I., Nwadiani, C.O. (2022). Office managers' utilization of digital communication tools for effective dissemination of information in the 21ST century business organisations. *Technical and Vocational Education Journal (TAVEJ)*, 8, 176-184.
23. Ober, J., Wiśniewska-Placheta, E., Brytańczyk, J. (2018). *Komunikacja wewnętrzna w zarządzaniu współczesną organizacją*. Humanitarnij korpus: Zbirnik naukovih statej z aktual'nih problem filosofii, kul'turologii, psihologii, pedagogiki ta istorii. Humanitarian corpus. Collection of scientific articles on contemporary problems of philosophy, cultural studies, psychology, pedagogy and history, Vinnica, TOV TVORI, pp. 65-72.
24. Robbins, S.P., Judge, T.A. (2018). Essentials of organizational behavior. *Pearson*.
25. Shahriar, H., Habibul, B. (2024). Exploring the Impact of Digital Tools on Business Communication. *International Journal of Applied Research in Business and Management*, 5(2). <https://doi.org/10.51137/wrp.ijarbm.2024.hset.45621>
26. Shawish, A., Salama, M. (2014). Cloud Computing: Paradigms and Technologies. In: F. Xhafa, N. Bessis, N. (eds.), *Inter-cooperative Collective Intelligence: Techniques and Applications. Studies in Computational Intelligence, Vol. 495*. Berlin/Heidelberg: Springer, https://doi.org/10.1007/978-3-642-35016-0_2
27. Śledziwska, K., Włoch, R. (2020). *Gospodarka cyfrowa. Jak nowe technologie zmieniają świat?* Warszawa: Wydawnictwo Uniwersytetu Warszawskiego.
28. Smith, A., Patmos, A., Pitts, M.J. (2018). Communication and teleworking: A study of communication channel satisfaction, personality, and job satisfaction for teleworking employees. *International Journal of Business Communication*, 55(1), 44-68, <https://doi.org/10.1177/2329488415589101>.
29. Stoner, J., Freeman, R., Gilbert, D. (1999). *Kierowanie*. Warszawa: PWN.
30. Sypniewska, B.A. (2013). Rola i znaczenie komunikacji w organizacji – raport z badań. *Zeszyty Naukowe PWSZ. Nauki Ekonomiczne, tom XVIII*.
31. Szadok-Bratuń, A., Bratuń, M. (2022). Digitalizacja komunikacji a opiniotwórczość mediów elektronicznych na początku XXI wieku. *Orbis Linguarum*.
32. Szombathelyi, K.M., Waldbuesser, P., Tench, R. (2015). *Digital age: Information and communication technologies, tools and trends for communication management*. 2015 6th IEEE International Conference on Cognitive Infocommunications (CogInfoCom), pp. 229-233.
33. Szydłowski, G. (2019). Rozwiązania do zarządzania projektami informatycznymi w chmurze. *Journal of Computer Sciences Institute, No. 13*, pp. 288-292.
34. Trzop, A. (2020). Przegląd rozwiązań z zakresu przemysłu 4.0 stosowanych w obszarze logistyki. *Zeszyty Naukowe Politechniki Poznańskiej. Organizacja i Zarządzanie, No. 81*, pp. 233-247.

35. Wang, W.Y., Pauleen, D.J., Zhang, T. (2016). How social media applications affect B2B communication and improve business performance in SMEs. *Industrial Marketing Management*, 54, pp. 4-14.
36. Wójcik, G.P., Rybicka, M. (2013). Rola technologii informacyjno-komunikacyjnych w rozwoju współpracy transgranicznej. *Nierówności społeczne a wzrost gospodarczy*, 7(32).

BENEFITS AND DRAWBACKS OF SIMPLIFICATIONS IN FINANCIAL REPORTING FOR MICRO AND SMALL ENTERPRISES

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Purpose: The main thesis of this study is that there are significant drawbacks to simplified financial statements dedicated to SMEs which - despite positive cost effects - generate negative informational, decision-making, and social consequences. The literature and practice reveal a multidimensional tension between the need to ease the burden on SMEs and the necessity to maintain the reliability and usefulness of financial statements. This issue is particularly important in light of the growing role of SMEs in job creation and the flexibility of local markets, as well as in the context of the stability of the financial system, where the lack of accurate and comparable information may lead to misallocation decisions and increased agency costs and information asymmetry.

Design/methodology/approach: The achievement of the objective involved the critical review of both national and international literature as the primary research method. Methodologically, the paper is based on a critical review of scientific literature and institutional reports, an analysis of legal acts and accounting standards, and an interpretation of empirical research results relating to the quality of financial information, the cost of capital, and the comparability of financial statements.

Findings: In the course of work, it was found: the balance of benefits and costs associated with reporting simplifications for micro, small, and medium-sized enterprises is not clear-cut. On the one hand, they provide administrative relief and lower the direct costs of accounting. On the other hand, they generate numerous drawbacks which, in the longer term, may outweigh short-term savings. It therefore seems necessary to conduct further research and empirical analyses on the impact of simplifications on SMEs' competitiveness, access to financing, and management culture.

Originality/value: Reporting simplifications take various forms: from exemptions from the obligation to prepare full documentation, through a reduction in the scope of disclosures, simplifications in measurement and presentation principles, and even the adoption of separate, less detailed accounting standards. The primary aim of these solutions is to rationalize costs, reduce bureaucratic requirements, and increase formal accessibility for entrepreneurs with limited resources. At the same time, however, simplifications are not epistemically neutral: they modify the scope and quality of information communicated to the market and to authorities, affecting transparency, data comparability, and the mechanisms of control and accountability.

The research objective is to identify and critically analyse, from multiple angles, the drawbacks of reporting simplifications applied to micro and small enterprises. The paper attempts to systematize the negative effects of these solutions, indicate the mechanisms through which they arise, and assess the implications for individual stakeholder groups.

Keywords: Financial reporting, International Financial Reporting Standard for Small and Medium-sized Entities, micro business, small business.

Category of the paper: Research Paper, Viewpoint.

1. Introduction

The article analyses the advantages and disadvantages of simplifications in financial reporting used by micro and small enterprises (SMEs) based on the Accounting Act, i.e. the Polish balance sheet law. Thus, there is no way to compare it with international standards. The main thesis of the research indicates that although these simplifications bring positive cost effects for SMEs, they also generate negative informational, decision-making and social consequences. The paper discusses in detail the legal basis for the classification of enterprises in Poland and the European Union, including the size criteria and regulations contained in the Accounting Act and EU directives, which are aimed at adapting reporting requirements to the resources of smaller entities. The author critically systematizes the negative effects of these simplifications, emphasizing their impact on information asymmetry, limited decision-making usefulness for external stakeholders, as well as a decrease in the comparability of financial data. The whole is based on a critical review of the scientific literature and analysis of legal acts, with the aim of identifying and assessing the implications of simplifications for different stakeholder groups.

Financial reporting plays a central role in the functioning of a market economy (Zarzycka, Krasodomska, 2022). It constitutes the primary source of information on the asset position, financial standing, and performance of enterprises, enabling stakeholders - owners, creditors, investors, contractors, and supervisory bodies - to make rational economic decisions (Bauer, 2025; Dratwińska-Kania, Ferens, Szewieczek, 2021; Wędzki, 2012; Hołda, Micherda, 2007; Chluska, 2016). It is also worth noting the critical view of financial statements as a source of information for broadly understood stakeholder groups (Bauer, 2025; Chen, Chen, Su, 2001; Zimmermann, Yahya-Zadeh, 2001; Parson, 2003). In the context of small enterprises - namely micro, small, and medium-sized enterprises (SMEs) - this reporting has both an economic and administrative dimension: on the one hand, it provides market information on the entity's value and risk; on the other, it is associated with reporting obligations, costs of preparing and storing documentation, and the risk of regulatory infringements. For this reason, many legal systems have introduced simplified solutions intended to reduce the administrative and cost burdens on

SMEs, allowing them to focus resources on their core operating activities (Kuzior, Pfaff, Poniatowska, Rówińska, 2014).

Conducting business activity involves producing material goods and providing services to satisfy general social needs (Mućko, Sokół, 2011). Legal regulations on running a business are reflected in numerous acts such as the Entrepreneurs' Law, the Personal Income Tax Act, the Value Added Tax Act, and the Accounting Act. The general procedures accompanying the commencement, conduct, suspension, and closure of business activity were described in detail in the Act on Freedom of Economic Activity introduced on 2 July 2004 and repealed on 1 March 2018. That act contained the following definition of activity: "economic activity is profit-oriented manufacturing, construction, trade, and service activity, as well as the exploration, recognition, and extraction of minerals from deposits, and professional activity carried out in an organized and continuous manner". In the Entrepreneurs' Law, which replaced the Act on Freedom of Economic Activity, Article 3 defines "economic activity" as organized profit-oriented activity carried out on a continuous basis.

The enterprise is the most common form of economic organization (Urbanowska-Sojkin, Banaszyk, 2009; Gruszecki, 2002). Using the size of the entity as a criterion, P. Drucker divided enterprises into:

- a) micro business - sole proprietorship or partnership operating without employees and without a distinct management structure,
- b) small business - one intermediate level in the form of boss-employee relations,
- c) medium-sized business - multi-level relations, with horizontal relations predominant; their characteristic feature is the presence of a management team,
- d) large business - clear separation between the top manager deciding on company strategy and the team of lower-level managers handling operations,
- e) very large business - where objectives and strategic plans are decided not by the top manager but by the entire team: the management board and supervisory board (Drucker, 2009).

2. Classification of Enterprises

The classification of enterprises is an important determinant defining the rules of conducting economic activity. Belonging to particular classification groups affects whether a given entity will keep only mandatory records aimed at tax settlements or full accounting; it also determines the scope of obligations related to the preparation of financial statements. The size criterion is also used for granting various types of subsidies and public aid and for imposing tax reporting obligations (Tkocz-Wolny, 2015).

A new classification of entities in the Accounting Act was introduced by the amending act of 6 December 2024 on amending the Accounting Act, the Act on Statutory Auditors, Audit Firms and Public Oversight, and certain other acts. The definition of a micro entity was modified. Under the current regulations (Article 3(1)(1a) of the Accounting Act), a micro entity is an entity which, in the financial year for which it prepares financial statements and in the preceding financial year (or, in the case of an entity commencing activity or keeping books under the Act—in the financial year in which it commenced such activity or keeping books), did not exceed at least 2 of the following 3 thresholds:

1. PLN 2,000,000 – balance sheet total at year-end,
2. PLN 4,000,000 – net revenue from sales of goods and products for the financial year,
3. 10 persons - average annual employment in FTEs.

Whereby an entity loses micro status if, in the financial year for which it prepares financial statements and in the preceding financial year, it exceeded at least 2 of these 3 thresholds.

Under the amended definition, micro status is acquired automatically. Meeting the above conditions is sufficient. Thus, an entity obtains micro status solely based on specified threshold values. The decision to adopt reporting simplifications for a micro entity, however, is still taken by the approving body. Pursuant to Article 14(3) of the amending act, the provisions on the new classification of entities in the Accounting Act applied for the first time to financial statements for a financial year beginning after 31 December 2023.

Table 1.
Classification of Enterprises under Legal Regulations

Regulations	Criterion	Micro	Small	Medium
Accounting Act	Average annual employment	10 FTE	50 FTE	-
	Revenue from sales	4 mln PLN	51 mln PLN	-
	Balance sheet total	2 mln PLN	25,5 mln PLN	-
Entrepreneurs' Law or	Average annual employment	10 FTE	50 FTE	250 FTE
	Revenue from sales	2 mln PLN	10 mln PLN	50 mln PLN
	Balance sheet total	2 mln PLN	10 mln PLN	43 mln PLN
EU Directive	Average annual employment (no more than)	10 FTE	50 FTE	250 FTE
	Revenue from sales	0,70 mln EUR	8 mln EUR	40 mln EUR
	Balance sheet total	0,35 mln EUR	4 mln EUR	20 mln EUR

Source: author's own study based on Ustawa z dnia 29 września 1994 r. *o rachunkowości*, Dz.U. z 2021 r. poz. 217, Ustawa z dnia 6 marca 2018 r. *Prawo przedsiębiorcy* Dz.U. z 2021 poz.. 162, Dyrektywa Parlamentu Europejskiego i Rady z dnia 26 czerwca 2013 r. *w sprawie rocznych sprawozdań finansowych, skonsolidowanych sprawozdań finansowych i powiązanych sprawozdań niektórych rodzajów jednostek, zmieniająca dyrektywę Parlamentu Europejskiego i Rady 2006/43/WE oraz uchylająca dyrektywy Rady 78/660/EWG i 83/349/EWG*, Dz. U. UE L 182/19.

As shown in Table 1, all the presented legal acts include definitions of micro and small entities. Directive 2013/34/EU also defines medium-sized enterprises. The Entrepreneurs' Law defines medium-sized enterprises but does not contain a typology of large enterprises.

Solutions implemented at the EU level in financial reporting tie the scope of information presented in annual financial statements primarily to the size of the entity. The directive specifies maximum threshold values while allowing Member States to adapt these general guidelines to their individual needs and specific circumstances.

Thus, a large entrepreneur is an entity that does not meet the conditions for a medium-sized entity. The Accounting Act does not distinguish between medium and large enterprises; instead, it differentiates entities subject to mandatory annual audit by a statutory auditor and those not subject to such an obligation. According to Article 64(1)(4) of the Accounting Act, an entity's financial statements are subject to mandatory audit if, in the preceding financial year for which it prepared financial statements, it met at least two of the following conditions:

- a) average annual employment in FTEs of at least 50 persons,
- b) balance sheet total at year-end equal to at least EUR 2,500,000,
- c) net revenue from sales of goods and products and financial operations for the year equal to at least EUR 5,000,000.

The classification of economic entities forms the foundation for many accounting and financial reporting regulations. Determining the category to which a given enterprise belongs directly affects the scope of reporting obligations, including the possibility of using simplifications in financial statements.

When analysing SME definitions, it should be noted that the definition of micro-enterprises in the Accounting Act does not coincide with the definition of a micro-entrepreneur in the Entrepreneurs' Law. The definition in the Accounting Act is more complex. A partial justification for a separate definition of a micro-entity - as compared to a micro-entrepreneur - is the fact that accounting is an information system used also by entities that are not entrepreneurs.

Micro entities, in the Accounting Act, are described as units that (Nowak 2015):

- employ few workers,
- are most often managed by their owners,
- have low or medium levels of revenues and assets,
- do not have investments in subsidiaries, associates, or joint ventures,
- do not hold or issue complex financial instruments,
- do not issue shares or share options.

SMEs are the main engine of the labour market. In Poland, SMEs account for over 60% of private-sector employment. Small and medium-sized firms often operate locally, creating jobs where large corporations may not be present—especially in smaller towns and rural areas. Thus, SMEs help reduce unemployment, particularly in regions with limited job opportunities. Micro and small enterprises significantly affect GDP (Mlaskawa, 2021; Grzywacz, 2015). Although SMEs typically have fewer resources than large corporations, they are often more innovative and flexible. The ability to respond quickly to changing market conditions,

proximity to customers, and less bureaucracy enable faster introduction of new products and services. SMEs often operate in niche markets where larger firms may not perceive profit potential. In this context, SMEs are a key source of innovation that drives economic development. SMEs operate across different sectors—from industry and trade to services and digital markets (Miszczak, 2022; Hejduk, 1998). This diversity makes the SME sector more resilient to economic shocks because problems in one sector do not necessarily translate into the entire economy. With their broad range of activities, SMEs create a dynamic and diversified economic landscape. It is beyond doubt that the SME group also faces many development barriers (Barber, Metcalfe, Porteous, 1998; Kamińska, 2011; Maćkowiak, 2023; Steinerowska-Streb, 2017).

3. Legal Regulations

The legal framework of financial reporting- including for micro, small, and medium-sized enterprises—is a product of many years of development of accounting standards, EU and national regulations, and the practical needs of the economy. Generally, these regulations aim to provide reliable, credible, and comparable financial information while tailoring the scope of reporting obligations to the organizational and financial capacities of each category of enterprise. The regulatory context for SMEs is unique: on the one hand, they form the backbone of the European and Polish economy; on the other, their limited resources necessitate a specific approach to reporting obligations.

National Regulations – the Accounting Act

In Poland, the principal legal act regulating financial reporting is the Accounting Act of 29 September 1994. This act sets the framework for keeping accounting books, principles for measuring assets and liabilities, and the preparation and presentation of financial statements. Since its adoption, the act has been amended numerous times, largely due to the need to align Polish law with EU regulations. Within the Accounting Act, a special role is played by provisions concerning micro and small entities. They allow the application of simplifications both in keeping books and in preparing financial statements. Micro-enterprises are defined using quantitative criteria (including net revenue from sales of goods and services, balance sheet total, and average annual employment). Similar criteria apply to small entities, with proportionally higher thresholds. For both categories, the legislator has provided for the possibility of using simplified versions of the balance sheet and the profit and loss account. Micro-enterprises are also exempted from the obligation to prepare notes (the additional information), which in practice significantly limits the scope of disclosures. Small entities benefit from slightly less far-reaching reliefs but likewise are not obliged to prepare full

financial statements. Instead, they may use shortened variants that reduce the number of reporting items. It should be emphasized that the legislator's intention was above all to reduce administrative and accounting costs, which for many small companies could be a barrier to doing business. At the same time, however, such an approach raises questions about the reliability and transparency of the picture of the financial position—issues discussed later in this paper.

EU Directives

EU regulations play a key role in shaping national solutions in financial reporting. The most important legal act is Directive 2013/34/EU of the European Parliament and of the Council on annual financial statements, consolidated financial statements and related reports of certain types of undertakings. It replaced the earlier IV and VII directives, simplifying and modernizing the rules and introducing uniform principles across Member States. The Directive provides for a system of categorizing undertakings into micro, small, medium, and large based on balance sheet, revenue, and employment criteria. Its objective was to reduce administrative burdens and thereby improve the competitiveness of European SMEs. The Directive allows for simplifications for the smallest entities, such as exemptions from preparing the cash flow statement or notes (additional information). Small entities may use simplified forms of the balance sheet and profit and loss account. The EU argued that such simplifications are necessary because small enterprises bear relatively higher costs of full accounting compared to large entities. According to European Commission analyses, the cost of preparing full financial statements per unit of revenue or per employee is significantly higher in SMEs than in corporations. Thus, the Directive was intended as a tool to level the playing field and reduce development barriers.

International Solutions – IFRS for SMEs

At the global level, a key initiative is IFRS for SMEs (International Financial Reporting Standard for Small and Medium-sized Entities), developed by the IASB. Adopted in 2009 as a separate set of accounting rules for entities not required to apply full IFRS, IFRS for SMEs covers all major areas of financial reporting but in a much simplified form. It reduces disclosures, limits measurement options, and in many cases introduces uniform solutions where full IFRS offers alternatives. Examples include abandoning the extensive use of fair value and simplifications in consolidation. Although the standard has not been adopted in the European Union as binding, it has been applied in many countries worldwide and serves as a reference point in discussions on SME reporting. Its philosophy is consistent with EU and national approaches: facilitate accounting for smaller entities while maintaining a minimum level of decision-useful information.

4. Characteristics of Micro and Small Enterprises

One of the most important features of SMEs is their flexibility. Smaller firms can adapt more quickly to changing market conditions, make rapid decisions, and introduce innovations without complex decision-making processes (Smolarek, 2015). This flexibility is particularly important in a dynamic economic environment where adaptability often determines a firm's survival (Lachiewicz, Matejun, 2012). SMEs often operate locally and maintain direct contact with customers. This proximity enables a better understanding of customer needs and faster responses. Owners of small firms typically have direct contact with customers, allowing long-term relationships based on trust and loyalty - hard to achieve in large corporations. Due to their structure, small firms tend to have lower operating costs than large enterprises. Less bureaucracy, lower marketing and management outlays, and often more flexible employment approaches help control costs. As a result, SMEs can compete with larger entities, especially in local markets (Maćkowiak, 2022).

4.1. Objectives of SME Activity

The primary objective of micro-enterprises, like other forms of business activity, is to generate profit and maintain profitability. However, in the case of micro-enterprises - small economic entities - their objectives can be more diversified and tailored to their specific functioning and the individual ambitions of owners (Lemańska-Majdzik, 2013; Deakins, Whittam, 2000). They include: generating profits that allow the owner's livelihood and further development of the firm; effective cost management to maintain profitability (Maćkowiak, 2019). Given the small size of the firm, every financial decision directly affects results. For many micro-enterprise owners, a key goal is achieving professional and personal independence. Running one's own business allows autonomous decision-making, shaping strategy, and flexible time management. Owners have full control over operations, giving greater freedom compared to working in larger organizational structures. Due to their small size, micro-enterprises can respond quickly to changing market conditions by introducing new products or services, changing business models, or tailoring their offerings to customer expectations. They often operate in niche markets, offering specialized products or services. Their goal is to meet specific customer needs, building loyalty and stable revenues. Given limited resources, micro-enterprises often focus on survival in difficult market conditions such as competition or a variable economic environment. They frequently operate locally and have close customer relationships. A major goal may be building customer loyalty by delivering high-quality products and services and an individual approach. In micro-enterprises, customer relationships are crucial for stability. Satisfied customers are more likely to return and recommend the firm to others, contributing to growth without costly marketing. For many entrepreneurs, running a business is a way to pursue passions, develop skills, and take on

challenges. Micro-enterprises often reflect the interests and talents of their owners and can build reputation in a given industry or local market, leading to long-term success and stability.

The objectives of small enterprises primarily include achieving profit and maintaining financial stability, but these goals may be more diversified and tailored to the firm's specifics and character. Small enterprises, operating on a more limited scale compared to larger entities, also set goals related to growth, maintaining competitiveness, and impact on the local community. Key areas include: profit generation and operating profitability; liquidity, which is crucial not only for small enterprises, as it ensures that current liabilities-such as supplier payments, wages, and other operating costs-are settled. Stable liquidity helps avoid financial problems, which is particularly important for small entities that do not have access to large financial reserves. Small enterprises also pursue growth and expansion, i.e., expanding operations and investing in innovation. They strive for growth by acquiring new customers, developing product or service offerings, and entering new markets (local, regional, and sometimes even international) (Morrison, Breen, Ali, 2003). Introducing new technologies or improvements in production or service processes can increase efficiency and competitiveness - a key strategic objective. As they develop, an important objective becomes building market position and competitive advantage. Small firms often compete in local markets and aim to acquire and retain loyal customers by delivering high quality. They build advantage through innovation, quality, or an individual approach to customers. Offering unique products or services that differentiate the company from competitors also helps build market advantage and generate stable revenues. Another objective is customer satisfaction and relationship building through high-quality service and meeting specific market needs. Small enterprises often place greater emphasis on building long-term, close customer relationships. High-quality service, customer satisfaction, and loyalty are crucial for long-term success. Tailoring the offer to changing customer needs and expectations-especially locally-makes it possible to gain advantage over larger, less flexible competitors. In terms of risk management, small firms must limit risks that could threaten their operations. The objective is to manage finances to minimize the impact of negative factors such as market fluctuations or changing economic conditions. Small enterprises may also seek to diversify income sources to reduce dependence on a single market or customer, increasing stability (Maćkowiak, 2019).

4.2. Objectives and Justifications for Introducing Simplifications

The fundamental objective of simplification regulations is to reduce administrative costs, which can be a significant burden for SMEs. According to European Commission reports, such costs often constitute a significant percentage of a firm's total expenditures, limiting its ability to invest and grow. Moreover, simplifications aim to increase the accessibility of reporting for entities with limited staffing and technology resources, as well as ensure compliance with the principle of proportionality, which requires tailoring regulatory requirements to an entity's scale and importance in the economy. Another justification is the limited number of external

stakeholders who actually use full financial statements for SMEs. Unlike large listed companies, which are accountable to a wide group of investors and supervisory institutions, small enterprises usually communicate primarily with banks, tax authorities, and owners. In this sense, the full scope of disclosures is often considered excessive relative to real information needs. Legal regulations-national, EU, and international-shape the framework of SME financial reporting, determining not only how books are kept and statements prepared, but also affecting enterprises' access to external financing, their ability to cooperate internationally, and their market competitiveness. In practice, this means that simplifications intended as support tools simultaneously become a source of limitations-forming the core subject of the critique discussed in subsequent parts of the paper.

When analysing financial statement simplifications permitted by the Accounting Act, two groups can be identified: „entity-based simplifications“ and „item-based (subject-matter) simplifications.“

Table 2.
Simplifications (Entity-based vs Item-based)

Entity-based simplifications		Item-based simplifications
Micro-entity	Small entity	
simplifications provided for a small entity and additionally: • resignation from the prudent principle in the valuation of individual assets and liabilities, i.e. waiver of impairment losses and provisions, • failure to apply fair value and adjusted purchase price to the measurement of assets and liabilities – Article 28 of the Accounting Act.	Waiver of the determination of deferred tax assets and provisions. Non-application of the Regulation of the Minister of Finance on financial instruments. No elimination of fixed costs of unused normal production capacity from the cost of manufacturing the inventory of products at the end of the year. Withdrawal from the preparation of the activity report Audited entities may resign from preparing a statement of changes in equity and a cash flow statement.	Simplification of depreciation – making collective write-offs for groups of assets similar in type and purpose or one-off write-offs such fixed assets. Valuation of materials and goods at the purchase price. Use of planned costs for product valuation. Valuation of products in progress with a production cycle of no more than 3 months after the partial cost of production.

Source: author's own study based on: Kabalski, 2016.

Micro-entities may use simplifications in keeping books and in preparing financial statements. The approving body of a micro-entity may decide to prepare: a simplified balance sheet (Art. 46(5)(4) of the Accounting Act) and a simplified profit and loss account (Art. 47(4)(4) of the Act) for micro-entities in accordance with Annex 4 to the Accounting Act.

A financial statement under Annex 4 to the Accounting Act is dedicated to micro-entities and to entities referred to in Article 80(4) of the Act (e.g., trade unions, employers' organizations, chambers of commerce). A financial statement prepared under Annex 4 includes:

- General information.
- The balance sheet.
- Supplementary information to the balance sheet.
- The profit and loss account.

According to Article 48(3) of the Accounting Act, a micro-entity may omit the notes (additional information) referred to in paragraph 1, provided it presents the supplementary information to the balance sheet specified in Annex 4. Furthermore, a micro-entity obliged to prepare a management report may omit it provided that, in the notes (additional information), and in the case referred to in Article 48(3), in the supplementary information to the balance sheet, it presents information on the acquisition of its own shares (stock) as specified in Annex 4 (Article 49(4) of the Act). Small and micro entities may omit, in the management report, key non-financial performance indicators related to the entity's activities and information on employee and environmental matters.

Under Article 45(3) of the Accounting Act, a micro-entity's financial statement does not include the statement of changes in equity (fund) or the cash flow statement. Micro-entities may prepare a statement of changes in equity or a cash flow statement voluntarily.

Simplification of financial statements for SMEs is an important issue aimed at lowering costs and reducing administrative burdens for companies while maintaining transparency and reliability of financial information. Such simplifications respond to the need to tailor reporting requirements to the specifics of smaller entities, which often lack advanced financial structures.

On 14 March 2012, a new Directive 2012/6/EU was introduced, amending the Fourth Directive with respect to micro-entities. In July 2013, Directive 2013/34/EU was adopted, replacing the Fourth and Seventh Directives. A key provision is Article 36 "Exemptions for micro-entities" (Kuzior, Pfaff, Poniatowska, Rówińska, 2014). It expresses, *inter alia*, the postulate that Member States exempt micro-entities from any or all of the following requirements (Maćkowiak, 2019):

- a) presenting "prepayments and accrued income" and "deferred costs and revenues",
- b) preparing notes (additional information) to the financial statements, provided that certain information is disclosed in a balance sheet footnote,
- c) preparing the management report, provided that the required information is disclosed in the notes to the financial statements or in a balance sheet footnote,
- d) publishing annual financial statements, provided that the balance sheet information contained in those statements is duly submitted, under national law, to at least one designated competent authority.

The above simplifications can be grouped into three areas (Chluska, 2016):

- a) Financial reporting.
- b) Measurement principles.
- c) Exemptions from certain provisions.

Simplifying financial statements for SMEs responds to the needs of smaller entities that do not have complex financial structures and can afford to limit reporting formalities. Simplifications reduce costs, increase operational efficiency, and make financial information more accessible to entrepreneurs.

One key area is the structure of the balance sheet. For micro and small entities, the legislator permitted shortened versions of this statement that reduce the number of items on both the asset and liability sides. Categories presented separately in a full balance sheet (e.g., different types of receivables or breakdowns of equity) may be aggregated into single items in the simplified balance sheet. For entrepreneurs, this means less complicated procedures when preparing documents; for readers, it means less detail. The shortened balance sheet allows only a general assessment of the entity's asset position, making it more difficult to perform in-depth analyses of the asset structure and sources of financing. Similar solutions apply to the profit and loss account. Micro-enterprises may prepare highly condensed statements that include only the basic categories of revenues and costs. Small entities may also limit the number of presented items, forgoing many breakdowns obligatory for larger entities. Such simplifications make the profit and loss account a document showing an overall result rather than a full picture of the sources of profitability and costs. For the owner or management of a micro-firm, this may suffice; however, external stakeholders such as banks or investors face significant limitations in assessing performance. A particularly significant simplification is the ability of micro-entities to omit notes (additional information) altogether. In practice, this means giving up commentary, explanations, or additional numerical data that are essential in full statements - e.g., on accounting policies, post-balance-sheet events, or contingent liabilities. Small entities are not entirely exempt from preparing notes but also benefit from a reduced scope of required disclosures. As a result, their financial statements are much less extensive and detailed than those of medium and large entities.

Regulations also allow simplified measurement principles for certain assets. Micro and small entities may, for example, resign from measuring assets at fair value, using historical cost only. For financial instruments—where large entities must apply complex measurement methods - smaller firms may limit themselves to simpler, easier-to-apply solutions, though less informative. Simplifications also concern depreciation. Some regulations allow simplified methods for determining useful life or uniform depreciation rates. While this reduces workload and costs, it flattens the picture of the value of fixed assets and their real consumption.

As noted, micro-enterprises are exempt from preparing the cash flow statement and statement of changes in equity. Consequently, their financial statements are limited to the balance sheet and profit and loss account (often in shortened form), significantly reducing the scope of available information. The absence of a cash flow statement prevents analysis of liquidity and cash-generating capacity - critical for assessing financial stability. Simplifications also affect consolidation obligations. Small and micro entities - even if they are parent entities - may be exempt from preparing consolidated financial statements. Stakeholders then receive no full information about the capital group, only about the parent entity itself. This reduces the reporting burden but limits the transparency of the group's picture.

Although tax simplifications are not formally part of financial accounting regulations, they closely correspond in practice. Micro-enterprises often use simplified tax records such as the revenue and expense ledger (KPiR) or lump-sum tax. This leads to a situation where reporting obligations are minimized and accounting serves primarily a fiscal rather than informational function. Consequently, the financial picture of such entities is significantly reduced and does not meet the standards of decision-useful financial reporting.

A characteristic feature of all these simplifications is their strong cost-minimization orientation. Micro and small enterprises often lack professional accounting departments, and their owners strive to limit administrative obligations. Legislators and international bodies therefore sought solutions enabling formal compliance with reporting obligations with minimal complexity. The consequence, however, is the creation of documents providing only basic - and often insufficient - information. In practice, the emphasis shifts from the informational function of financial statements to their formal-legal function, a process controversial from the standpoint of accounting science and frequently criticized.

Table 3.

Financial reporting simplifications for SMEs

EU Directive 2013/34/EU	The European Union introduced Directive 2013/34/EU to simplify financial statements for micro, small, and medium-sized enterprises. It established size categories and corresponding reporting rules: • Micro-enterprises: the simplest form of reporting. They may prepare shortened balance sheets and profit and loss accounts without many additional disclosures. • Small enterprises: slightly more detailed requirements than for micro, but still exempt from many notes. • Medium-sized enterprises: more detailed reporting, but simplified compared to large entities - e.g., fewer requirements for notes.
Accounting Act (Poland)	The Polish Accounting Act allows simplification for SMEs, for example: • No obligation to prepare the cash flow statement: small entities are not required to prepare it. • Limited notes: smaller entities may submit limited notes, reducing administrative burden. • Simplified financial reports: small enterprises may submit shortened statements, such as a condensed balance sheet and profit and loss account.
Standard Audit File for Tax (SAF-T / JPK)	The obligation for SMEs to submit the Standard Audit File is another tool that to some extent substitutes for traditional financial statements, as accounting data are transmitted electronically and systematically to the tax administration. SAF-T enables automation of reporting, reducing errors and administrative burden.
IFRS for SMEs	IFRS has developed a special version of standards dedicated to SMEs, which is simpler than full IFRS. It contains simplified rules for: • measurement of assets and liabilities, • disclosure of financial information, • reporting financial performance.

Source: author's own study.

5. Drawbacks of Financial Statement Simplifications for Micro and Small Entities

Simplified financial statements, while beneficial in reducing administrative burdens, have limitations. In particular, they provide less detail, which may affect stakeholders' assessment of a company's financial condition (Jonas, 2015).

Several limitations can be identified. First, two issues should be highlighted: limited detail due to the lack of comprehensive notes, since simplified statements usually include fewer notes, which are key to fully understanding certain transactions, methods for measuring assets and liabilities, and the company's accounting policies (Chluska, 2016). Shortened balance sheets and profit and loss accounts present aggregated data that prevent detailed analysis of the asset and performance situation. Without breakdowns by categories of assets or costs, the reader cannot conduct an in-depth assessment of financial structure. This particularly affects analyses of liquidity, indebtedness, or efficiency of specific business areas. While simplified data may suffice for the owner of a small firm, they are far from sufficient for banks, investors, or suppliers. Consequently, simplified statements lose decision-usefulness and become merely formal documents meeting legal requirements while failing in their informational role. Excessive simplification flattens the picture of the enterprise. Resignation from the cash flow statement or notes deprives readers of knowledge about crucial aspects: cash-generating capacity, accounting policies, post-balance-sheet events, or contingent liabilities. As a result, micro and small entities' statements exhibit lower transparency, and their credibility in the eyes of stakeholders is weakened. The lack of details also hinders verification of data reliability, increasing the risk of errors and abuses. Simplified statements often lack information on segments of activity, which may be essential for stakeholders assessing performance by business area. Information on long-term capital investments may be omitted or simplified, making it harder to understand development strategy and future revenue sources. In simplified P&L statements, cost categories may be less detailed, limiting the ability to analyse operating costs and identify areas for optimization.

The second issue is limited information on risks. Full statements usually include details on financial risks (e.g., credit and liquidity risk). In simplified statements, these may be limited or omitted. Small enterprises are often exempt from preparing the cash flow statement, a key document providing information on actual cash inflows and outflows, which makes it more difficult to assess liquidity and the ability to meet obligations.

Simplified statements may also lack detailed information on the structure of equity, including changes in its components or the amount of reserves. This limits understanding of long-term financial stability. Conversely, information on liabilities, such as long-term loans or leases, may be presented in less detail, hindering assessment of debt structure and related risks. Simplified statements may omit future obligations such as guarantees, contingent liabilities,

or lease commitments. Such information is crucial for assessing a company's true financial position but may be omitted or inadequately disclosed. In smaller firms using simplifications, assets may be measured in simplified ways that do not always reflect their fair market value, affecting balance sheet accuracy and potentially leading to under- or overstatement of the company's assets. The literature repeatedly emphasizes that simplifications exacerbate information asymmetry between the enterprise and its stakeholders. Owners or management possess knowledge of the entity's situation that cannot be fully inferred from a simplified statement. External users - creditors, investors, trading partners - make decisions under uncertainty and with incomplete data. This asymmetry results in a higher cost of capital, greater collateral requirements, and more cautious counterparties. These factors weaken a firm's competitiveness by limiting access to external financing and new markets.

A core attribute of good financial reporting is comparability over time and across entities. Simplifications weaken this principle. Shortened forms of the balance sheet and profit and loss account are not directly comparable with full statements of large entities. Differences impede industry and sector analysis and weaken supervisory bodies' ability to monitor the economy. Simplifications also hinder international comparisons. When some companies report under full IFRS and others use national simplifications, obtaining consistent data becomes problematic - creating barriers for SMEs' internationalization and cooperation with foreign partners.

Financial statements have a control function - allowing tax authorities and auditors to assess lawful conduct and tax settlements. Simplifications significantly limit this function. The absence of detailed data in notes or cash flow statements makes it harder to detect irregularities, including potentially unlawful activities. For the tax administration, this implies a higher risk of errors and abuses; for auditors - limited ability to conduct in-depth analysis. Simplifications may thereby lead to an expansion of the shadow economy and undermine trust in the entire financial reporting system. Although simplifications are primarily addressed to external users, enterprises themselves feel the consequences. Abandoning more detailed reporting limits internal analysis and strategic planning. Owners of micro and small firms often rely on simplified statements, which may lead to superficial assessments and misguided managerial decisions. Another drawback is the shift from reporting as an informational tool to its formal-legal function. Micro and small entities prepare statements mainly to meet statutory requirements rather than to provide decision-useful information. Consequently, accounting in this segment plays a more administrative than managerial or analytical role. This weakens accounting's function as the language of business and a tool supporting decision-making. In the long run, it may marginalize the role of financial statements in the SME sector and entrench their perception as a bureaucratic obligation.

6. Conclusion

The analysis of the drawbacks of simplified financial statements for micro, small, and medium-sized enterprises allows several conclusions of both theoretical and practical significance. Although simplifications are introduced to reduce administrative burdens and tailor reporting requirements to the capacity of the smallest entities, their consequences go far beyond reducing the costs of record-keeping and reporting.

Above all, simplifications reduce the decision-usefulness of financial statements. The reduced scope of information presented turns statements from tools supporting economic decision-making into documents of a purely formal nature. This weakens accounting's fundamental function as a source of reliable, complete, and comparable information.

From the perspective of external stakeholders, simplifications generate information asymmetry, leading to higher agency costs, greater caution among creditors and investors, and a worsened negotiating position for the enterprise with counterparties. In practice, this translates into limited access to capital, the need to provide additional collateral, and higher transaction costs.

In a broader context, simplifications weaken market transparency, reduce the possibility of international and sectoral comparisons, and hinder public institutions' monitoring of the economy's condition. A limited scope of statistical and financial data means that economic policy may be based on incomplete premises, increasing the risk of misguided regulatory decisions.

Simplifications also impact accounting culture. Their use reinforces the belief among entrepreneurs that accounting is merely a set of formal requirements rather than a managerial and analytical tool. This hinders the professionalization of financial staff in the SME sector and limits the implementation of modern management tools. In summary, the balance of benefits and costs associated with reporting simplifications for micro, small, and medium-sized enterprises is not clear-cut. On the one hand, they provide administrative relief and lower the direct costs of accounting. On the other hand, they generate numerous drawbacks which, in the longer term, may outweigh short-term savings. It therefore seems necessary to conduct further research and empirical analyses on the impact of simplifications on SMEs' competitiveness, access to financing, and management culture. The results could underpin potential legal modifications to balance the need to reduce costs with ensuring the reliability, transparency, and decision-usefulness of financial statements. From the standpoint of economic policy, a flexible model should be considered - allowing enterprises to choose between simplifications and full reporting depending on their development strategy and financing needs. Such a solution would help build awareness that full accounting is not only an obligation but also an investment in credibility and the enterprise's durability.

References

1. Barber, J., Metcalfe, J.S., Porteous, M. (1989). *Barriers to Growth in Small Firms*. London: Routledge.
2. Bauer, K. (2025). *Sprawozdanie finansowe jako źródło informacji dla interesariuszy zewnętrznych przedsiębiorstw w postępowaniu restrukturyzacyjnym*. Wydawnictwo Uniwersytetu Ekonomicznego w Krakowie,
3. Bauer, K. (2025). Sprawozdanie finansowe jako źródło informacji do podejmowania decyzji w postępowaniu restrukturyzacyjnym – stałość czy zmienność potrzeb interesariuszy. *Zeszyty Teoretyczne Rachunkowości*, vol. 49, no. 3. Warszawa: Stowarzyszenie Księgowych w Polsce.
4. Chen, C.J., Chen, S., Su, X. (2001). Is Accounting Information Value – relevant in the Emerging Chinese Stock Market? *Journal of International Accounting, Auditing and Taxation*, vol. 10, no. 1.
5. Chluska, J. (2016). Uproszczenia rachunkowości jednostek mikro i małych - szanse i zagrożenia. *Studia Ekonomiczne, Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach*, Katowice.
6. Deakins, D., Whittam, G. (2000). Business Start-up: Theory, Practice and Policy. In: S. Carter, D. Jones-Evans (eds.), *Enterprise and Small Business. Principles, Practice and Policy*. Harlow: Financial Times.
7. Dratwińska-Kania, B., Ferens, A., Szewieczek, A. (2021). *Rapostowanie zintegrowane o modelu biznesu w kreowaniu wartości przedsiębiorstwa*. Warszawa: CeDeWu.
8. Drucker, P. (2009). *Praktyka zarządzania*. Warszawa: MT Biznes.
9. Gruszecki, T. (2002). *Współczesne teorie przedsiębiorstwa*. Warszawa: PWN.
10. Hołda, A., Micherda, B. (2007). *Kontynuacja działalności jednostki i modele ostrzegające przed upadłością*. Warszawa: Krajowa Izba Rewidentów.
11. Kamińska, A. (2015). Stymulatory i bariery rozwoju małych i średnich przedsiębiorstw w Polsce. *Zarządzanie. Teoria i Praktyka*, 11(1).
12. Kamińska, A. (2011). *Regionalne determinanty rozwoju małych i średnich przedsiębiorstw*. Warszawa: Difin.
13. Kuzior, A., Pfaff, J., Poniatowska, L., Rówińska, M. (2014). *Kierunki transformacji sprawozdawczości małych i średnich przedsiębiorstw na tle regulacji międzynarodowych*. Warszawa: CeDeWu.
14. Lachiewicz, S., Matejun, M. (2012). Specyfika zarządzania małymi i średnimi przedsiębiorstwami. In: M. Matejun (ed.), *Zarządzanie małą i średnią firmą w teorii i w ćwiczeniach*. Warszawa: Difin.
15. Lemańska-Majdzik, A. (2013). Powody prowadzenie własnej działalności gospodarczej małych firm. *Zeszyty Naukowe Wyższej Szkoły Humanitas, Zarządzanie*, cz. 1.

16. Maćkowiak, E. (2023). A new concept of value management in SMEs. *Scientific Papers of Silesian University of Technology. Organization & Management [Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie]*, 179.
17. Maćkowiak, E. (2013). *Model przekształcenia sprawozdania finansowego na potrzeby zarządzania wartością przedsiębiorstwa*. Katowice: Wydawnictwo UE w Katowicach.
18. Maćkowiak, E. (2019). *Wielowymiarowe podejście do zarządzania wartością w małym i średnim przedsiębiorstwie*. Warszawa: CeDeWu.
19. Miszczak, M. (2022). Leader's digital competence in motivating employees during the Covid-19 pandemic – research findings. *Zeszyty Naukowe. Organizacja i Zarządzanie*, no. 159. Politechnika Śląska.
20. Młaskawa, J. (2021). *Innowacje bankowe a rozwój małych i średnich przedsiębiorstw*. Dąbrowa Górnicza: Wydawnictwo Naukowe Akademii WSB.
21. Morrison, J., Breen, S.A. (2003). Small Business Growth: Intention, Ability, and Opportunity. *Journal of Small Business Management*, nr 41.
22. Mućko, P., Sokół, A. (2011). *Jak założyć i prowadzić działalność gospodarczą w Polsce i wybranych krajach europejskich*. Warszawa: CeDeWu.
23. Nowak, E. (2015). Sprawozdanie finansowe mikrojednostek w świetle regulacji rachunkowości. In: D. Zarzecki (ed.), *Czas na pieniądź*. *Zeszyty Naukowe Uniwersytetu Szczecińskiego*, nr 854. Szczecin.
24. Parson, L.M. (2003). Is Accounting Information from Nonprofit Organizations Useful to Donors? A Review of Charitable Giving and Value – relevance. *Journal of Accounting Literature*, no. 22.
25. Steinerowska-Streb, I. (2017). *Zachowania rynkowe mikro-, małych i średnich przedsiębiorstw w Polsce. Diagnoza, analiza, scenariusze rozwoju*. Warszawa: CH Beck.
26. Tkocz-Wolny, K. (2015). Zakres sprawozdania finansowego małych i średnich przedsiębiorstw. *Studia Ekonomiczne*, nr 252. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach*.
27. Urbanowska-Sojkin, E., Banaszyk, P. (2009). Ewolucja przedsiębiorstw w Polsce w okresie transformacji gospodarki po 1989 roku. *Ruch prawniczy, ekonomiczny i socjologiczny*, Zeszyt 2.
28. Wędzki, D. (2012). The Sequence of Cash Flow in Bankruptcy Prediction: Evidence from Poland. *Theoretical Journal of Accounting*, vol. 68, no. 124.
29. Zarzycka, E., Krasodomska, J. (2022). Non – financial Key Performance Indicators: What Determines the Differences in the Quality and Quantity of the Disclosures? *Journal of Applied Accounting Research*, vol. 23, no. 1.
30. Zimmerman, J.L., Yahya-Zadeh, M. (2011). Accounting for Decision Making and Control. *Issues in Accounting Education*, vol. 26, no. 1.

CLUSTER ANALYSIS AS A TOOL FOR STUDYING THE SOCIO-ECONOMIC DIVERSITY OF AFRICAN COUNTRIES

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Purpose: This paper examines the socio-economic diversity of African countries in light of the continent's rising importance in the global economy. The aim is to identify clusters of countries with similar development characteristics, providing insights into Africa's internal heterogeneity.

Design/methodology/approach: The research applies agglomerative hierarchical cluster analysis to a dataset of African countries, covering selected economic and social indicators such as GDP per capita, education, urbanization, infant mortality, gender inequality, corruption perception, and economic freedom. The analysis was conducted using the R statistical program, which provided the tools for building and interpreting clusters. The methodological approach allows for the identification of groups of countries sharing common socio-economic profiles, highlighting patterns and contrasts within the region.

Findings: The study identified distinct clusters of African countries, each reflecting different levels of socio-economic development and diversification. The results demonstrate significant internal diversity, revealing groups of countries with relatively advanced development indicators as well as those facing persistent socio-economic challenges. These findings confirm that Africa cannot be treated as a homogeneous entity but rather as a continent with complex and varied development trajectories.

Research limitations/implications: The research is constrained by the availability and comparability of statistical data across African countries.

Practical implications: The classification of African countries has practical value for policymakers, investors, and development institutions. The results can support the design of more tailored strategies, the allocation of resources, and investment planning aligned with the specific needs of different groups of countries.

Social implications: A better understanding of socio-economic diversity in Africa can help address inequalities, improve policy design, and promote inclusive and sustainable development. The findings may also inform initiatives aimed at improving living standards and social cohesion.

Originality/value: The paper provides a novel and systematic application of cluster analysis to socio-economic data on African countries. It contributes to the literature by offering an evidence-based classification of the region, adding value to researchers, practitioners, and policymakers concerned with economic development and regional studies.

Keywords: socio-economic development, Africa, cluster analysis, economic diversification.

1. Introduction

Africa, despite being perceived for many years mainly in terms of socio-economic problems, has been, since the beginning of the 21st century, increasingly recognized as an area with significant development potential. Dynamic economic growth in some countries, the abundance of natural resources, increasing regional integration and growing importance in international markets are attracting the attention of investors, international organizations and academia. However, the continent is characterized by significant internal diversity – there are economies with relatively high level of development and stable institutions, yet some countries are struggling with serious structural barriers and limited access to infrastructure.

The main objective of the study was to identify the structure of socio-economic differentiation among African countries by isolating groups of countries with similar development profiles. The analysis was based on a set of indicators covering both economic and social aspects, including the level of economic development, access to education, health status of the population, urbanization, gender equality and quality of institutions, among others. Agglomerative cluster analysis was used to identify individual groups, thus capturing similarities and differences between countries. Calculations and visualizations were performed in R using dedicated functions and statistical packages.

The results of the analysis carried out provide an in-depth knowledge of the internal development structure of African countries, and the resulting breakdown can serve as a starting point for further, more focused research.

2. The concept and measurement of socio-economic development

The concept of “socio-economic development” only began to be used more widely in the economic literature in the post-war period (Łopatka et al., 2024). Churski (2008, p. 19) defines socio-economic development as a process of sustained and targeted change involving both the social and economic sectors. It is a broad concept, which, according to Dach’s (2011, p. 6) approach, is a combination of economic growth, economic development and social development, and takes into account paramount transformations in social relations and in the institutions that shape the functioning of the economy and society. In turn, Kupiec (1993) describes socio-economic development as a process of quantitative and qualitative changes of a positive nature, involving the improvement of existing and the creation of new phenomena in the area of economic, social and cultural activities. Measures of development should encompass not only the value of goods and services produced, but also the quality of life of citizens, including access to education, health care, equal opportunities, the level of infrastructure,

and the quality of public institutions (Stiglitz et al., 2019). Measuring socio-economic development solely on the basis of GDP fails to account for many key aspects such as inequalities, unmeasurable institutional factors or differences in quality of life. As a result, development is a multidimensional concept that requires broader measures (United Nations Secretary-General, 2023). Recognizing the numerous limitations of measures based solely on the material realm of the economy, efforts were undertaken to develop tools that also take into account the qualitative aspects of well-being. Despite the increasing number and complexity of proposed indicators, there is still no universally accepted, uniform method for constructing them (Kubiczek, 2014).

The most commonly used measure is gross domestic product (GDP) per capita, particularly in terms of purchasing power parity (PPP), which allows for the comparison of living standards between countries by eliminating the effect of price differences (Todaro, Smith, 2020). Although GDP is a simple and widely available indicator, its limitation is that it does not take into account quality of life, social inequalities or access to public goods (Stiglitz et al., 2019). In addition to GDP, there are other quantitative indicators of economic development, such as GDP per capita, GNP (Gross National Product), GNP per capita, NNP (Net National Product or national income) and NNP per capita. To obtain a more comprehensive picture, synthetic indicators are used, such as the Human Development Index (HDI), which combines information on income, education, and health (United Nations Development Program, 2023), or the Gender Inequality Index (GII), which assesses gender disparities in health, education, and the labour market (Sen, 1999). In development analyses, health indicators are gaining increasing importance, including infant mortality, which serves as a sensitive measure of the quality of medical care, living conditions, and the overall level of social development (Todaro, Smith, 2020). Another important aspect is the degree of urbanization, which reflects access to technical infrastructure, public services and modern technology (World Bank, 2023). Institutional indicators, on the other hand, such as the Corruption Perceptions Index (CPI) or the Index of Economic Freedom, provide information on the quality of governance, transparency of institutions and the freedom of business activity, which are key to sustainable growth and development (Stiglitz et al., 2019). However, the literature emphasizes that the above can also be complemented by poverty indicators such as the Poverty Headcount Ratio or the Multidimensional Poverty Index (MPI), which capture deprivation along multiple dimensions – from income and education to housing (Alkire, Santos, 2010, p. 38). Measures of income inequality are also an important component, e.g. the Gini coefficient to assess how evenly the benefits of development are distributed (De Maio, 2007). There is also an emphasis on the need to complement traditional indicators with measures of economic well-being that take into account environmental aspects and sustainability, such as DEN/MEW (Net Economic Welfare/Measure of Economic Welfare), ISEW (Index of Sustainable Economic Welfare) or EAW (Index of the Economic Aspects Welfare). The inclusion of these indicators in the analyses allows for a more comprehensive understanding of development differentiation, particularly in

the context of developing countries. A comprehensive view of development therefore requires the use of a set of indicators describing its various dimensions.

3. Empirical classification of African countries using agglomerative cluster analysis

To conduct an analysis of the socio-economic disparities among African countries, a multidimensional approach was employed, encompassing seven carefully selected indicators. These variables represent different, complementary dimensions of development. The variables chosen for the cluster analysis are indicators measuring the fundamental dimensions of development. The components of complex indices were broken down into their individual elements to avoid redundancy and enhance the interpretative transparency of the results. The aim of this chapter is to empirically identify the internal socio-economic differentiation of African countries on the basis of selected development indicators. For this purpose, agglomerative cluster analysis was used, a method that falls into the category of hierarchical techniques allowing objects to be grouped in such a manner that within one cluster there are objects with the greatest possible similarity and between clusters there are the greatest possible differences (Walesiak, Gatnar, 2009).

The concept of cluster analysis was coined by R.C. Tryon in 1939 in his work of the same title (Tyron, 1939). Cluster analysis refers to various techniques and numerical methods that are part of statistical classification methods, enabling the identification and evaluation of groups (clusters), the creation of classifications, and data mining.

This study uses Ward's (1963) agglomerative method together with the squared Euclidean distance as a measure of similarity. This method minimizes the sum of squared deviations of points from the cluster center, thereby producing groups that are as homogeneous as possible. The process involves dividing a set of S observations into classes (groups, clusters). However, the number of classes is not predetermined – it is determined by analysis of the dendrogram and agglomerative steps. Objects that express similarity (i.e. are close to each other in variable space) are assigned to the same class, while objects that differ are assigned to different classes (Migdał-Najman, Najman, 2005).

The study used data for 2023 covering 42 African countries. The analysis was carried out in R. Empirical data were obtained from the following websites: World Bank Group, The Heritage Foundation, Transparency International. The indicators used in the study reflect key areas of development and include:

- economy – GDP per capita (PPP),
- education – average years of adult schooling,
- infrastructure and society – urbanization index,

- health – infant mortality rate,
- social inequality – gender inequality indicator,
- institutional transparency – corruption perceptions index,
- economic environment – index of economic freedom.

The process of performing the cluster analysis in R consisted of the following steps:

- normalizing metric variables,
- calculating the distance matrix between countries using Euclidean distance,
- performing a hierarchical cluster analysis using Ward's method,
- creating a dendrogram that illustrates the process of grouping countries together,
- establishing a division into k classes and forming four groups of similar countries,
- interpreting the results.

Before calculating the distance matrix, the variables were standardized. This ensured that the variables expressed in different units were scaled to a comparable level. The entire data cleaning and standardization process was performed in R using the packages (Kabacoff, 2022):

- `readxl` – for importing data from Excel files,
- `scale()` – R's built-in function for standardizing variables.

The squared Euclidean distance, widely used in analyses of standardized data, was used to measure similarity between objects, which makes it possible to emphasize larger differences between objects more strongly and to obtain a clearer cluster division (Everitt et al., 2011). The following were used for the analysis (R Core Team, 2024):

- `stats::dist()` – calculation of the Euclidean distance matrix,
- `stats::hclust()` – performing hierarchical agglomerative cluster analysis using Ward's method,
- `factoextra::fviz_dend()` – dendrogram visualization with class labeling.

The results of the analysis are presented in Figure 1 in the form of a dendrogram – a hierarchical tree illustrating the process of grouping countries together. The dendrogram allows the graphical identification of the tree's "cut" point corresponding to a specific number of classes.

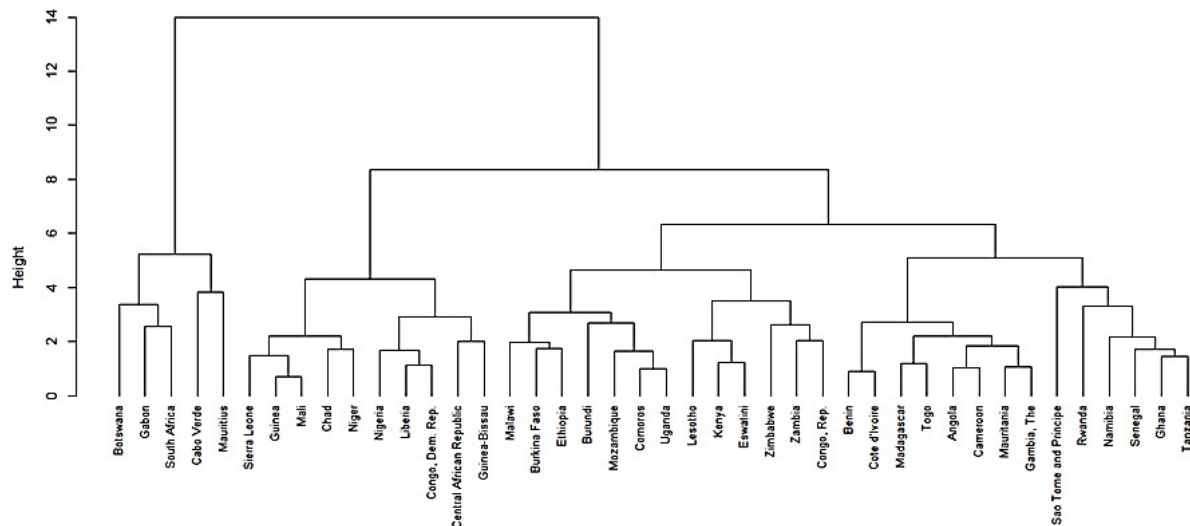


Figure 1. Dendrogram showing hierarchical cluster analysis of 42 African countries.

Source: own elaboration.

In hierarchical cluster analysis, the initial merging steps involve the most similar objects, resulting in a small increase in the distance measure. If the number of classes had been selected solely on the basis of the first large increase in this measure, a very large number of groups would have been obtained, so the first mergers were omitted and the analysis was carried out focusing on the later stages, where the increase in distance indicates the merging of more diverse groups (Everitt et al., 2011). In order to determine the optimal number of classes, an analysis was carried out using various methods to minimize the risk of arbitrary division (Thorndike, 1953).

The average silhouette width for different class sizes was calculated using the function `fviz_nbclust` (method = “silhouette”). The highest value (0.45) was obtained for 2 classes, indicating the best separation of groups. The values for $k = 3$ and $k = 4$ were slightly lower (0.19 and 0.17, respectively) (Figure 2). The Gap Statistic method used the `clusGap()` function from the cluster package and the `fviz_gap_stat()` visualization from the factoextra package to compare clustering results with randomly generated data. The point of greatest difference between the actual and random data indicated 2-4 classes as the potentially optimal solution (Figure 3). In addition, an agglomeration schedule was analyzed, which shows the incremental value of the distance measure in subsequent stages of cluster merging. The graph of height increment differences indicated a clear local jump at the stage when the last 4 groups were combined into 3 classes. According to the recommendations of the method, the optimal cut of the dendrogram should take place before such a jump, which in this case corresponds to a division into 4 classes (Figure 4) (Yim, Ramdeen, 2015). In addition, the Elbow Method was used. The `fviz_nbclust` (method = “wss”) function revealed clear “breakpoints” in the curve at two and four clusters, which confirmed the earlier observations. The Dindex (Difference Index) method is an approach used to determine the optimal number of classes, which analyses the rate at which the value of the within-group measure (or other fit index) decreases as the number of

classes increases. Figure 5 shows the Dindex values (left) and their second differences (right), which allows us to identify the “curve breakdown point” – the point at which further increases in the number of classes bring a slight improvement in clustering quality. The study shows a clear turning point around 4 classes which is the rationale for choosing this number of groups (Charrad et al., 2014).

Although many methods pointed to the optimality of 2-class division, this solution yielded very unequal group sizes – 5 countries in the first class and 40 in the second. This large disparity makes it difficult to interpret the results and does not allow subtle differences between countries to be discerned. All methods indicated the need to consider several options for the number of classes. After analyzing the graphs and indicator values, it was considered that the division into four classes best reflected the internal diversity of the countries reviewed. The division into 4 classes was found to be the most satisfactory, as it provided a more equal group size, allowed greater socio-economic variation between states to be captured, and was consistent with observations of dendrogram height increments (agglomeration review), which indicated an optimal cut with 4 groups.

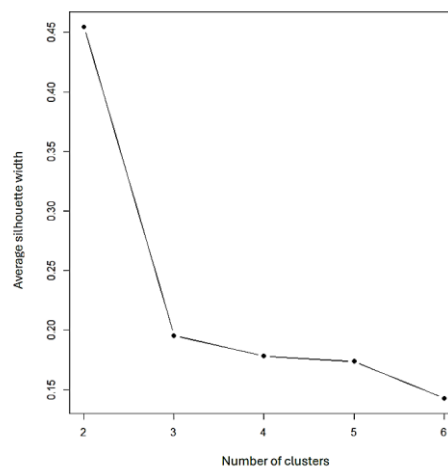


Figure 2. Results of the silhouette index-based criterion for selecting the optimal number of classes

Source: own elaboration.

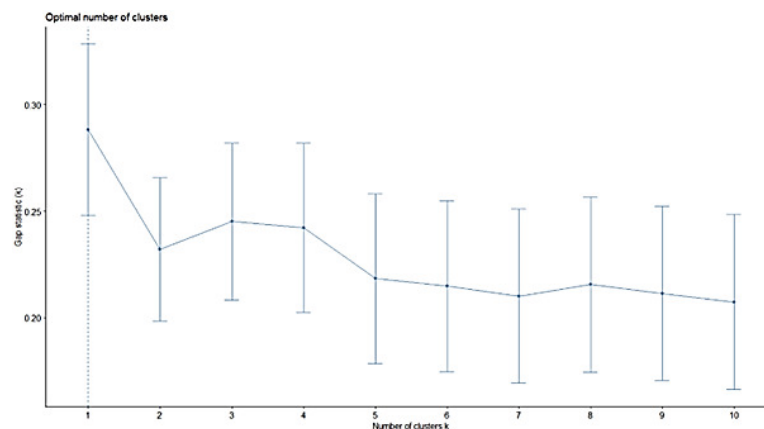


Figure 3. Results of the Gap Statistic method for selecting the optimal number of classes.

Source: own elaboration.

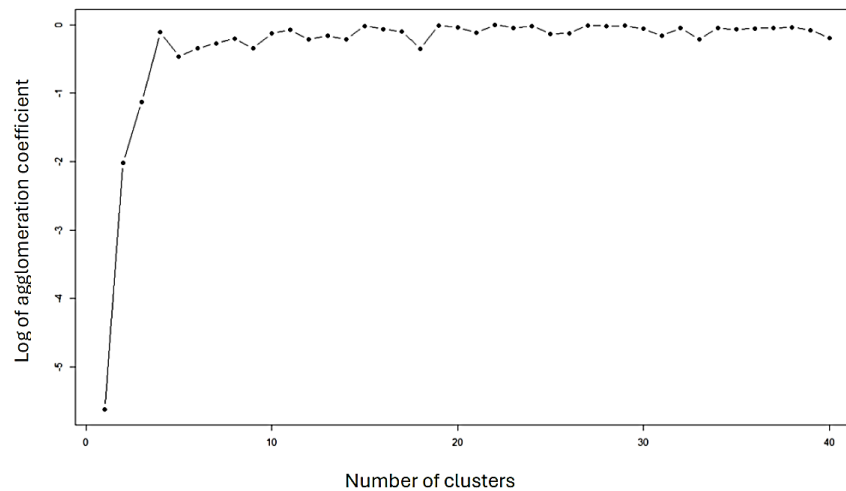


Figure 4. Graph of agglomeration increments (height differences) in hierarchical cluster analysis.

Source: own elaboration.

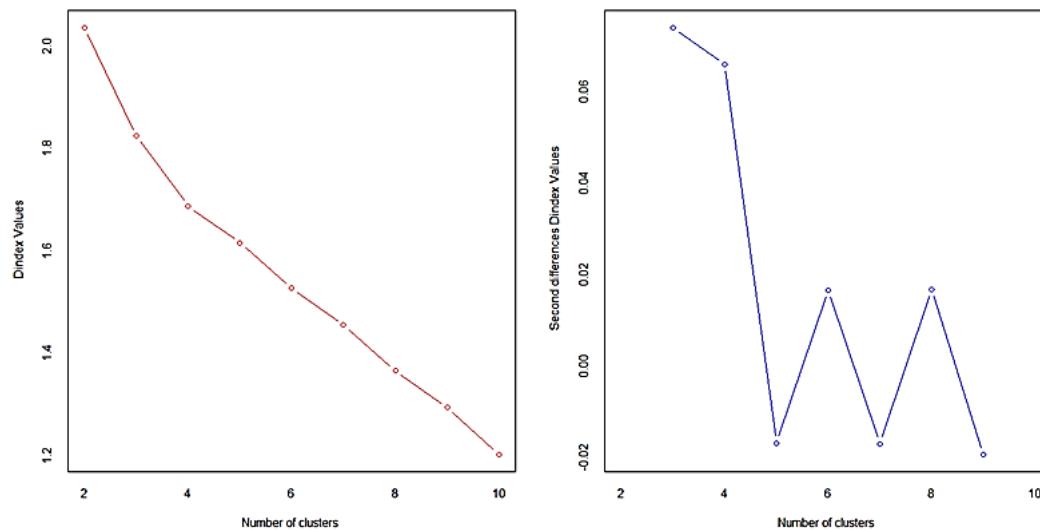


Figure 5. Results of the Dindex method for selecting the optimal number of classes (5a. Dindex values as a function of the number of clusters, 5b. Second differences of Dindex values depending on the number of clusters).

Source: own elaboration.

Figure 6 shows the result of the hierarchical analysis, in which the optimal cut of the dendrogram shows the division of the reviewed objects into four classes.

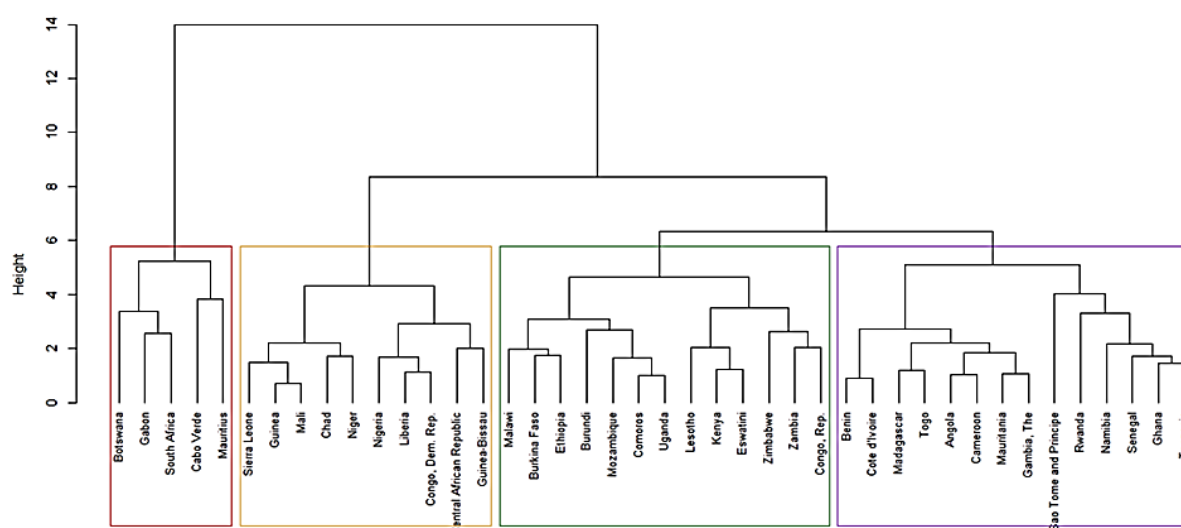


Figure 6. Dendrogram showing a hierarchical cluster analysis of 42 African countries divided into four classes.

Source: own elaboration.

Table 1 shows the division of African countries into four classes, distinguished on the basis of the socio-economic indicators analyzed.

Table 1.

Assignment of objects to clusters

Class	Country name
Class 1	Botswana, Gabon, South Africa, Cape Verde, Mauritius
Class 2	Sierra Leone, Guinea, Mali, Chad, Niger, Nigeria, Liberia, Democratic Republic of the Congo, Central African Republic, Guinea-Bissau
Class 3	Malawi, Burkina Faso, Ethiopia, Burundi, Mozambique, Comoros, Uganda, Lesotho, Kenya, Eswatini, Zimbabwe, Zambia, Republic of the Congo
Class 4	Benin, Côte d'Ivoire, Madagascar, Togo, Angola, Cameroon, Mauritania, Gambia, São Tomé and Príncipe, Rwanda, Namibia, Senegal, Ghana, Tanzania

Source: own elaboration.

Table 2 presents the basic descriptive statistics for the socio-economic indicators selected for the study by the four groups of African countries.

Table 2.

Basic statistical measures by class

Class	Risk	Mean	The median	Min.	Max.	The standard deviation	Coefficient of variation
1	Corruption Perceptions Index	48.60	51.00	28.00	64.00	14.43	29.70
1	Index of Economic Freedom	62.62	64.90	55.70	70.60	6.51	10.39
1	GDP per capita (PPP)	7592.75	7826.35	4861.29	11182.19	2402.82	31.65
1	Urbanization	68.31	68.82	40.87	91.03	17.96	26.29
1	Gender inequality index	0.41	0.39	0.30	0.51	0.09	21.91
1	Infant mortality rate	22.72	24.04	11.00	38.20	10.94	48.17

Cont. table 2.

1	Average years of schooling	9.59	10.10	6.09	11.61	2.09	21.74
2	Corruption Perceptions Index	25.07	25.00	20.00	35.00	4.88	18.98
2	Index of Economic Freedom	50.34	51.10	43.80	54.50	3.86	7.68
2	GDP per capita (PPP)	946.67	882.06	495.98	1596.64	373.71	39.48
2	Urbanization	41.44	44.88	17.05	54.28	12.01	28.97
2	Gender inequality index	0.61	0.61	0.51	0.68	0.05	8.04
2	Infant mortality rate	56.21	58.15	43.10	67.40	7.57	13.47
2	Average years of schooling	4.02	3.60	1.41	7.59	2.28	56.66
3	Corruption Perceptions Index	29.69	30.00	20.00	41.00	7.40	24.92
3	Index of Economic Freedom	50.04	51.60	39.00	56.20	4.98	9.95
3	GDP per capita (PPP)	1448.61	1272.36	192.07	3741.69	955.29	65.95
3	Urbanization	32.09	30.13	14.78	69.19	13.81	43.04
3	Gender inequality index	0.52	0.52	0.48	0.58	0.03	5.90
3	Infant mortality rate	37.14	35.70	27.06	55.40	8.34	22.47
3	Average years of schooling	6.15	6.32	2.27	8.93	2.39	38.87
4	Corruption Perceptions Index	38.50	40.00	25.00	53.00	8.34	21.65
4	Index of Economic Freedom	55.94	57.70	45.10	60.40	4.22	7.54
4	GDP per capita (PPP)	1854.33	1717.45	508.72	4187.61	980.73	52.89
4	Urbanization	52.42	54.02	17.89	76.40	14.54	27.74
4	Gender inequality index	0.53	0.54	0.39	0.60	0.06	11.39
4	Infant mortality rate	34.57	34.85	9.04	46.60	9.59	27.75
4	Average years of schooling	5.34	5.37	2.93	7.27	1.30	24.36

Source: own elaboration.

Cluster analysis revealed four clearly distinguishable groups of African countries that differ in both their level of economic development and the structure of their social problems. These differences are evident in almost all the indicators reviewed.

Group 1 comprises countries with the highest level of socio-economic development. They are characterized by high GDP per capita, low gender inequality index, the highest level of the Corruption Perceptions Index, low infant mortality and the best educational performance. Their average GDP per capita (USD 7593) is more than four times that of Group 2 and more than five times that of Group 3. The average years of schooling (9.59) exceeds the other groups by at least three years, and the Corruption Perceptions Index (48.6) indicates a significantly better quality of institutions than in groups 2-4 (a difference of 16 points compared with the lowest score). The gender inequality index (0.407) is a third lower than in Group 2, and urbanization (68.3%) is the highest. This group includes five countries: Botswana, Gabon, South Africa, Cape Verde, Mauritius. The above group is composed of countries with stable economies, well-developed infrastructure and robust institutions.

Group 2 is the opposite of Group 1. It includes countries with the lowest average GDP per capita (USD 947) and the level of urbanization (42.7%) remains below the African average. The gender inequality index (0.611) is the highest of all groups – roughly 50% higher than in Group 1 – and infant mortality (58.6) is almost double that of Group 1. The CPI (32.0) and index of economic freedom (48.6) are moderate, but do not compensate for the poor social performance. This group comprises countries struggling with an array of economic and social problems, limited access to infrastructure, and difficult living conditions. Eleven countries were included, such as Sierra Leone, Guinea, Mali, Chad, Niger, Nigeria, Liberia, Democratic Republic of the Congo, Central African Republic and Guinea-Bissau.

Group 3 comprises countries with an average level of development and high average internal disparity (66%). They have low to moderate GDP per capita and education indicators. Social problems are evident in high GII values and infant mortality. Urbanization is relatively low. Compared to Group 2, it has a slightly lower Gender Inequality Index (0.566) and lower infant mortality (45.8), but lags significantly behind Group 1 on every development indicator. Urbanization (36.9%) is the lowest of all groups, highlighting the limited access to urban infrastructure. The group is composed of thirteen countries, including Malawi, Burkina Faso, Ethiopia, Burundi, Mozambique, Comoros, Uganda, Lesotho, Kenya, Eswatini, Zimbabwe, Zambia and Republic of the Congo. These are countries that are nearing continental averages in some areas, but lagging behind in others.

Group 4 is distinguished by a relatively high level of urbanization (53.7%), similar to Group 1, but in contrast is characterized by weak institutions (CPI = 32.6) and low economic freedom (51.5). GDP per capita (USD 1854) is higher than in Groups 2 and 3. The gender inequality index (0.550) is high and comparable to Group 3, indicating persistent social barriers. Fourteen countries were included in this group, such as Benin, Côte d'Ivoire, Madagascar, Togo, Angola, Cameroon, Mauritania, Gambia, São Tomé and Príncipe, Rwanda, Namibia, Senegal, Ghana and Tanzania. Although they have the potential for development it is hampered by corruption and governance issues.

4. Conclusion

The cluster analysis conducted identified four distinct groups of African countries, differing in terms of their level of socio-economic development and the structure of their key challenges. The results confirm that the continent is characterized by considerable socio-economic development disparities. The first group includes countries with relatively high levels of development, strong institutions and favorable social indicators, serving as a benchmark for all the others. At the opposite end is the second group, comprising countries with the lowest GDP per capita, the highest infant mortality, and significant gender inequalities, indicating

a concentration of development barriers. The third group represents a medium level of development, but is distinguished by a high degree of internal disparity, suggesting that the development strategy for these countries needs to take into account their specific circumstances. Group 4, on the other hand, is characterized by a relatively high level of urbanization but weak institutions and limited economic freedom, which constrain its growth potential. A comparison of the results shows that GDP alone is not a sufficient measure of development, and that taking into account social, demographic and institutional indicators allows a more complete understanding of the individual countries' situation.

For the lowest-performing countries, strengthening institutions, improving infrastructure, and reducing inequalities are crucial. The results of the analysis can provide a starting point for further comparative studies.

References

1. Alkire, S., Santos, M.E. (2010). Acute Multidimensional Poverty: A New Index for Developing Countries. *OPHI Working Paper*, 38.
2. Charrad, M., Ghazzali, N., Boiteau, V., Niknafs, A. (2014). NbClust: An R Package for Determining the Relevant Number of Clusters in a Data Set. *Journal of Statistical Software*, 61(6), pp. 1-36.
3. Churski, P. (2008). *Czynniki rozwoju regionalnego i polityka regionalna w Polsce w okresie integracji z Unią Europejską*. Adam Mickiewicz University Press.
4. Dach, Z. (2011). Rozwój społeczno-gospodarczy w teorii ekonomii. *Scientific Journals of the Kraków University of Economics*, 872, pp. 5-16.
5. De Maio, F.G. (2007). Income inequality measures. *Journal of Epidemiology and Community Health*, 61(10), pp. 849-852.
6. Everitt, B., Landau, S., Leese, M., Stahl, D. (2011). *Cluster Analysis (5th ed.)*. Wiley.
7. <https://data.worldbank.org/indicator/SP.DYN.IMRT.IN>, <https://data.worldbank.org/indicator/NY.GDP.PCAP.CD>, <https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS>, 1 August 2025.
8. <https://www.heritage.org/>, 1 August 2025.
9. <https://www.transparency.org/en/>, 1 August 2025.
10. Kabacoff, R. (2022). *R in Action: Data Analysis and Graphics with R and Tidyverse*. Manning.
11. Kubiczek, A. (2014). How to measure countries' socio-economic development today. *Social Inequality and Economic Growth*, 38, pp. 40-56.
12. Kupiec, L. (1993). *Socio-economic development*. Białystok: Publishing Department of the University of Warsaw Branch.

13. Łopatka, P., Jancz, A., Jadach, R. (2024). Rozwój społeczno-gospodarczy regionów w Unii Europejskiej. *Scientific Journals of the Upper Silesian Academy*, 5(17), pp. 50-62.
14. Migdał-Najman, K., Najman, K. (2005). Analiza porównawcza wybranych metod analizy skupień w grupowaniu jednostek o złożonej strukturze grupowej. *Taxonomy 12, Scientific Papers of the Wrocław University of Economics*, No. 1076.
15. R Core Team (2024). *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing.
16. Rousseeuw, P.J. (1987). Silhouettes: A graphical aid to the interpretation and validation of cluster analysis. *Journal of Computational and Applied Mathematics*, 20, pp. 53-65.
17. Sen, A. (1999). *Development as Freedom*. Oxford University Press.
18. Stiglitz, J.E., Fitoussi, J.P., Durand, M. (2019). *Poza PKB. Mierzmy to, co ma znaczenie dla rozwoju społeczno-gospodarczego*. Warsaw: Polish Economic Society, OECD Publishing.
19. Stiglitz, J.E., Sen, A., Fitoussi, J.-P. (2009). *Report by the Commission on the Measurement of Economic Performance and Social Progress*. Paris: Commission on the Measurement of Economic Performance and Social Progress.
20. Thorndike, R.L. (1953). Who belongs in the family? *Psychometrika*, 18(4), pp. 267-276.
21. Tibshirani, R., Walther, G., Hastie, T. (2001). Estimating the number of clusters in a data set via the gap statistic. *Journal of the Royal Statistical Society Series B: Statistical Methodology*, 63(2), pp. 411-423.
22. Todaro, M.P., Smith, S.C. (2020). *Economic Development (13th ed.)*. Pearson.
23. Tryon, R.C. (1939). *Cluster Analysis: Correlation Profile and Orthometric (Factor) Analysis for the Isolation of Unities in Mind and Personality*. Ann Arbor: Edwards Brothers.
24. United Nations Development Program (2023). *Human Development Report 2023/24*. UNDP.
25. United Nations Secretary-General (2023). *Framework to progress beyond gross domestic product (Our Common Agenda Policy Brief No. 4)*. United Nations.
26. Walesiak, M., Gatnar, E. (2009). *Statystyczna analiza danych z wykorzystaniem programu R*. Warsaw: PWN.
27. Ward, J.H. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association*, 58(301), pp. 236-244.
28. World Bank (2023). *World Development Indicators*. World Bank Group.
29. Yim, O., Ramdeen, K.T. (2015). Hierarchical cluster analysis: Comparison of three linkage measures and application to psychological data. *The Quantitative Methods for Psychology*, 11(1), pp. 8-21.

ANALYSIS OF THE IMPACT OF THE U.S. PRESIDENTIAL CYCLE FRAMEWORK ON STOCK MARKET RETURNS: EVIDENCE FROM U.S. STOCK INDEXES

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Purpose: This study aims to evaluate the validity of the U.S. presidential cycle framework in predicting returns on U.S. stock indexes, including sector indexes, to address the research gap in its application to sector-specific indexes.

Design/methodology/approach: The research analyzes monthly returns from 18 U.S. stock indexes (3 major, 15 sector-specific) from their inception (1971-2002) to January 2025. It tests two hypotheses: H_1 , that returns are highest in the third year and lowest in the first year of presidential terms; H_2 , that returns are higher in the second half (years 3-4) than the first half (years 1-2). Robust and simplified approaches compare annual and halved-term returns, respectively. To determine whether the results are statistically significant, one-way ANOVA tests are used.

Findings: The presidential cycle framework shows limited validity in the robust approach, with only 1.85% of cases having the highest returns in year 3 and lowest in year 1. It is more valid for predicting higher returns in year 3 (52.78%), especially for Republican presidents (59.26%), but invalid for lowest returns in year 1 (0%). In the simplified approach, higher returns in the second half are confirmed in 63.89% of cases, particularly for Republican presidents (77.78%).

Research limitations/implications: Limited historical data for some sector indexes may affect generalizability. Future research could incorporate monetary policy or investor sentiment to explain sectoral deviations.

Practical implications: Investors may benefit from anticipating higher returns in the second half of Republican presidents' terms, aiding portfolio strategies.

Originality/value: This study uniquely validates the presidential cycle framework across 15 sector indexes, addressing a gap in prior literature focused on major indexes

Keywords: presidential cycle, stock market returns, sector indexes, U.S. elections, investor sentiment.

Category of the paper: research paper, conceptual paper.

1. Introduction

The U.S. presidential cycle framework is significant for both researchers and investors. For researchers, it elucidates the influence of political dynamics on financial markets, while for investors, it enables the prediction of periods with higher and lower returns (Nguyen, Mathieu, 2008). This framework, introduced by Yale Hirsch in the *Stock Trader's Almanac*, published annually since 1967, posits that U.S. stock market returns follow a recurring pattern driven by four-year presidential cycles (Hirsch, 1967).

The first year of the cycle, coinciding with the presidential inauguration, exhibits the lowest returns throughout the cycle. Investor behavior is marked by caution due to emerging concerns regarding planned reforms, new regulations, and changes in fiscal policy. This year is often associated with restrictive monetary policy, constraining financial market liquidity. The second year, continuing the presidential term, shows a slight improvement in returns, though they typically remain below average. Congress's increasing legislative involvement introduces uncertainty. Historically, the second year has frequently coincided with wars and recessions. The third year of a U.S. presidential term, a pre-election year, is potentially characterized by the highest returns according to the presidential cycle framework. This arises from the incumbent administration's focus on economic stimulation to enhance voter sentiment. The year often features looser fiscal and monetary policies, fostering greater investor optimism. The fourth year, an election year, yields above-average returns, albeit not as high as in the pre-election year. Political decisions are cautious to avoid alienating voters. Financial markets respond to campaigns, polls, and potential changes in administration, generating uncertainty (Hirsch, 1967).

According to the U.S. presidential cycle framework, the returns for each year of a presidential term are characterized by the following equation:

$$R_3 > R_4 > R_2 > R_1,$$

where:

R_4 – returns in year 4,

R_3 – returns in year 3,

R_2 – returns in year 2,

R_1 – returns in year 1.

Prior empirical studies, including Santa-Clara and Valkanov (2003) and Long (2015), confirm higher average returns under Democratic administrations and in the second half of U.S. presidential terms for the S&P 500, DJIA, and NASDAQ indexes (Arnott et al., 2017; Beyer et al., 2008, 2015). The literature also highlights a premium for small-cap stocks under Democratic administrations (Bonaparte, 2017; Bazley, Bonaparte, 2020) and the impact of political uncertainty on volatility (Białkowski et al., 2019). Most of these studies focus on major

U.S. stock indexes, such as the S&P 500, or stock baskets, with limited analysis of the validity of the U.S. presidential cycle framework for sector indexes. This paper addresses this research gap.

This study aims to evaluate the validity of the U.S. presidential cycle framework in predicting returns on U.S. stock indexes, including sector indexes. The analysis is based on data from eighteen U.S. stock indexes, comprising three major indexes and fifteen sector indexes representing key sectors of the U.S. economy.

The following research hypotheses were tested:

- **H₁**: The U.S. presidential cycle framework accurately predicts that returns on U.S. stock indexes are highest in the third year and lowest in the first year of presidential terms.
- **H₂**: The U.S. presidential cycle framework accurately predicts that returns on U.S. stock indexes are higher in the second half (years 3-4) and lower in the first half (years 1-2) of presidential terms.

The research problem aligns with the following economic theories:

- the U.S. presidential cycle framework, on which this paper directly draws to assess its validity (Hirsch, 1967),
- the efficient market hypothesis, suggesting that cyclical return patterns from presidential cycles may reflect deviations from full market efficiency (Fama, 1970),
- behavioral finance, through the analysis of investor sentiment's impact during individual years of presidential terms on stock market dynamics (Kahneman, Tversky, 1979).

The paper comprises six sections. The introduction defines the U.S. presidential cycle framework, identifies a research gap, articulates the research objective and hypotheses, and establishes the paper's foundation in economic theories. The second section reviews the literature on the impact of presidential cycles on the U.S. stock market. The third section outlines the research assumptions and methodology. The fourth section presents the empirical findings. The fifth section offers conclusions and a discussion of these findings. The final, sixth section provides details on the funding sources for this publication.

2. Literature review

The literature confirms the existence of systematic patterns of returns on the American stock market linked to presidential cycles. Empirical research most often indicates: higher rates of return in the second half of the term, maximum rates of return in the pre-election year, variation in rates of return depending on the size of individual companies, and those Democratic administrations are more conducive to higher rates of return on the stock market than Republican presidents.

Based on patterns observed across presidential terms, Arnott et al. (2017) confirm the presence of higher returns in the second half of U.S. presidential terms, while noting the absence of such patterns in international markets. Beyer et al. (2008) report lower returns in the first half and higher returns in the second half of U.S. presidential terms, with the most significant increases occurring in the third year, attributed to monetary policy and prevalent political uncertainty. In a subsequent study, Beyer et al. (2015) demonstrate that returns are influenced by political and monetary factors but are independent of the president's political affiliation. Hensel and Ziemba (1995) and Wong and McAleer (2009) provide statistically significant evidence of cyclical trends, characterized by lower returns in the first half and higher returns in the second half of a president's term. Conversely, Benenson (2020) suggests that these patterns have diminished in recent years.

Santa-Clara and Valkanov (2003) demonstrate that annual excess returns, calculated using value-weighted portfolios, reach 10.69% under Democratic administrations, compared to only 1.69% under Republican administrations. Their earlier study (Santa-Clara, Valkanov, 2000) reports returns 9-16 percentage points higher for Democratic administrations for both value-weighted and equally weighted portfolios. Similar findings are reported by Long (2015), who, accounting for the risk-free rate, finds returns of 10.83% for Democratic administrations and -1.20% for Republican administrations. These differences are statistically significant.

The literature also highlights differences in returns based on firm size. Bonaparte (2017) and Bazley and Bonaparte (2020) demonstrate higher returns under Democratic administrations, as well as superior performance for small-cap firms relative to large-cap firms, and the influence of investor sentiment on stock selection. Białkowski et al. (2019) examined the effects of political uncertainty on market volatility, demonstrating that political factors—such as presidential cycles—increase volatility, particularly during midterm elections.

Literature analysis also indicates variability in the effects of the presidential cycle across historical periods. For example, in the period 1971-1990, characterized by high inflation and oil crises, the cycle effects were less pronounced compared to the period 1991-2010, when economic stabilization favored more pronounced cyclical patterns (Benenson, 2020). Segmenting the data by decade suggests that monetary policy and global economic conditions may modulate the strength of the presidential cycle. However, the lack of a meta-analytic synthesis in the literature makes it difficult to clearly identify these relationships.

Table 1 presents a summary of the literature review on the impact of presidential cycles on the stock market.

Table 1.*Summary of the literature review on the impact of presidential cycles on the stock market*

Author and year	Research methods	Research period	Indices examined	Main conclusions
Santa Clara, Valkanov, 2003	Time series analysis, econometric analysis	1927-1998	US equity market (capitalisation-weighted and balanced portfolios)	- returns are higher during Democratic presidencies, regardless of the economic cycle
Santa Clara, Valkanov, 2000	Quantitative analysis and quantile regressions	1927-1998	US equity market (capitalisation-weighted and balanced portfolios)	- during periods of Democratic rule, risk and returns are higher, particularly for small businesses and balanced portfolios, suggesting that presidential cycles have a significant impact on the stock market
Long, 2015	Regression analysis and comparison of rates of return	1929-2012	CRSP Value Market Index (NYSE, AMEX, NASDAQ)	- stock markets indicate higher returns under Democratic administrations – these differences are not fully explained by macroeconomic factors such as interest rates or economic growth
Arnott et al., 2017	Time series analysis of rates of return	1950-2017, (1988-2017 for France and Germany)	S&P/ASX (Australia), S&P/TSX (Canada), CAC-40 (France), DAX-30 (Germany), FTSE All Shares (United Kingdom)	- no evidence of systematic influence of the ruling party on stock market returns - returns are mainly driven by random events, which weakens the argument that politics has a stable influence on the financial market
Beyer et al., 2008	Time series analysis	1957-2004	New York Stock Exchange (NYSE)	- confirmation of the relationship between stock market returns and presidential cycles - higher returns in the second half of the term, especially in the third year - monetary policy actions correspond to the identified pattern of returns
Beyer et al., 2015	Regression analysis and comparison of average rates of return	1965-2008	S&P 500, small companies, long-term bonds, treasury bills	- in the third year of a presidential term, higher rates of return are observed on the stock market, which may be due to the policies of presidents and the actions of the central bank – this process is particularly evident in the case of small companies
Hensel, Ziemba, 1995	Time series analysis, comparative market research	1928-1993	US large-cap equities, small-cap equities, various bond indices and cash	- regardless of the party to which the president belonged, returns on shares of small and large companies were significantly higher in the second half of the term - returns on shares of small companies were higher under Democratic administrations - returns on shares of large companies were statistically identical regardless of the party to which the president belonged

Cont. table 1.

Wong, McAleer, 2009	Spectral analysis and EGARCH model	1965-2003	S&P 500	- a clear four-year presidential cycle has been detected, characterised by declines in the second year and increases in the third or fourth - the observed cycle is stronger during periods of Republican government
Bonaparte, 2017	Time series analysis	1945-2014	US equity market (capitalisation-weighted and balanced portfolios)	- Democratic presidents have a greater ability to positively influence the stock market - party politics usually have a negative impact on the stock market
Bazley, Bonaparte, 2020	Time series analysis, econometric analysis	No data available	S&P 500	- at the beginning of a term of office, when political uncertainty is at its highest, risk aversion among investors increases, leading to lower returns and higher volatility - as time passes, uncertainty decreases and investors' risk tolerance increases, which improves returns on equities and reduces market volatility
Białkowski, Nahavandi, 2019	Statistical analysis, regression analysis, comparison of historical rates of return	1954-2017	S&P 500	- the occurrence of the election effect, increasing rates of return in the period following elections, particularly in the case of mid-term elections
Benenson, 2020	Statistical analysis, systematisation and generalisation	1887-2020	DJIA	- the presidential cycle affects market returns, especially in the year before an election - in recent years, patterns associated with presidential cycles have been disappearing

Source: own study.

The referenced studies confirm higher returns under Democratic administrations and in the second half of presidential terms, primarily for major indexes (S&P 500, DJIA, NYSE, NASDAQ). However, the literature addresses sector indexes to a limited extent. The absence of comprehensive analyses evaluating the validity of presidential cycles in predicting returns for sector indexes represents a research gap, which this study addresses through empirical validation of the concept across eighteen indexes, including fifteen sector-specific indexes.

3. Methods

The study utilizes data from the inception of the selected indexes (between January 1, 1971, and January 1, 2002) to January 1, 2025. Given the nature of the presidential cycle framework, which compares annual returns, a monthly interval was adopted. The study includes three major U.S. indexes: the S&P 500, Dow Jones, and Nasdaq, alongside sector indexes representing key

economic sectors from the S&P 500, Dow Jones, and Nasdaq sector indexes. Data availability served as the criterion for selecting sector indexes, with the index having the longest data history chosen for each sector. The parameters of the selected indexes are presented in Table 2.

Table 2.

Parameters of indices selected for the study

Index name	Available data	Data used	Industry
NASDAQ Bank	1982-01-05	1983-01-01	Banking
NASDAQ Biotechnology	1993-11-02	1994-01-01	Biotechnology
NASDAQ Industrial	1980-03-18	1981-01-01	Industry
NASDAQ Insurance	1982-01-05	1983-01-01	Insurance
NASDAQ Other Finance	1982-01-05	1983-01-01	Finance - other
NASDAQ Telecommunications	1982-01-05	1983-01-01	Telecommunications
NASDAQ Transportation	1982-01-05	1983-01-01	Transport
S&P 500 Consumer Discretionary	1989-09-12	1990-01-01	Other consumer goods
S&P 500 Consumer Staples	1989-09-12	1990-01-01	Basic goods
S&P 500 Energy	1989-09-12	1990-01-01	Energy resources
S&P 500 Health Care	1989-09-12	1990-01-01	Healthcare
S&P 500 Information Technology	1989-09-12	1990-01-01	Technology
S&P 500 Materials	1989-09-12	1990-01-01	Raw materials
S&P 500 Real Estate	2001-10-10	2002-01-01	Real estate
S&P 500 Utilities	1989-09-12	1990-01-01	Public utilities
S&P 500	1970-02-01	1971-01-01	Main
Dow Jones	1970-02-01	1971-01-01	Main
Nasdaq	1980-04-01	1981-01-01	Main

Source: own study.

The study includes a total of 18 indexes, comprising 3 major indexes (Enderle, 2003) and 15 sector indexes (Zalgiryte et al., 2014), with 7 NASDAQ sector indexes and 8 S&P 500 sector indexes. No Dow Jones sector indexes were selected. When data were available from a date later than January 1 of a given year, data from January 1 of the subsequent year were used in the calculations.

The study was conducted using an analysis of returns. One-way analysis of variance (ANOVA; Lani, 2010; Malska, Twaróg, 2017) was employed to confirm the statistical significance of the relationships examined. All relationships presented are statistically significant, as confirmed by one-way ANOVA.

The research procedure comprised the following steps:

1. Downloading monthly prices for major indexes and sector indexes of the S&P 500, Dow Jones, and Nasdaq from www.investing.com.
2. Selecting target sector indexes based on the longest available time series.
3. Calculating annual returns for each target index per year, followed by analysis and comparison of annual returns (robust approach).
4. Calculating annual returns for each index per year, followed by analysis and comparison of returns across the terms of Democratic and Republican presidents (robust approach).

5. Analyzing and comparing returns from the first and second halves of all presidential terms, as well as those of Democratic and Republican presidents (simplified approach).
6. Conducting statistical tests using one-way analysis of variance (ANOVA) to confirm the statistical significance of the results.
7. Analyzing results and formulating conclusions.

To assess the utility of the presidential cycle framework, the study was conducted using two approaches, designated as robust and simplified. The robust approach assumes that returns in the third year of a presidential term are the highest and those in the first year the lowest among the four years analyzed. The simplified approach assumes that returns in the second half of a presidential term are at least higher than those in the first half.

4. Results

Figure 1 presents a summary of the years of presidential terms with the highest and lowest returns for all presidents.



Figure 1. Years of presidential terms with the highest and lowest returns for all presidents [%].

Source: own study.

Among all analyzed indexes, the third year of a presidential term most frequently exhibited the highest returns (52.8% of cases), consistent with the presidential cycle framework. In contrast, the second year of a presidential term recorded the lowest returns in 76.9% of cases, which is inconsistent with the presidential cycle framework (which predicts the first year as the lowest). For none of the indexes was the first year the lowest or the third year the highest in the majority of cases.

Figure 2 presents a summary of the years of presidential terms with the highest and lowest returns for Democratic presidents [%].

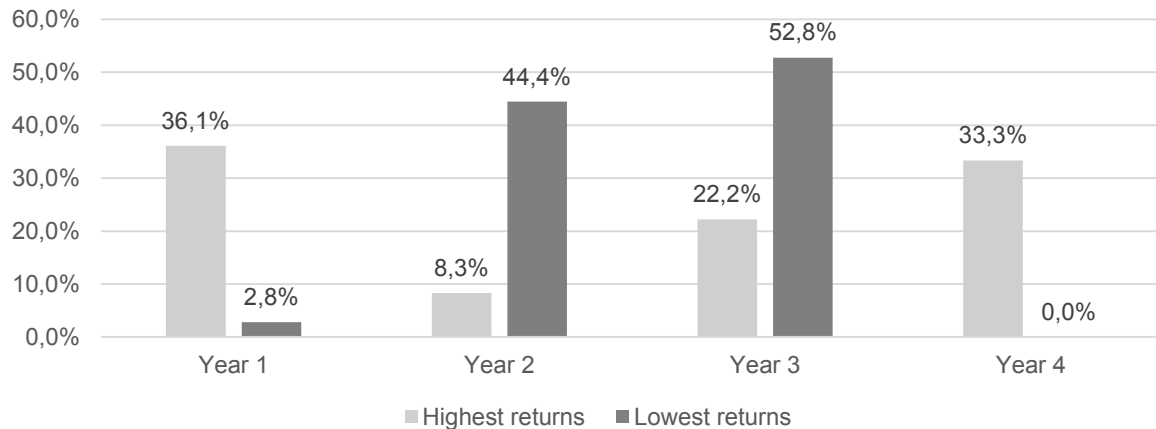


Figure 2. Years of presidential perms with the highest and lowest returns for Democratic presidents [%].

Source: own study.

Among all analyzed indexes, the first year of a Democratic president's term most frequently exhibited the highest returns (36.1% of cases), which is inconsistent with the presidential cycle framework (predicting the third year as the highest). In contrast, the third year recorded the lowest returns in 52.8% of cases, which is inconsistent with the presidential cycle framework (predicting the first year as the lowest). Only the NASDAQ Biotechnology Index exhibited the third year as the highest and the first year as the lowest in most cases.

Figure 3 presents a summary of the years of presidential terms with the highest and lowest returns for Republican presidents [%].

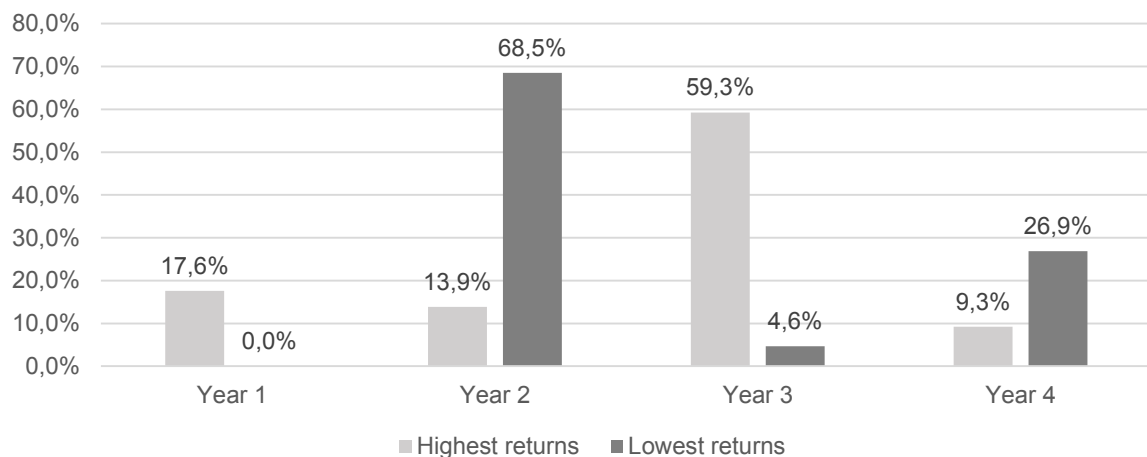


Figure 3. Years of presidential perms with the highest and lowest returns for Republican presidents [%].

Source: own study.

Among all analyzed indexes, the third year of a Republican president's term most frequently exhibited the highest returns (59.3% of cases), consistent with the presidential cycle framework. In contrast, the second year recorded the lowest returns in 68.5% of cases, which is inconsistent with the presidential cycle framework (predicting the first year as the lowest). No index exhibited the first year as the lowest and the third year as the highest in most cases.

The study also compared returns in the first (years 1-2) and second (years 3-4) halves of presidential terms for all presidents, as well as for Democratic and Republican presidents (see Figure 4).

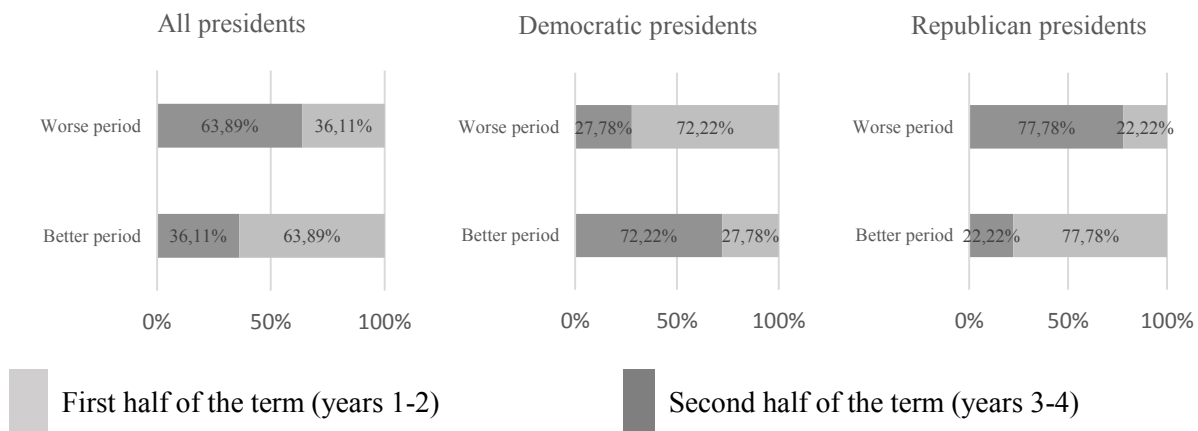


Figure 4. Comparison of returns in the first and second halves of presidential terms for all presidents and by Democratic and Republican presidents [%].

Source: own study.

Among all analyzed indexes, the second half of presidential terms exhibited higher returns than the first half in 63.9% of cases for all presidents. For Democratic presidents, the second half exhibited higher returns than the first in only 27.8% of cases. In contrast, for Republican presidents, the second half exhibited higher returns than the first in 77.8% of cases.

Table 3 summarizes the validity of the presidential cycle framework in the robust approach (years with the highest and lowest returns) and the simplified approach (halves of presidential terms with higher and lower returns).

Table 3.

Summary of the Validity of the Presidential Cycle Framework

Predicting the years with the highest and lowest returns (robust approach):			
Prediction	All presidents	Democrats	Democrats
Year 3 with the highest returns	52,78%	22,22%	59,26%
Year 1 with the lowest returns	0,00%	2,78%	0,00%
Prediction of the Halves of Presidential Terms with Higher and Lower Returns (Simplified Approach):			
Lower returns in the first half and higher returns in the second half of presidential terms	63,89%	27,78%	77,78%

Source: own study.

In the robust approach, the presidential cycle framework exhibited higher validity in predicting the highest returns in the third year of presidential terms (52.78%), particularly for Republican presidents (59.26%). In the simplified approach, the validity was higher in all cases than in the robust approach.

5. Discussion

The study validated the presidential cycle framework in the U.S. The results indicate partial validity, particularly in the simplified approach, where the second half of presidential terms (years 3-4) exhibits higher average returns than the first half (years 1-2) in 63.89% of cases for all presidents. This aligns with findings in Arnott et al. (2017), Beyer et al. (2008, 2015), Hensel and Ziemba (1995), and Wong and McAleer (2009), which confirm higher average returns in the second half of presidential terms and the highest returns in the third year. These studies, primarily based on major U.S. stock indexes, demonstrate statistically significant cyclicity, where the first half of presidential terms is marked by political uncertainty and restrictive monetary policy, leading to lower returns, while higher returns in the second half result primarily from economic stimulus.

However, in the robust approach—assuming the highest returns in the third year and the lowest in the first—the presidential cycle framework exhibited low validity, with returns simultaneously highest in the third year and lowest in the first in only 1.85% of cases. These results partially contrast with prior research, where Benenson (2020) documented a significant increase in returns in the pre-election year for the DJIA index from 1887-2020, and Beyer et al. (2008) indicated higher returns in later years of presidential terms. This discrepancy may arise from expanding the analysis to sector indexes, which have rarely been examined previously.

The results also highlight variation depending on the president's political affiliation. In the simplified approach, the presidential cycle framework exhibited a validity of 77.78% for Republican presidents but only 27.78% for Democratic presidents, indicating that presidential cycles more reliably predict higher returns in the second half of presidential terms (years 3-4) for Republican administrations. These findings partially diverge from prior research, where Santa-Clara and Valkanov (2000, 2003) and Long (2015) reported higher returns under Democratic administrations. This discrepancy may arise from including U.S. sector indexes, where the highest returns for Democratic presidents often occurred in the first year (36.1% of cases), potentially due to sectoral responses to initial reforms in industries such as technology or consumer goods. Additionally, Białkowski et al. (2019) highlight the role of political uncertainty in driving volatility, which may obscure cyclical patterns in the analyzed sectors under Democratic administrations.

The study results also show partial consistency with the literature, but differences in cycle effects across decades suggest that historical factors, such as changes in monetary policy or economic crises, may impact the validity of the presidential cycle model. For example, in periods after 2008, cycle effects were less pronounced, which may be related to the greater influence of global financial markets (Białkowski et al., 2019).

The findings may be valuable for individual investors, particularly during the second half of Republican presidents' terms (years 3-4), where the presidential cycle framework demonstrates the highest validity (77.78%). However, the low validity in the robust approach—where the highest returns are expected in the third year and the lowest in the first (1.85% of cases)—suggests that Hirsch's (1967) theory is not a universal predictive tool, especially for U.S. sector indexes, thus addressing a research gap identified in the literature. Future studies could incorporate additional factors in forecasting returns, such as central bank monetary policy or investor sentiment, as partially explored by Beyer et al. (2015) and Bazley and Bonaparte (2020), among others. This could better elucidate the causes of sectoral deviations within the presidential cycle framework. Future research could also employ a sector-specific fixed effects model to further explore cross-sector variability, which could strengthen conclusions about differences in the response of individual sectors to presidential cycles.

6. Conclusions

The research enabled the following conclusions (C₁–C₃ refer to the robust approach, C₄–C₅ to the simplified approach):

- C₁: The presidential cycle framework exhibits limited validity in forecasting returns for individual years. Only 3/54 cases (1.85%) showed the highest returns in the third year and the lowest in the first year of presidential terms.
- C₂: The presidential cycle framework is more valid in predicting the third year of presidential terms as having the highest returns (validity: 52.78%) but entirely invalid in predicting the first year as having the lowest returns (validity: 0.00%).
- C₃: Among all analyzed indexes, the validity of predicting the third year of a Republican president's term as having the highest returns is the highest (validity: 59.26%).
- C₄: The presidential cycle framework reliably predicts that the first half of presidential terms for all presidents exhibits lower returns than the second half (validity: 63.89%).
- C₅: The presidential cycle framework is more valid in predicting that the first half of a Republican president's term exhibits lower returns than the second half (validity: 77.78%) compared to a Democratic president's term (validity: 27.78%).

Based on the analyses conducted, hypothesis **H₁** is accepted in the part stating that the presidential cycle framework enables accurate prediction of the highest returns on U.S. stock indexes in the third year of presidential terms for Republican presidents and rejected in the part stating that the presidential cycle framework enables accurate prediction of the lowest returns on U.S. stock indexes in the first year of presidential terms.

Hypothesis **H₂**, stating that the presidential cycle framework enables accurate prediction of higher returns on U.S. stock indexes in the second half (years 3-4) and lower returns in the first half (years 1-2) of presidential terms, is accepted, except for the terms of Democratic presidents (validity: 27.78%).

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Resources

1. Arnott, R.D., Cornell, B., Kalesnik, V. (2017). *Presidential Politics and Stock Returns*. Available at SSRN. Retrieved from: <http://www.ssrn.com/abstract=2960458>, 14.07.2025.
2. Bazley, W.J., Bonaparte, Y. (2020). *The Presidential Life Cycle and the Stock Market*. Available at SSRN. Retrieved from: <http://www.ssrn.com>, 14.07.2025.
3. Benenson, O. (2020). Specific features of using the presidential election cycle for forecasting the dominant trend on the US stock market. *European Journal of Management Issues*, pp. 127-134, doi: 10.15421/192012
4. Beyer, S.B., Garcia-Feijoo, L., Jensen, G.R., Johnson, R.R. (2015). What to expect when you're electing. *Managerial Finance*, Vol. 41, Iss. 10, pp. 1032-1045, doi: 10.1108/MF-03-2015-0088
5. Beyer, S.B., Jensen, G.R., Johnson, R.R. (2008). The presidential term. *Journal of Portfolio Management*, Vol. 34, Iss. 2, p. 135, doi: 10.3905/jpm.2008.701624
6. Białkowski, J., Nahavandi, A. (2019). Midterm elections' stock market surge: An unintentional gift from US politicians. *The Journal of Wealth Management*, Vol. 21, pp. 76-84, doi: 10.3905/jwm.2019.21.4.076
7. Bonaparte, Y. (2017). *US Presidents and Stock Market Performance: The Good, the Bad and the Useless*. Available at SSRN. Retrieved from: <http://www.ssrn.com/abstract=3034312>, 14.07.2025

8. Enderle, F.J., Pope, B., Siegel, L.B. (2003). Broad-Capitalization Indexes of the US Equity Market. *Journal of Investing*, Vol. 12, Iss. 1, pp. 11-22, doi: 10.3905/joi.2003.319496
9. Fama, E.F. (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *Journal of Finance*, Vol. 25, Iss. 2, pp. 383-417, doi: 10.2307/2325486
10. Hensel, C.R., Ziemba, W.T. (1995). United States investment returns during Democratic and Republican administrations, 1928-1993. *Financial Analysts Journal*, Vol. 51, pp. 61-69, doi: 10.2469/faj.v51.n2.1882
11. Hirsch, Y. (1967). *Stock Trader's Almanac*. Old Tappan, NJ: Hirsch Organization.
12. Investing.com. Retrieved from: <http://www.investing.com>, 14.07.2025.
13. Kahneman, D., Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, Vol. 47, Iss. 2, pp. 263-291, doi: 10.2307/1914185
14. Lani, J. (2010). *ANOVA (Analysis of Variance). Statistics Solutions*. Retrieved from: <http://www.statisticssolutions.com>, 14.07.2025.
15. Long, M.S. (2015). *Why Market Returns Favor Democrats in the White House?* Available at SSRN. Retrieved from: <http://www.ssrn.com/abstract=2622236>, 14.07.2025.
16. Malska, W., Twaróg, B. (2017). Testy Anova jako narzędzie wspomagające weryfikację hipotez statystycznych. *Acta Scientifica Academiae Ostroviensis. Sectio A, Nauki Humanistyczne, Społeczne i Techniczne*, Vol. 10, Iss. 2, pp. 148-159, doi: 10.36021/asao.2017.1002.10
17. Nguyen, A., Roberge, M. (2008). Timing the stock market with a joint examination of the presidential U.S. election cycle and the yield curve. *Studies in Economics and Finance*, Vol. 25, Iss. 3, pp. 152-164, doi: 10.1108/10867370810894694
18. Santa-Clara, P., Valkanov, R. (2000). *Political Cycles and the Stock Market*. Available at SSRN. Retrieved from: <http://www.ssrn.com/abstract=244728>, 14.07.2025.
19. Santa-Clara, P., Valkanov, R. (2003). Political Cycles and the Stock Market. *Journal of Finance*, Vol. 58, Iss. 5, pp. 1841-1872, doi: 10.1111/1540-6261.00590
20. Wong, W.-K., McAleer, M. (2009). Mapping the Presidential Election Cycle in US stock markets. *Mathematics and Computers in Simulation*, Vol. 79, pp. 3267-3277, doi: 10.1016/j.matcom.2009.05.007
21. Zalgirytė, L., Guzavicius, A., Tamulis, V. (2014). Stock market and economic growth in the US France: Evidence from stock market sector indices. *Inžinerinė ekonomika*, Vol. 25, Iss. 1, pp. 47-53, doi: 10.5755/j01.ee.25.1.3206

COST EFFICIENCY AND SHAREHOLDER STRUCTURE IN CENTRAL EUROPEAN BANKS OVER THE PAST TWO DECADES

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Purpose: Cost efficiency constitutes an important part of management processes, influencing many areas of bank activity. The level of cost in relation to income might affect bank profitability, quality of customer services, credit risk problems or bank probability of failure. Many empirical analyses have been conducted to verify how efficiently bank operates over the last years. As shareholders appear to play a crucial role in bank cost practices, some research addresses the ownership structure and its association with bank cost efficiency. This article aims to review the literature on cost efficiency and shareholder structure. Specifically, it seeks to organise and summarise studies that examine the importance of bank owners in cost management. This approach enables us to specify the research problem, which is to examine cost efficiency and shareholder structure in the relatively understudied Central European region over a long-term period of more than two decades.

Design/methodology/approach: To achieve the objective of this paper, relevant literature has been reviewed and standard methods of descriptive statistics have been applied. The analysed literature primarily consists of empirical studies, with particular emphasis on cost management practices and bank shareholder structure. In terms of quantitative aspects of this research, it has been studied how cost efficiency fluctuates in the long-term horizon of the past two decades for Central European banks depending on their ownership type.

Findings: The literature review highlights the difference in cost efficiency between banks depending on their shareholder structure. It also outlines theoretical aspects of those differences. Empirical research findings on cost efficiency and ownership type remain inconclusive, leaving the cost-shareholder relationship unclear. Using hand-collected data for 11 Central European countries we find that shareholder structure and cost efficiency seem to be closely related. Foreign banks consistently exhibit higher efficiency than their domestic private counterparts, while state-owned banks display persistent inefficiencies.

Originality/value: This paper provides a comprehensive overview of cost efficiency in banks in terms of their shareholder structure, incorporating both theoretical and empirical perspectives. By summarising empirical studies on this topic, it organises key findings related to the research area. It also provides evidence on cost efficiency and shareholder structure for little studied Central European banks. Therefore, it serves as a valuable reference for bank owners as well as policymakers and regulators in terms of long-term cost management.

Keywords: corporate governance, cost efficiency, shareholder structure.

Category of the paper: Research paper.

1. Introduction

Over the last years, there have been two increasingly explored strands in banking empirical research. One strand investigates cost efficiency, whereas a second relates to shareholder structure in banks. Authors provide theoretical and empirical evidence on many areas related to cost management decisions, analysing both bank-level and macroeconomic determinants of bank efficiency. From the perspective of bank functioning, cost efficiency has been identified as a significant indicator of future non-performing loans and problem banks (Berger, de Young, 1997). In contrast, for a sample of European banks, inefficient financial institutions appear to hold more capital and take on less risk (Altunbas et al., 2007). Additionally, it has been observed that the higher level of costs reduces bank profitability (Davis et al., 2021; Dietrich, Wanzenried, 2014). Other studies relate to banking sector environment. Authors argue that efficiency is recognized as a significant determinant of competitive behaviour among banks. The lack of competition between banks enables inefficient banks to persist and therefore leads to instability of the banking sector as a whole (Moussawi, Mansour, 2022). Furthermore, Fries and Taci (2005) show that banking sector reforms and liberalization in the transition countries are significantly associated with a decrease in bank cost efficiency.

The next area of analysis addresses shareholder structure in banks. It has been a widely studied topic in banking literature during recent years. Authors very often examine how shareholder structure affects bank profitability (Claessens, Van Horen, 2012; Iannotta et al., 2007; La Porta et al., 2002), the likelihood of failure (Angkinand, Wihlborg, 2010; Dong et al., 2014; Lassoued et al., 2016; Yeyati, Micco, 2007) and loan growth (Cull, Peria, 2013; De Haas, Van Lelyveld, 2010; Fungáčová et al., 2013). There is also broad empirical literature studying the link between foreign-owned banks and credit risk (Chen et al., 2017; Dong et al., 2014; Shaban, James, 2018; Škrabić Perić et al., 2018) as well as relationship between state ownership and credit risk (Berger et al., 2005; Cornett et al., 2010; De Nicolò, Loukoianova, 2007; Zhu, Yang, 2016).

A separate area of research is devoted to bank ownership and its association with cost efficiency. The major shareholder is supposed to affect how efficiently bank operates. The existing literature provides theoretical and empirical insights into differences between foreign and state-owned banks, as they often pursue distinct objectives and are oriented towards different goals (Berger et al., 2005). There are some studies showing that shareholder structure and cost efficiency seem to be related (Berger et al., 2005; Fries, Taci, 2005; Lin et al., 2016; Moussawi, Mansour, 2022). Not many of them consider the cost to income ratio as a proxy for efficiency (Boubakri et al., 2020; Khan et al., 2020; Shaban, James, 2018). Therefore, this study links both of these areas of interests, namely bank ownership and cost management.

We contribute to the existing research in several important ways. First, we analyse less commonly studied Central European banks using hand-collected dataset on shareholder structure. Second, we account for long-time period of over two past decades. This enables us to observe trends and identify emerging patterns in a changing macroeconomic environment. Third, we focus on cost to income ratio being often neglected in the shareholder structure type of studies.

2. A literature review on cost efficiency and shareholder structure

There are some theories showing that shareholder structure may shape both the behavioural and institutional mechanisms underlying cost management in banks. Drawing on agency theory, property rights theory and the resource-based view, ownership configuration influences managerial incentives, decision-making autonomy and resource allocation efficiency, which in turn may determine bank cost behaviour. For instance, foreign banks often operate under stricter governance and accountability frameworks, which reduces agency costs and develops cost monitoring practices. Conversely, state-owned banks are being politically connected and subjected to sometimes conflicting goals. This dilutes profit incentives and leads to persistent inefficiencies. At the same time, domestic private banks, while more focused on profits, may still face structural constraints such as limited access to advanced technologies or weaker regulatory oversight, also affecting cost outcomes.

These theoretical linkages highlight that shareholder structure serves as both a governance mechanism and a determinant of strategic behaviour affecting cost structures. From a conceptual standpoint, ownership influences efficiency through three interrelated channels, which are: managerial discipline, access to organizational capabilities and technological resources, exposure to institutional and regulatory constraints. We assume that these pathways provide a framework for interpreting the observed empirical findings in cost efficiency across different bank types.

Empirical studies on shareholder structure and efficiency typically examine differences between foreign banks and domestic banks as well as state-owned banks and private banks (Berger et al., 2005). Banks with foreign ownership may benefit from stronger access to capital markets, advanced technologies and the ability to serve multinational clients. However, these banks face disadvantages such as managing at a distance, adapting to multiple regulatory environments and limited access to local information. Empirical evidence from developed countries generally finds foreign banks less efficient than domestic banks, except in some cases for U.S. banks abroad (DeYoung, Nolle, 1996; Berger et al., 2000). Conversely, in developing countries, foreign banks operate often more efficient than domestic banks (Claessens et al., 2001; Bonin et al., 2005). According to authors, that observed efficiency may reflect parent-

bank support, discretionary cost and revenue booking or tax considerations (Berger et al., 2005). Further research suggests that foreign entry and following reductions in restrictions enhance competition in developing banking systems (Claessens, Laeven, 2004).

Studies of the effects of state ownership on efficiency emphasise different objectives of state-owned banks, which are often aimed at directed lending or pursuing objectives such as developing specific industries and regions. The loan portfolio of state-owned banks is not designed to maximize profits and might be allocated for political advantage (Sapienza, 2004). In addition, these banks generally operate with government subsidies (Berger et al., 2005).

In banking, existing research focusing on ownership structure and cost efficiency explores the relationship between shareholder type and cost management (Moussawi, Mansour, 2022), privatization and cost efficiency rank (Berger et al., 2005), a link between changes in bank ownership on cost efficiency (Lin et al., 2016), banking reforms in sector with different ownership structure (Fries, Taci, 2005) or entry of foreign banks and its association with cost efficiency (Poghosyan, Poghosyan, 2010; Havrylchyk, 2006). These studies provide valuable insight into shareholder – bank costs link, but do not use cost to income ratio as a proxy for cost efficiency.

The authors analyse the association between competition, cost efficiency, and bank stability, considering the ownership structure of banks. As competition is positively related to both the cost efficiency and stability of the banks, the shareholder type affects relationships between competition and banking stability. Private banks lead to a positive, while public or foreign banks to a negative relationship between competition and banking stability (Moussawi, Mansour, 2022).

A study on bank privatization shows that state-owned banks undergoing this process had particularly poor performance beforehand measured, among others, by cost efficiency rank. Additionally, researchers confirm that banks with state ownership on average exhibit poorer long-term performance than domestically banks or foreign banks. The results also suggest that foreign banks may behave less efficiently than domestic banks (Berger et al., 2005). Lin et al. (2016) using a stochastic frontier approach find that foreign ownership enhances cost efficiency, particularly in financially liberalized countries. After the financial crisis, government ownership improves bank costs managing, while domestic private shareholder is linked to lower efficiency in countries with higher financial freedom. Further, Fries and Taci (2005) analysing banks in Eastern European countries show that a high share of foreign-owned banks in banking systems improves cost efficiency. Early stages of banking reforms are associated with cost reductions, while costs increase at more advanced stages. Private banks exhibit higher efficiency than state-owned banks, with foreign banks being most efficient and domestically owned ones the least. Finally, it has been found that the mode of foreign entry matters. Foreign Greenfield banks exhibit superior cost efficiency in comparison with foreign and domestic banks (Poghosyan, Poghosyan, 2010; Havrylchyk, 2006).

A distinct avenue of research investigates cost efficiency measured by cost to income ratio and shareholder structure (Boubakri et al., 2020; Khan et al., 2020; Shaban, James, 2018). Foreign banks have been recognised to outperform both private banks and state-owned banks in terms of efficiency confirmed by lower cost to income ratio. This association shows that foreign banks are more effective in controlling overhead costs relative to income. At the same time, banks with state ownership display cost inefficiency. These results diverge when examining the total costs to total revenues. Authors provide evidence on relatively lower efficiency of foreign banks compared to private banks and better managing of costs by state-owned banks than private banks (Shaban, James, 2018). In contrast, Khan et al. (2020) find that state ownership exhibits slightly lower cost inefficiency than private banks, with no significant evidence regarding foreign banks. Similarly, Boubakri et al. (2020) report that state ownership in newly privatized banks negatively affects efficiency. These findings suggest that the relationship between shareholder structure and bank efficiency varies, with foreign banks presenting mixed results in cost management and state ownership often associated with cost inefficiencies.

Topics of cost efficiency measured by the cost to income ratio and shareholder type in Central European banks considered collectively have not gathered a significant attention by academic researchers. Authors study banks operating in 16 countries from the Middle East and North Africa (MENA) region (Moussawi, Mansour, 2022) or in the worldwide context from 45 countries (Boubakri et al., 2020). Others provide single-country analysis, for countries such as Argentina (Berger et al., 2005) or Indonesia (Shaban, James, 2018). The research sample also includes Islamic and conventional banks (Khan et al., 2020). The time horizon in existing bank efficiency literature is quite short and includes years of 2005-2012 (Shaban, James, 2018), 2010-2017 (Khan et al., 2020) or finishes relatively earlier even if covers long-time period, such as for years 1999-2018 (Moussawi, Mansour, 2022) or 2000-2017 (Boubakri et al., 2020). Thus, we employ a cross-country dataset of 11 Central European countries for the period 2002-2022 to verify trends in cost to income ratio and accounting for shareholder structure.

3. Data and methodology

Our sample consists of banks from 11 Central European countries, all of which are members of European Union*. We have used several blocks of data. The financial data, namely bank cost efficiency reflected in the cost to income (C/I) ratio, is taken from the Bureau van Dijk's Bankscope (2002-2014) and Orbis (2015-2022) databases. The shareholder structure data is hand-collected using annual reports or other bank sources. We analyse primary shareholders of

* Countries in our sample are Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

banks distinguishing between domestic private banks, state-owned and foreign banks. We use a long time period (2002-2022), accounting for periods of growth and crises. Our initial sample includes 322 banks with the resulting final sample of 4111 bank-year observations restricted by C/I ratio availability. Table 1 presents our sample, showing the number of bank-year observations analysed in each country and table 2 provides an overview of the number of bank-year observations across years.

Table 1.

Number of observations by countries

Country	Number of observations
Bulgaria	410
Croatia	580
Czech Republic	403
Estonia	143
Hungary	491
Latvia	333
Lithuania	164
Poland	579
Romania	441
Slovakia	266
Slovenia	301
Total	4111

Source: own elaboration.

Table 1 shows the distribution of the 4111 observations across the 11 Central European countries under study. The highest number of observations is visible in Croatia (580) and Poland (579), which together account for a significant proportion of the sample. These are followed by countries that also contributes notably to the dataset, namely Hungary (491), Romania (441), Bulgaria (410) and the Czech Republic (403). Latvia (333), Slovenia (301) and Slovakia (266) exhibit relatively lower number of observations. The smallest contribution to the sample is made by banking sectors in Lithuania (164) and Estonia (143). To sum up, the data structure shows that the sample is not evenly distributed across countries. The majority of observations is concentrated in Croatia, Poland, Hungary and Romania, which jointly comprise more than half of the dataset.

Table 2.

Number of observations by years

Year	Number of observations
2002	149
2003	154
2004	181
2005	210
2006	204
2007	200
2008	211
2009	225
2010	226
2011	227

Cont. table 2.

2012	221
2013	222
2014	225
2015	215
2016	205
2017	198
2018	182
2019	173
2020	171
2021	165
2022	147
Total	4111

Source: own elaboration.

Table 2 illustrates how the dataset fluctuates across the period 2002-2022. The number of observations increases gradually from 149 in 2002 to a peak of 227 in 2011. After 2011, the figures remain relatively stable, varying between 198 and 225 observations annually until 2016. A downward trend begins in 2017 when the number of observations starts decreasing from 198 in 2017 to 147 in 2022 reaching the lowest point in the sample period. The data distribution suggests a concentration of observations in the years between 2009 and 2015, followed by a gradual decline in the most recent years.

In our analysis of bank cost efficiency, we use the cost to income (C/I) ratio. In line with the banking empirical literature, this is a common indicator reflecting cost management practices (Boubakri et al., 2020; Goddard et al., 2013; Pasiouras, Kosmidou, 2007; Shaban, James, 2018; Trujillo-Ponce, 2013). It reflects the efficiency of the bank management regarding expenses relative to the revenues it generates. Higher ratios indicate lower efficiency (Pasiouras, Kosmidou, 2007). Consequently, C/I ratio allows to assess how efficiently bank operates.

We use standard methods of descriptive statistics to illustrate the cost management behaviour of Central European banks during the last decades. This allows us to introduce a complex view on cost efficiency trends in the long-term. We have winsorised the financial data using 1/99 percentiles to minimise the effect of outliers. Table 3 provides summary statistics for the cost to income ratio, based on 4111 bank-year observations from banks in 11 Central European countries during the period 2002-2022.

Table 3.

Summary statistics of the cost to income ratio

Variable	Mean	Standard deviation	Min	Max
Cost to income ratio	71.82	37.46	22.15	290.75

Source: own elaboration.

Table 3 represents that a mean value of the C/I ratio equals 71.82% with a standard deviation of 37.46%. This indicates substantial variation in terms of cost efficiency across the sample. The minimum observed value is 22.15%, while the maximum reaches 290.75% even after procedure of winsorizing applied. These variations might suggest notable heterogeneity in cost

efficiency across banks. While the average C/I ratio suggests a moderate level of cost efficiency, the wide range shows that the research sample includes both highly efficient banks and relatively inefficient banks. In turn, this may reflect differences in country-specific factors.

To verify whether there are significant variations in the cost efficiency between countries, we present the average values of C/I ratio for each of analysed country for the years 2002-2022 (Figure 1).

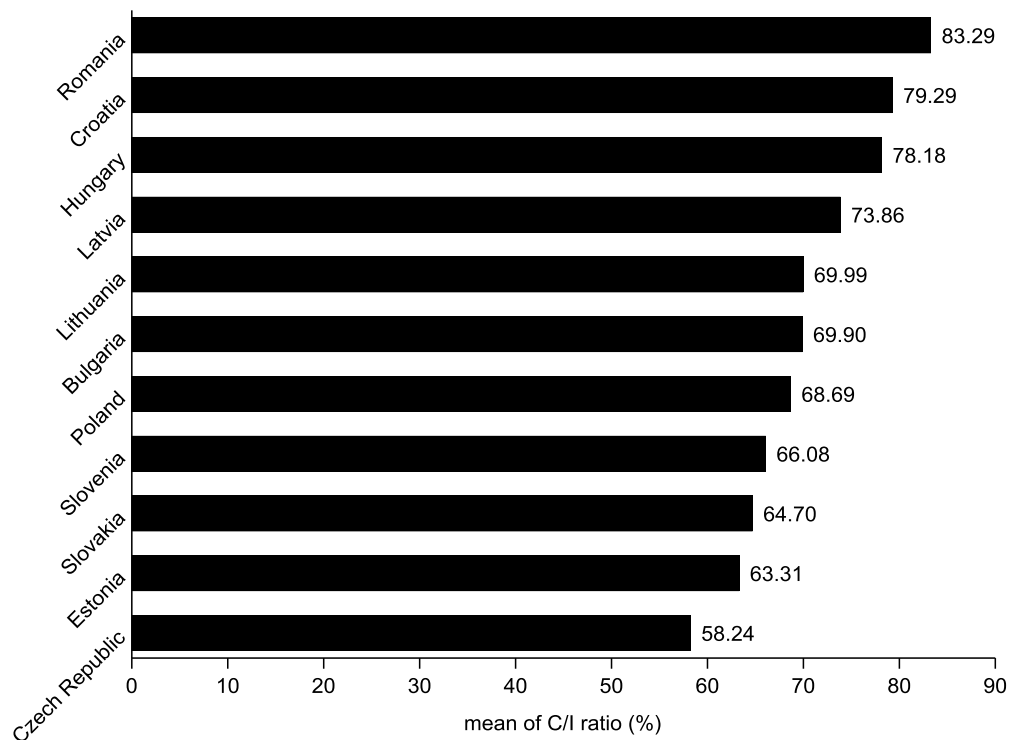


Figure 1. The average cost to income by countries.

Source: own elaboration.

Figure 1 illustrates significant differences in cost efficiency among countries. Romanian banks have the highest average C/I ratio at 83.29%, followed by Croatian banks (79.29%) and Hungarian ones (78.18%). This indicates relatively low cost efficiency in these banking sectors. In contrast, the Czech Republic shows the lowest average C/I ratio at 58.24%, suggesting the highest level of cost efficiency in analysed countries. Other countries, such as Latvia (73.86%), Lithuania (69.99%), Bulgaria (69.90%), Poland (68.69%), Slovenia (66.08%), Slovakia (64.70%) and Estonia (63.31%), are placed on intermediate positions. As noted, figure 1 highlights significant heterogeneity in cost management practices across banks in the region, with a clear distinction around 25 percentage points (Romania 83.29% versus Czech Republic 58.24%) between the most and least cost-efficient banking sectors.

Taking into account that our database covers long time period over the past two decades, we check how cost efficiency has been fluctuating in banks before and after periods of crises or economic growth. Figure 2 illustrates the average values of C/I ratio during the period 2002-2022 jointly for all analysed countries.

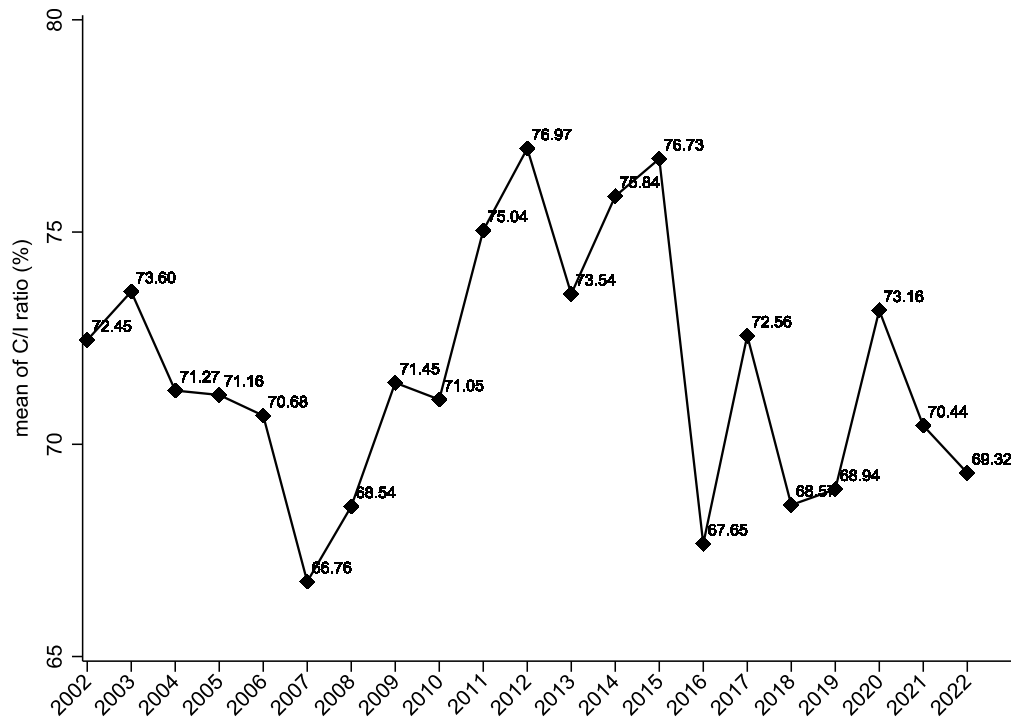


Figure 2. The average cost to income by years.

Source: own elaboration.

Figure 2 shows that the average level of efficiency in given years exhibits substantial fluctuations between 2002 and 2022. The C/I ratio starts at 72.45% in 2002, peaks at 73.60% in 2003 and then gradually decreases to 70.68% in 2006, followed by a sharp drop to 68.76% in 2007. After this event, cost efficiency begins to steadily increase and reaches the highest point of 76.97% in 2012, fluctuating relatively high until 2015 (76.73%). However, a significant decline occurs in 2016, when the C/I ratio falls to the value of 67.05%. In the subsequent years, the C/I ratio shows a short-term volatility, rising to 72.56% in 2017, decreasing again in 2018-2019 (around 68%) and then growing up to 73.16% in 2020 before declining to 69.32% in 2022. These results highlight fluctuations in the average C/I ratio. There are periods of growth and abrupt decreases, what may suggest the influence of external factors rather than a steady trend.

As we observe notable variations in cost efficiency across countries and years, the next part of the analysis accounts for shareholder structure, which may affect cost management practices between banks. Owners may pursue different objectives and exert pressure on statutory bodies to align decisions with their preferred direction, thereby influencing how efficiently banks operate. Regarding ownership type, we classify banks in our sample into three categories: foreign banks, state-owned banks and domestic private banks. We analyse primary shareholders using hand-collected information from annual reports or other bank documents. The definitions of the respective shareholder types are presented in table 4.

Table 4.*Definitions of variables related to shareholder types*

Variable	Definition
Foreign bank	Binary variable equals 1 when the main shareholder is a bank domiciled abroad and has minimum 40% share in capital, and 0 otherwise.
State-owned bank	Binary variable equals 1 when the main shareholder is the state (both central and local governments, state agencies and state-owned enterprises) and has minimum 10% share in capital, and 0 otherwise.
Domestic private bank	Binary variable equals 1 when the main shareholder is neither a bank domiciled abroad nor the state.

Source: own elaboration.

Following the shareholder types presented in Table 4, we check how the cost efficiency fluctuates in banks determined by their ownership structure. We present obtained findings in the section Results below.

4. Results and policy implications

At the beginning of the analysis, we verify whether there exist any differences in average cost efficiency across ownership groups. We present the breakdown of our sample by shareholder types and report the mean level of cost to income ratio for the entire period 2002-2022, distinguishing between foreign banks, state-owned banks and domestic private banks (Table 5). We consider only those bank-year observations for which we have complete data available on both, cost efficiency and shareholder structure.

Table 5.*Average cost to income ratio by shareholder type*

Shareholder type		Mean of C/I ratio (%)	Number of observations
Foreign bank	Yes	67.45	1960
	No	74.16	1622
	Total	70.49	3582
State-owned bank	Yes	70.65	256
	No	70.33	3326
	Total	70.49	3582
Domestic private bank	Yes	74.82	1366
	No	67.82	2216
	Total	70.49	3582

Source: own elaboration.

Table 5 shows that the overall average C/I ratio in the sample amounts to 70.49%. A comparison between foreign and non-foreign banks provides evidence on higher cost efficiency among foreign banks (67.45%) than banks without major foreign shareholder (74.16%). State ownership does not appear to be associated with significant differences in efficiency, as state-owned banks exhibit an average C/I ratio of 70.65%, similarly to the 70.33% recorded for non-state-owned counterparts. A more visible divergence emerges for domestic

private banks. This group shows a higher average C/I ratio of 74.82% in comparison with 67.82% for banks without major domestic private shareholder, suggesting that privately owned domestic banks operate with comparatively weaker cost efficiency than their peers. Summing up, these descriptive results by ownership type highlight shareholder structure as a potential determinant of cost efficiency between banks.

Considering the differences observed between ownership types and cost efficiency, we provide a more detailed breakdown of the average cost to income ratio for foreign banks, state-owned banks and domestic private banks for each year separately (Table 6). In addition, we account for the number of bank-year observations in order to capture potential changes that may influence the composition of our data.

To accompany this dataset, we present trends and comparisons over time regarding cost efficiency for all shareholder types (figure 3). We believe this provides more comprehensive view on yearly changes in cost to income ratio grouping by ownership structure.

Table 6.

Average cost to income ratio by shareholder type and year

Year	Shareholder structure					
	Foreign banks		State-owned banks		Domestic private banks	
	Mean of C/I ratio (%)	Number of observations	Mean of C/I ratio (%)	Number of observations	Mean of C/I ratio (%)	Number of observations
2002	71.38	44	76.86	9	72.26	40
2003	67.35	50	74.95	8	76.52	43
2004	70.43	70	66.55	11	71.36	49
2005	68.08	85	66.15	12	68.13	57
2006	66.17	94	67.30	12	72.82	53
2007	66.57	103	61.09	11	61.42	49
2008	63.35	110	69.88	10	68.80	56
2009	67.73	120	73.30	12	75.98	61
2010	64.22	117	97.46	12	72.21	70
2011	70.22	118	67.06	12	79.45	76
2012	73.38	119	68.19	12	79.07	78
2013	70.68	118	84.48	16	74.51	76
2014	70.21	114	84.44	18	78.91	79
2015	71.81	111	65.88	16	80.47	77
2016	63.71	104	65.88	14	71.13	78
2017	67.61	98	63.21	14	79.70	77
2018	64.16	90	65.92	12	73.16	72
2019	63.04	83	60.18	13	76.38	69
2020	68.05	77	72.14	11	77.84	72
2021	66.85	73	64.84	11	75.13	71
2022	57.78	62	61.52	10	75.74	63
Total	67.45	1960	70.65	256	67.29	1366

Source: own elaboration.

The long-term analysis of C/I ratio from 2002 to 2022 reveals marked disparities in cost efficiency across different bank ownership structures. Foreign banks consistently maintain the highest efficiency with a mean C/I ratio of 67.45% across 1,960 observations. Those banks show relatively stable ratios, ranging between 63% and 73%, with a notable improvement to 57.78% in 2022. The superior efficiency of foreign banks may suggest the influence of more

rigorous governance frameworks and advanced operational practices, stable cost managing as well as resilience to external shocks under varying market conditions. Conversely, state-owned banks, with only 256 observations, demonstrate both higher average ratios (70.65%) and considerable fluctuations in cost management, observed in the dramatic spike to 97.46% in 2010. This may reflect both, the institutional inefficiencies as well as macroeconomic stress during the global financial crisis. Domestic private banks (on average 67.29% across 1366 observations) show a sustained upward trend in C/I ratio from 2010, peaking at 80.47% in 2015, indicating persistent cost pressures.

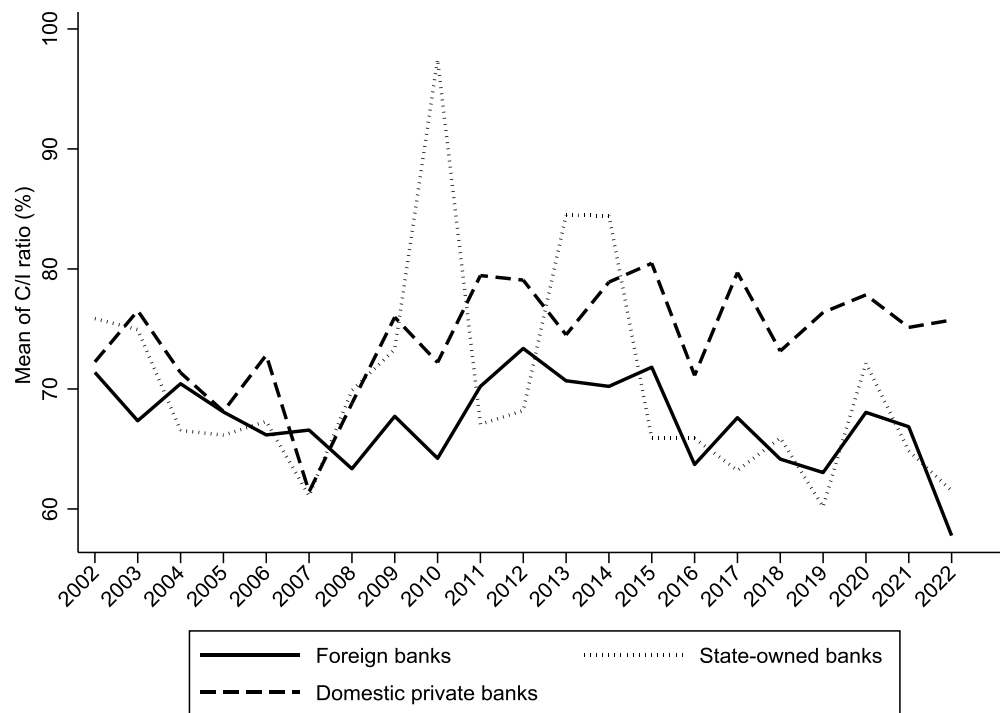


Figure 3. The average cost to income by shareholder types.

Source: own elaboration.

These temporal patterns regarding cost efficiency suggest that ownership structure significantly mediates efficiency outcomes but does not fully account for cost management policies. Thus, the observed differences in cost efficiency have important policy implications. Foreign banks may benefit from stronger governance, cost-income monitoring and operational practices, whereas state-owned and domestic private banks are potentially more susceptible to policy-driven and market-induced inefficiencies. This suggests that state-owned banks and domestic private banks may require targeted interventions. State-owned banks, in particular, would benefit from comprehensive reforms that focus on optimizing cost management processes, administrative structures and enhancing internal accountability mechanisms. In the similar vein, domestic private banks could improve efficiency through the adoption of advanced cost analysis tools and programs aimed at strengthening managerial expertise, as well as performance-based evaluation systems.

In addition, regulatory frameworks and external economic conditions seem to interact with cost efficiency. Consequently, regulators may consider implementing efficiency-focused benchmarking and incentive structures to align institutional efficiency with sector-wide objectives. Efficiency evaluations, transparency in cost-related disclosures and the inclusion of efficiency metrics within prudential assessments could enhance accountability and promote convergence toward best practices.

5. Conclusions

Overall, the analysis of the relationship between cost efficiency and shareholder structure reveals that ownership structure is an important indicator of banking efficiency, but its effect may depend on a range of factors, including internal management practices and external economic conditions that evolve over time. The findings suggest that foreign banks consistently exhibit higher efficiency than their domestic private counterparts likely due to superior technology adoption, more stringent governance standards and better access to international best practices. In contrast, state-owned banks display persistent inefficiencies, which may stem from bureaucratic constraints, less profit-oriented objectives and limited managerial autonomy.

These results shed light on the significance of policies aimed at better governance and improving cost management practices across all bank types as shareholder structure and cost efficiency in the banking sector seem to be closely related. They also emphasize the need for targeted reforms that promote transparency, accountability and stronger managerial incentives. Policies encouraging improved corporate governance and more effective cost management systems across all ownership types could also improve cost outcomes. Ultimately, these findings underscore that the relationship between shareholder structure and cost efficiency is complex. Enhancing efficiency in the banking sector therefore requires a strategy that combines internal governance reforms and regulatory oversight to ensure long-term financial stability.

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References

1. Altunbas, Y., Carbo, S., Gardener, E.P.M., Molynue, P. (2007). Examining the Relationship Between Capital, Risk and Efficiency in European Banking. *European Financial Management*, 13(1), pp. 49-70, doi: <https://doi.org/10.1111/j.1468-036X.2006.00285.x>
2. Angkinand, A., Wihlborg, C. (2010). Deposit insurance coverage, ownership, and banks' risk-taking in emerging markets. *Journal of International Money and Finance*, 29, pp. 252-274, doi: <https://doi.org/10.1016/j.jimonfin.2009.08.001>
3. Berger, A.N., DeYoung, R. (1997). Problem loans and cost efficiency in commercial banks. *Journal of Banking and Finance*, 21(6), pp. 849-870, doi: [https://doi.org/10.1016/S0378-4266\(97\)00003-4](https://doi.org/10.1016/S0378-4266(97)00003-4)
4. Berger, A.N., Clarke, G.R.G., Cull, R., Klapper, L., Udell, G.F. (2005). Corporate governance and bank performance: A joint analysis of the static, selection, and dynamic effects of domestic, foreign, and state ownership. *Journal of Banking and Finance*, 29, pp. 2179-2221, doi: <https://doi.org/10.1016/j.jbankfin.2005.03.013>
5. Bonin, J.P., Hasan, I., Wachtel, P. (2005). Bank privatization and performance: Evidence from transition countries. *Journal of Banking and Finance*, 29(8-9), pp. 2155-2178, doi: <https://doi.org/10.1016/j.jbankfin.2004.09.012>
6. Boubakri, N., El Ghouli, S., Guedhami, O., Hossain, M. (2020). Post-privatization state ownership and bank risk-taking: Cross-country evidence. *Journal of Corporate Finance*, 64, 101625, doi: <https://doi.org/10.1016/j.jcorpfin.2020.101625>
7. Chen, M., Wu, J., Jeon, B.N., Wang, R. (2017). Do foreign banks take more risk? Evidence from emerging economies. *Journal of Banking and Finance*, 82, pp. 20-39, doi: <https://doi.org/10.1016/j.jbankfin.2017.05.004>
8. Claessens, S., Demirgüç-Kunt, A., Huizinga, H. (2001). How does foreign entry affect the domestic banking market? *Journal of Banking and Finance*, 25(5), pp. 891-911, doi: [https://doi.org/10.1016/S0378-4266\(00\)00115-6](https://doi.org/10.1016/S0378-4266(00)00115-6)
9. Claessens, S., Laeven, L. (2004). What drives bank competition? Some international evidence. *Journal of Money, Credit and Banking*, 36(3), pp. 563-583, doi: <https://doi.org/10.1353/mcb.2004.0034>
10. Claessens, S., Van Horen, N. (2012). Being a foreigner among domestic banks: Asset or liability? *Journal of Banking and Finance*, 36, pp. 1276-1290, doi: <https://doi.org/10.1016/j.jbankfin.2011.11.020>
11. Cornett, M.M., Guo, L., Khaksari, S., Tehranian, H. (2010). The impact of state ownership on performance differences in privately-owned versus state-owned banks: an international comparison. *Journal of Financial Intermediation*, 19(1), pp. 74-94, doi: <https://doi.org/10.1016/j.jfi.2008.09.005>

12. Cull, R., Pería, M.S.M. (2013). Bank ownership and lending patterns during the 2008-2009 financial crisis: Evidence from Latin America and Eastern Europe. *Journal of Banking and Finance*, 37, pp. 4861–4878, doi: <https://doi.org/10.1016/j.jbankfin.2013.08.017>
13. Davis, E.P., Karim, D., Noel, D. (2021). The effects of macroprudential policy on banks' profitability. *International Review of Financial Analysis*, 101989, doi: <https://doi.org/10.1016/j.irfa.2021.101989>
14. De Haas, R., Van Lelyveld, I. (2010). Internal capital markets and lending by multinational bank subsidiaries. *Journal of Financial Intermediation*, 19, pp. 1-25, doi: <https://doi.org/10.1016/j.jfi.2009.02.001>
15. De Nicolò G., Loukoianova, E. (2007). Bank Ownership, Market Structure and Risk. *IMF Working Papers*, 07/215, doi: <https://doi.org/10.5089/9781451867794.001>
16. DeYoung, R., Nolle, D.E. (1996). Foreign-owned banks in the US: Earning market share or buying it? *Journal of Money, Credit and Banking*, 28(3), pp. 622-636, doi: <https://doi.org/10.2307/2077882>
17. Dietrich, A., Wanzenried, G. (2014). The determinants of commercial banking profitability in low-, middle-, and high-income countries. *The Quarterly Review of Economics and Finance*, 54(3), pp. 337-354, doi: <https://doi.org/10.1016/j.qref.2014.03.001>
18. Dong, Y., Meng, Ch., Firth, M., Hou, W. (2014). Ownership structure and risk-taking: Comparative evidence from private and state-controlled banks in China. *International Review of Financial Analysis*, 36, pp. 120-130, doi: <https://doi.org/10.1016/j.irfa.2014.03.009>
19. Fries, S., Taci, A. (2005). Cost efficiency of banks in transition: Evidence from 289 banks in 15 post-communist countries. *Journal of Banking and Finance*, 29(1), pp. 55-81, doi: <https://doi.org/10.1016/j.jbankfin.2004.06.016>
20. Fungáčová, Z., Herrala, R., Weill, L. (2013). The influence of bank ownership on credit supply: Evidence from the recent financial crisis. *Emerging Markets Review*, 15, pp. 136-147, doi: <https://doi.org/10.1016/j.ememar.2013.02.002>
21. Havrylchyk, O. (2006). Efficiency of the Polish banking industry: Foreign versus domestic banks. *Journal of Banking and Finance*, 30(7), pp. 1975-1996, doi: <https://doi.org/10.1016/j.jbankfin.2005.10.007>
22. Iannotta, G., Nocera, G., Sironi, A. (2007). Ownership structure, risk and performance in the European banking industry. *Journal of Banking and Finance*, 31(7), pp. 2127-2149, doi: <https://doi.org/10.1016/j.jbankfin.2006.07.013>
23. Khan, M.H., Fraz, A., Hassan, A., Abedifar, P. (2020). Female board representation, risk-taking and performance: Evidence from dual banking systems. *Finance Research Letters*, 37, 101541, doi: <https://doi.org/10.1016/j.frl.2020.101541>
24. La Porta, R., Florencio, L., Andrei, S., Robert, W. (2002). Government ownership of banks. *Journal of Finance*, 57(1), pp. 256-301, doi: <https://doi.org/10.1111/1540-6261.00422>

25. Lassoued, N., Sassi, H., Attia, M.B.R. (2016). The impact of state and foreign ownership on banking risk: Evidence from the MENA countries. *Research in International Business and Finance*, 36, pp. 167-178, doi: <https://doi.org/10.1016/j.ribaf.2015.09.014>
26. Lin, K.-L., Doan, A.T., Doong, S.-C. (2016). Changes in ownership structure and bank efficiency in Asian developing countries: The role of financial freedom. *International Review of Economics and Finance*, 43, pp. 19-34, doi: <https://doi.org/10.1016/j.iref.2015.10.029>
27. Moussawi, C., Mansour, R. (2022). Competition, cost efficiency and stability of banks in the MENA region. *The Quarterly Review of Economics and Finance*, 84, pp. 143-170, doi: <https://doi.org/10.1016/j.qref.2021.12.005>
28. Poghosyan, T., Poghosyan, A. (2010). Foreign bank entry, bank efficiency and market power in Central and Eastern European countries. *Economics of Transition*, 18(3), pp. 571-598, doi: <https://doi.org/10.1111/j.1468-0351.2010.00373.x>
29. Sapienza, P. (2004). The effects of government ownership on bank lending. *Journal of Financial Economics*, 72(2), pp. 357-384, doi: <https://doi.org/10.1016/j.jfineco.2003.10.002>
30. Shaban, M., James, G.A. (2018). The effects of ownership change on bank performance and risk exposure: Evidence from Indonesia. *Journal of Banking and Finance*, 88, pp. 483-497, doi: <https://doi.org/10.1016/j.jbankfin.2017.02.002>
31. Škrabić Perić, B., Smiljanić, A.R., Aljinović, Z. (2018). Credit risk of subsidiaries of foreign banks in CEE countries: Impacts of the parent bank and home country economic environment. *North American Journal of Economics and Finance*, 46, pp. 49-69, doi: <https://doi.org/10.1016/j.najef.2018.03.009>
32. Yeyati, E.L., Micco, A. (2007). Concentration and foreign penetration in Latin American banking sectors: impact on competition and risk. *Journal of Banking and Finance*, 31(6), pp. 1633-1647, doi: <https://doi.org/10.1016/j.jbankfin.2006.11.003>
33. Zhu, W., Yang, J. (2016). State ownership, cross-border acquisition, and risk-taking: Evidence from China's banking industry. *Journal of Banking and Finance*, 71, pp. 133-153, doi: <https://doi.org/10.1016/j.jbankfin.2016.05.004>

DIGITAL RESILIENCE IN PUBLIC GOVERNANCE – THE STATE OF THE ART AND FUTURE RESEARCH DIRECTIONS

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Purpose: The variability and uncertainty surrounding the functioning of public organizations in today's world—characterized by rising natural and anthropogenic threats alongside rapid digital transformation—have given rise to the concept of digital resilience in recent years. However, research on this topic is still in its infancy, fragmented, and interdisciplinary. It remains unclear what digital resilience in public governance truly means, what activities it involves, and what outcomes it can produce. Therefore, this article aims to systematize knowledge on digital resilience in public governance.

Design/methodology/approach: Given the novelty of digital resilience, its interdisciplinary nature, and the dispersion of research on the topic, this article relies on a systematic literature review guided by the Prisma Group methodology.

Findings: The results reveal that digital resilience in public governance evolved from the foundations of organizational resilience, with public policies and social innovations as its main drivers. It goes beyond simply bouncing back, emphasizing bouncing forward and beyond. It requires both static elements—such as establishing robust foundations for organizational sustainability and development—and dynamic aspects involving adaptation, learning, and innovation. Digital resilience is not an end in itself, but a capability that bridges resources and actions with effectiveness and sustainability. Future research should explore the impact of artificial intelligence on digital resilience and its relationship with sustainable development.

Originality/value: Digital resilience is an emerging concept in research, characterized by an interdisciplinary nature and dispersion. The findings systematize existing knowledge on digital resilience, enhancing the understanding of its significance in public governance.

Keywords: digital resilience, organizational resilience, public governance, digital transformation, digital technologies.

Category of the paper: research paper.

1. Introduction

The increasing scale of both natural and man-made threats has presented public governance with new and complex challenges due to a limited capacity to meet diverse public expectations. Events such as the war in Ukraine, COVID-19, and flash floods have created a need to adapt to new operational conditions and change how public services are delivered. Consequently, resilience is becoming increasingly important.

From an organizational perspective, resilience is the ability to cope and thrive in all operating conditions (Głód, Ingram, 2025; Hillmann, Guenther, 2021; Duchek, 2020). In the case of public organizations, it enables finding ways to meet emerging challenges and also indicates opportunities for transformation and achieving a higher level of development. Therefore, it is considered both in terms of ongoing adaptation activities and as a way to ensure organizational evolution (Jonek-Kowalska, Wolniak, 2025; Bartuseviciene et al., 2024; Kozuch, Sienkiewicz-Małyjurek, 2024). Resilience is critical as it enables public organizations to operate effectively amidst uncertainty, pressure, and threats.

At the same time, the dynamic development of digital technologies has made them an integral part of the functioning of societies, businesses, and public and non-governmental organizations. Digital technologies have also revolutionized and redefined the functioning of all organizations, including public institutions (Dunleavy, Margetts, 2025; Sienkiewicz-Małyjurek, Zyzak, 2025; Tangi et al., 2021). Innovations such as the Internet of Things, social media, blockchain, big data analytics, and artificial intelligence have opened up new opportunities for public organizations to tackle complexity and overcome challenges.

The relationships between digital transformation-driven changes and organizational resilience have led to the emergence of the concept of digital resilience as an organizational capability to function and execute processes under uncertainty through the use of digital technologies (Lee et al., 2024; Boh et al., 2023; Liu et al., 2023; Park et al., 2023; Tremblay et al., 2023). However, research on this topic has only recently begun, making it an emerging research field. Current studies on digital resilience primarily focus on its definitions (Lee et al., 2024; Boh et al., 2023; Liu et al., 2023), importance for organizational functioning (Park et al., 2023; Tremblay et al., 2023), manifestations (Boh et al., 2023; Tremblay et al., 2023), and development determinants (Mahmood et al., 2024; Boh et al., 2023). Nevertheless, research on digital resilience is dispersed, and knowledge on this topic is not systematic. Therefore, this article aims to systematize knowledge on digital resilience in public governance by seeking answers to the following research questions:

1. What are the leading causes of emerging digital resilience?
2. How has research on digital resilience evolved?
3. What matters does digital resilience concern?
4. What are the characteristics of digital resilience?
5. What are the research needs for digital resilience?

This research addresses these research questions through a systematic literature review following the PRISMA Group methodology (Page et al., 2021). This approach facilitates the integration of diverse and interdisciplinary knowledge. VOSviewer (van Eck, Waltman, 2010) and Bibliometrix (Aria, Cuccurullo, 2017) software are used to compile and visualize the most significant findings. By organizing information on digital resilience, this article provides valuable insights into public governance and resilience theory in the digital era (Dunleavy, Margetts, 2025; Sienkiewicz-Małyjurek, Zyzak, 2025a).

2. Literature review

Resilience is an interdisciplinary concept that originated in management sciences through insights from engineering, ecology, and psychology. In engineering, resilience is viewed as "the ability of the system to absorb disturbances and subsequently return to equilibrium. A perfectly resilient system in that respect is, for example, a perfectly elastic mechanical system, where any energy that is absorbed can be emitted without any losses, returning the system to its previous stable state" (Mamouni Limnios et al., 2014, p. 105). This approach to resilience emphasizes the ability to withstand disturbances and the speed of returning to a previously stable state.

In ecology, resilience refers to socio-ecological systems and is defined as "the ability of people, communities, societies, and cultures to live and develop with change, with ever-changing environments. It is about cultivating the capacity to sustain development in the face of change, incremental and abrupt, expected and surprising" (Folke, 2016, p. 4). From this viewpoint, resilience is about adaptation, learning, self-organization, and transformation, ultimately achieving a new level of stability. Thus, the engineering perspective focuses on "bouncing back", while the ecological approach emphasizes "bouncing forward".

These two perspectives are further influenced by a psychological perspective, which defines resilience as "the capability of individuals to cope successfully in the face of significant change, adversity, or risk" and as the positive psychological capacity to rebound, to bounce back from adversity, uncertainty, conflict, failure or even positive change, progress and increased responsibility" (Luthans, 2002, p. 702). This understanding of resilience highlights the individual and group impacts of humans within organizations and acknowledges their role in responding quickly and effectively to change.

The integration of engineering, ecology, and psychology in management science has led to the concept of organizational resilience. This is currently defined as "the ability of an organization to adapt, return to normal activities following shocks or threats, and use lessons learned as a driving force to bounce forward. [...] It focuses on permanent adaptive changes in organizations" (Bartuseviciene et al., 2024, p. 155). Organizational resilience emphasizes not

only the need to return to a state of stability but also to engage in continuous change that fosters organizational development. It is considered a dynamic capability that evolves over time, increasing or decreasing in response to initiatives undertaken within the organization.

In addition, digital resilience encompasses coping, adaptation, and transformation (Duchek, 2020; Sienkiewicz-Małyjurek, Zyzak, 2025). Coping involves identifying potential threats, recognizing critical changes, and understanding preventive and intervention actions. Adaptation requires adjusting to new conditions, implementing necessary changes to the organization's structure, processes, or functions to ensure survival and ongoing functionality in a new environment. Lastly, transformation is based on learning processes that facilitate changes to procedures and processes, as well as proactive anticipation and preparation for future threats. Through experiences of coping and adaptation, transformation leads to significant changes in an organization's structure and culture, ultimately enhancing operational effectiveness.

This approach to organizational resilience is also evident in the field of public governance, where the research of Hood (1991), Wildavsky (1988), Weick (1987; 1993), and Weick and Sutcliffe (2001) have made the most significant contributions. Wildavsky (1988) emphasized that redundancy, diversity, and resilience are essential for organizations in public administration to address emerging threats effectively. He viewed resilience as a dynamic and evolving strategy for managing risks and challenges in society. In contrast, Weick (1987, 1993) and Weick and Sutcliffe (2001) focused on high-reliability organizations, where the core emphasis lies on information processes, bricolage, and mindfulness. These drivers help organizations derive meaning from events and form the foundation of resilience. In this context, the capacity to handle threats takes precedence over mere operational effectiveness. Further research has explored organizational resilience within the framework of complex public management systems (Boin, Lodge, 2016; Duit et al., 2010) and multi-level public management systems (Casula, Pazos-Vidal, 2021; Ostrom, Janssen, 2004).

Recent research highlights the connection between governance and digital transformation, which extends far beyond mere digitization. It impacts not only the IT systems in use but also processes, employees, organizational culture, and structure (Sienkiewicz-Małyjurek, 2025; Zyzak et al., 2024; Kozuch, Sienkiewicz-Małyjurek, 2024; Tangi et al., 2021; Romanelli, 2021). Consequently, we are now facing governance challenges in the digital era (Dunleavy, Margetts, 2025). In this context, technologies are becoming an additional component in the processes of providing public services, which are subject to institutionalization and routinization. The resilience of these processes relies significantly on technology, leading to the emergence of the concept of digital resilience (Boh et al., 2023; Liu et al., 2023; Sienkiewicz-Małyjurek, 2025).

Digital resilience is defined as "the organizational and technological capabilities of public organizations and their stakeholders to effectively and safely utilize digital technologies for organizational improvement and development, as well as to co-create public value in diverse operating conditions. It enables handling threats and challenges, leading to greater stability in

public service delivery processes by fostering appropriate social conditions (awareness and competencies), organizational conditions (technology adaptation, management methods, interorganizational cooperation), and contextual conditions (legal regulations, specific local conditions) conditions" (Sienkiewicz-Małyjurek, 2025, p. 160). Therefore, this concept is perceived as an organizational capability that enables the functioning and implementation of processes under uncertainty through the use of digital technologies. Digital resilience stems from the processes and dynamics of intra- and interorganizational relationships, influenced by digital technologies, that enable the organization to respond to threats effectively. These processes and relationships are specific and individual to each organization and are based on the adopted concept of building digital resilience. Colding et al. (2020) proposed seven principles for developing digital resilience, which include:

1. Maintaining diversity and redundancy of digital technologies.
2. Managing interactions using digital technologies.
3. Managing feedback loops that enable digital technologies.
4. Fostering thinking in terms of complex adaptive systems.
5. Encouraging continuous learning and experimentation in the use of digital technologies.
6. Engaging diverse stakeholders to increase the legitimacy of digital technology use.
7. Promoting polycentric governance.

As a result, digital technologies have created opportunities for organizations to enhance their resilience in the digital landscape. The innovative implementation of digital technologies enables public organizations to not only "bounce back" but also to "bounce forward" and "bounce beyond". However, the level of digital resilience achieved depends not solely on the technology implementation, but on how skillfully it is applied in delivering public services (Lee et al., 2024; Boh et al., 2023; Tremblay et al., 2023). Consequently, the recent dynamic development of research on digital resilience is fostering new conditions that can improve the effectiveness of public governance activities.

3. Methodology

Given the novelty of digital resilience, its interdisciplinary nature, and the dispersion of research on the topic, this article relies on a systematic literature review to systematize existing knowledge on this emerging research concept. This approach is guided by the Prisma Group methodology (Page et al., 2021), as shown in Figure 1.

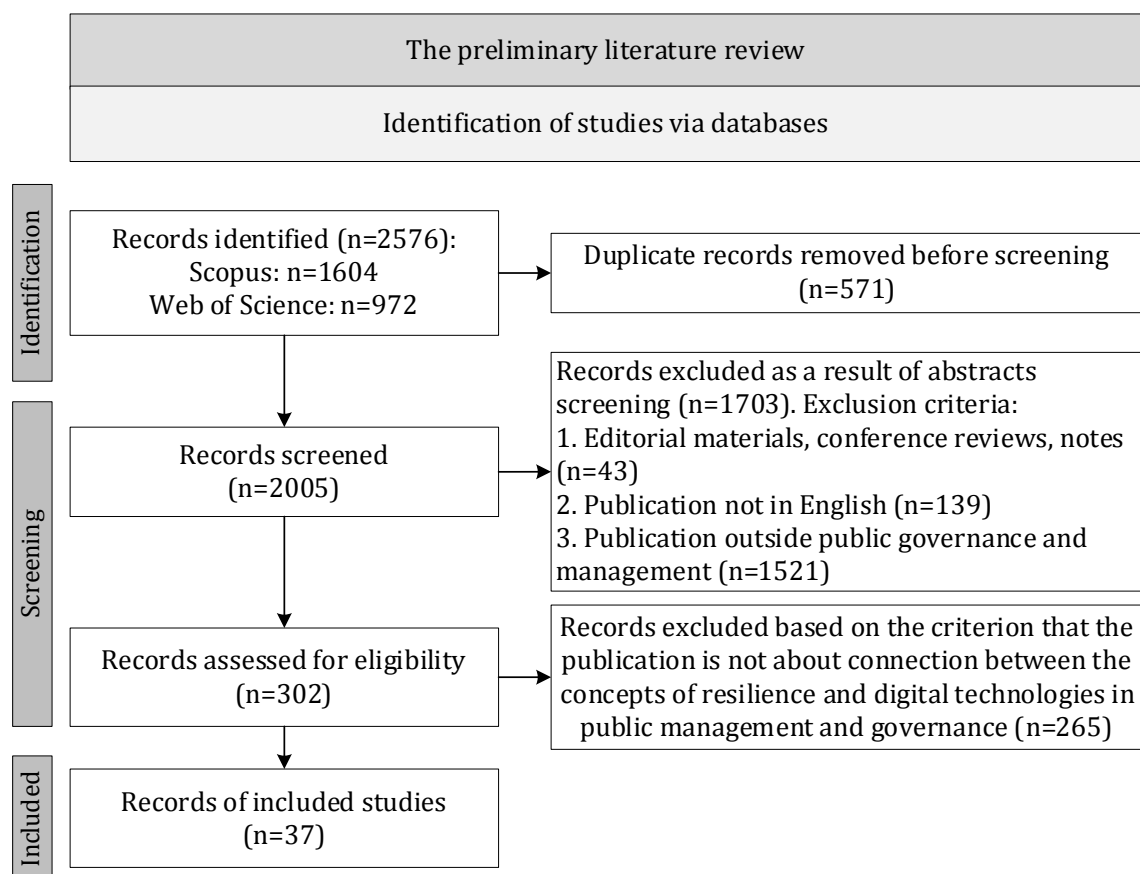


Figure 1. The systematic literature review.

Source: Own elaboration based on the Prisma Group methodology (Page et al., 2021).

At the beginning of the research process, a preliminary literature review was conducted to define the scope of the research and select keywords for the publication search. The search term "resilience*" was used in conjunction with "digit*", "tech*", and "inform*", followed by a combination of terms with "public", as shown in Table 1. Two databases were used in this process: Scopus and Web of Science, as they are reliable sources for systematic literature reviews due to their journal selection processes, rigorous review criteria, publication impact assessment systems, and comprehensive metadata, which ensure the high quality of the data searched (Mongeon, Paul-Hus, 2016; Prancutė, 2021). No restrictions were applied during the search, yielding 2,576 publications. The results obtained for each term's associations are presented in Table 1.

Table 1.
Phrases used in the search process

	Scopus			Web of Science		
	resilienc* + digit*	resilienc* + tech*	resilienc* + inform*	resilienc* + digit*	resilienc* + tech*	resilienc* + inform*
"public organi*"	23	28	37	13	15	27
"public sector*"	92	161	173	50	94	132
"public manage*"	12	34	22	9	28	20
"public govern*"	4	16	14	1	7	11
"public administr*"	83	111	113	38	58	58

Cont. table 1.

"public serv*"	94	131	136	65	91	106
"public agenc*"	5	14	20	3	8	15
"public instit*"	21	38	46	13	26	36
"public poli*"	108	391	427	47	206	248
"public affair*"	0	5	4	0	2	1
"public value*"	13	16	12	6	17	14

The next step in the research process involved applying exclusion criteria, which included the following: editorial materials, conference reviews, and notes; publications not in English; and materials beyond public governance and management. Further analysis identified 302 English-language publications on public management and governance (see Figure 1). These included articles, conference papers, books, and book chapters. After reviewing their full texts, only those that also included considerations on resilience and digital technologies in public management and governance were selected for analysis. The research process identified 37 key publications on digital resilience in public management and governance. An overview of these publications is presented in Appendix 1. The identified publications formed the basis for systematizing knowledge on digital resilience in public governance.

4. Results

4.1. Bibliometric analysis

The bibliometric analysis reveals that research on digital resilience in public governance began to develop around 2000, with the first findings primarily published in conference papers. Although the number of these publications was initially limited, it has increased significantly since 2022, likely influenced by factors such as the COVID-19 pandemic. In 2025, the majority of publications on digital resilience were scientific articles, as shown in Appendix 1. Overall, the identified publications consist of 83.8% articles and 16.2% conference papers. The research methodologies employed in these publications include case studies (45.9%), surveys (29.7%), and literature reviews (24.4%).

The analysis of relationships among the various dimensions of bibliometric data from the identified publications demonstrates that digital resilience is built on the foundations of organizational resilience. The connection between this type of resilience and digital technologies acted as a trigger for the emergence of digital resilience. The Three-Field Plot shown in Figure 2 provides a clear overview of the sources contributing to the development of digital resilience.

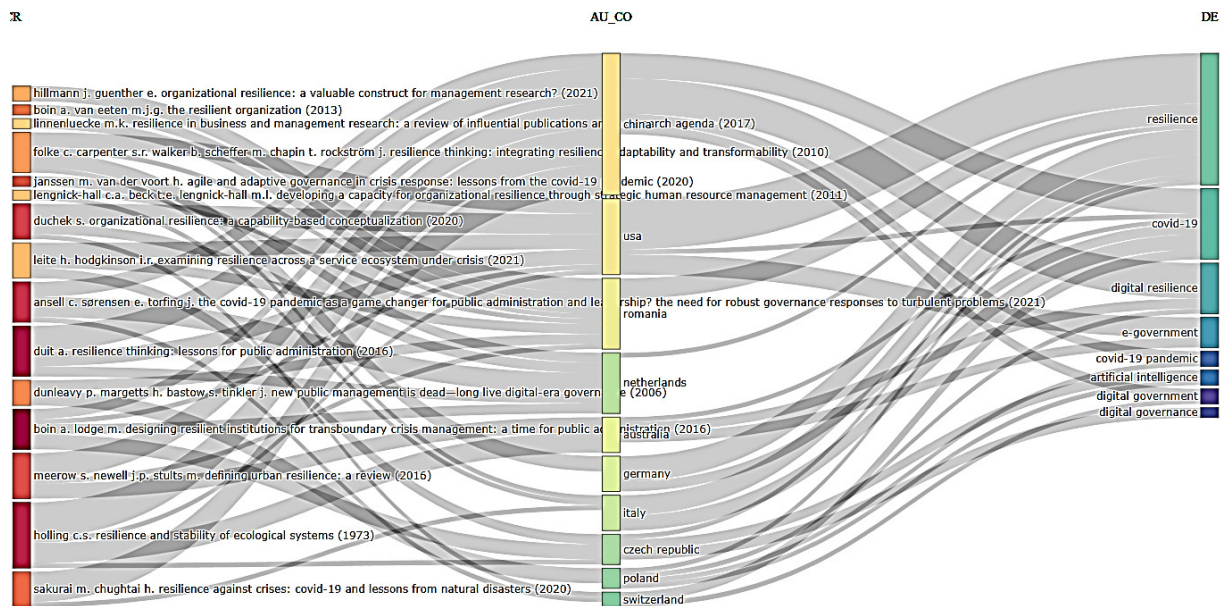


Figure 2. Three-Field Plot.

Source: Own elaboration using Bibliometrix (Aria, Cuccurullo, 2017).

As the left side of Figure 2 illustrates, the development of digital resilience originated primarily from an ecological approach and resilience thinking. This development was facilitated by research conducted in various countries, including China, the United States, Romania, the Netherlands, Austria, Germany, Italy, the Czech Republic, Poland, and Switzerland, as shown in the middle section of Figure 2. The right side, on the other hand, explains that the contemporary understanding of digital resilience stems from a joint consideration of resilience, COVID-19, e-government, digital government, and digital governance. These findings demonstrate the evolution of resilience and its adaptation to contemporary approaches to public management in the digital era of governance.

4.2. The evolving research field of digital resilience

To provide a more detailed understanding of the digital resilience concept, this article utilized Vosviewer (van Eck, Waltman, 2010) for analysis. This software enabled us to examine keyword co-occurrence, which helped us identify the thematic structure, trends, and evolution of research on digital resilience. The interactive maps created from these analyses visualize the progress of digital resilience research (see Figure 3) and highlight its key research issues (see Figure 4).

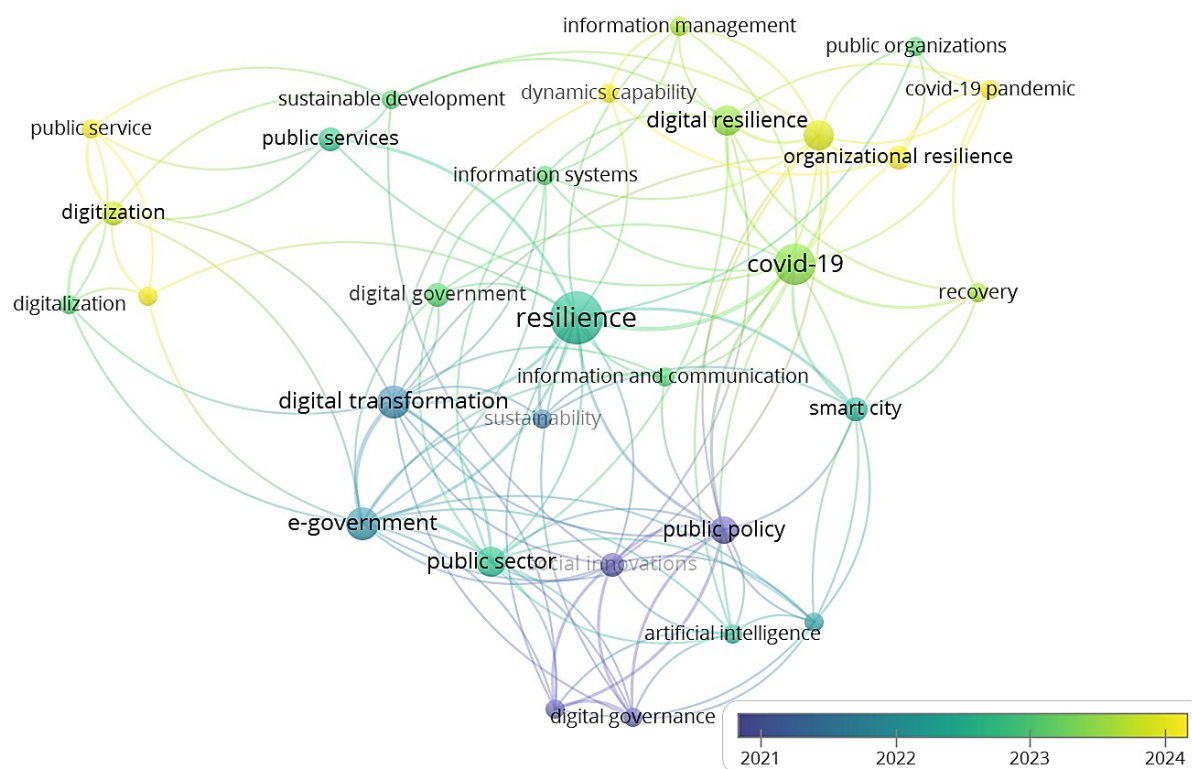


Figure 3. Advancing digital resilience research.

Source: Own elaboration using VOSviewer version 1.6.20 (van Eck, Waltman, 2010).

The development of digital resilience research reveals that it originated in digital governance issues related to social innovations shaping public policy. Consequently, the impact of both top-down initiatives—such as digitalization policies—and bottom-up initiatives, which involve communities and public institutions co-creating solutions at the local level, has become evident. After 2021, research began to focus more on digital transformation, e-government, and sustainability. In subsequent years, this was complemented by the development of a general theory of resilience, emphasizing the role of information and communication technologies (ICT) and artificial intelligence (AI) in the public sector. This research aims to ensure the effective delivery of public services in alignment with sustainable development principles. The evolution of this field also led to the integration of knowledge from information management and organizational resilience, which is viewed as a dynamic capability. This integration has significantly influenced the current understanding of digital resilience. Furthermore, the interdisciplinary nature of digital resilience's antecedents influenced the emergence of its four main research trends, illustrated in Figure 4.

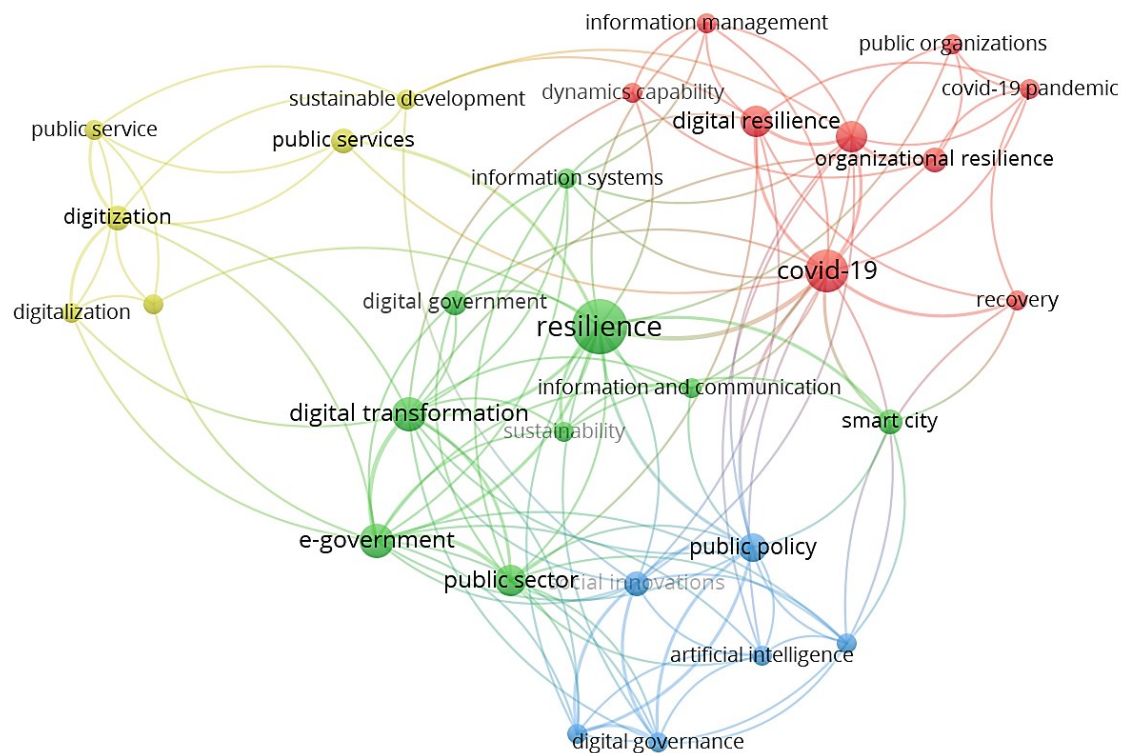


Figure 4. Research trends in digital resilience.

Source: Own elaboration using VOSviewer version 1.6.20 (van Eck, Waltman, 2010).

An analysis of research on digital resilience reveals that a key trend links the general theory of resilience with the integration of information and communication technologies and the digital transformation of the public sector (green cluster). This cluster is closely related to three other clusters. The blue cluster focuses on public policies and social innovations that drive the development of digital governance. In the public sector, where policies shape organizational operations, an emphasis on technology-based governance supports the foundations of digital resilience. The third trend (yellow cluster) examines the digitization and digitalization of public services in line with sustainable development principles. Finally, the red cluster explores resilience from both organizational and digital perspectives, particularly in light of the COVID-19 pandemic. Together, these identified trends, presented as clusters, provide a comprehensive understanding of contemporary digital resilience.

Determining the future direction of research on digital resilience is also crucial. Analyzing the thematic map shown in Figure 5 will provide an answer.

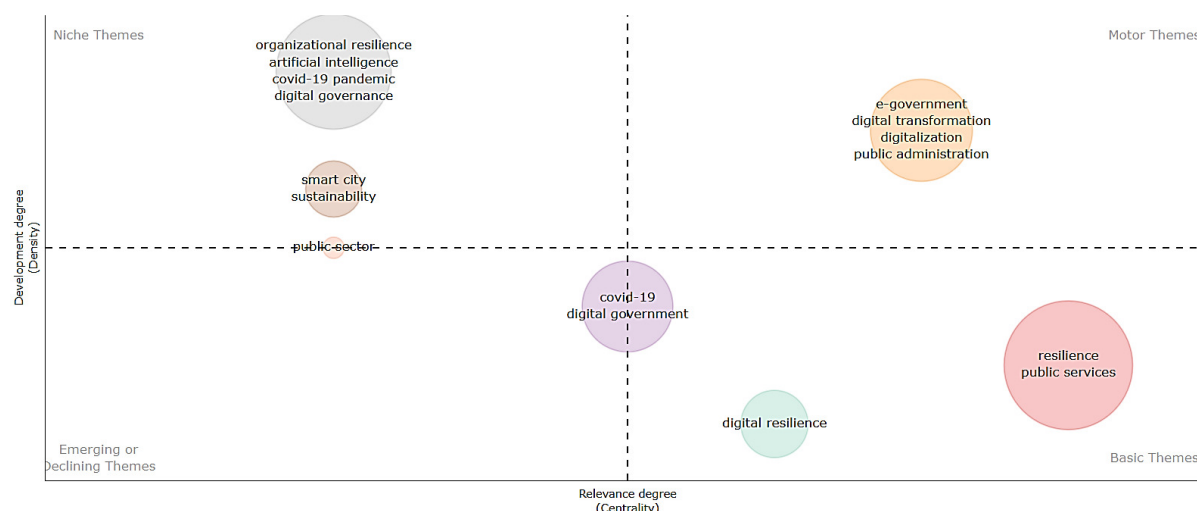


Figure 2. Thematic map (leading eigenvalues clustering algorithm).

Source: Own elaboration using Bibliometrix (Aria, Cuccurullo, 2017).

The basic themes that serve as a foundation for research on digital resilience in public governance include applying resilience theory to processes of public service delivery and exploring digital resilience issues. This research has been shaped by the evolution of the digital government concept and the impacts of the COVID-19 pandemic. Motor themes focus on the effects of the digital transformation within public administration. Niche themes, which encompass issues requiring future exploration, address the further development of organizational resilience in the context of digital governance, including the use of artificial intelligence. An important avenue for future research may also involve linking digital resilience to sustainability within the functioning of the public sector and in the context of smart cities. The thematic map indicates that there are no emerging or declining themes at this time; although the context of public sector operations and the impact of Covid-19 on digital government lie on the border with other areas.

5. Discussion

A thorough examination of the identified publications reveals that digital technologies facilitate and enhance public organizations' ability to adapt to change, respond to unforeseen events, and overcome problems. The emerging concept of digital resilience in public governance not only refers to responding to emerging problems (bouncing back) but is primarily focused on proactive actions and the search for new ways of survival and development (bouncing forward and beyond). It is characterized by complexity and multidimensionality, as the individual, group, organizational, and interorganizational levels complement each other (Fischer et al., 2023; Sagarik, 2024). Building digital resilience in public governance solely at the organizational level is impossible without developing employees' knowledge and digital

competencies. Similarly, countries' digital resilience depends on the capabilities and resources of the local, regional, and central levels. Nevertheless, this is a crucial concept, as the appropriate use of digital technologies can enhance the effectiveness of actions and drive sustainable development (Wolniak, Grebski, 2025; Sira, Kuzior, 2025; Drăgoicea et al., 2020). For example, during the war in Ukraine, digital resilience enables the co-creation of defense operations and the continuity of civilian services (Mamediiieva, Moynihan, 2023). It is also worth emphasizing that it is not an end in itself, but an ability that mediates between resources, actions taken, and the effectiveness of the processes conducted

By treating knowledge as a growing resource, digital resilience in public governance adapts the factors of effective activities to the current situation and contextual conditions. These factors include, above all, public policies, which determine the design and implementation of appropriate digital technologies (Drăgoicea et al., 2020). For example, the implementation of digital platforms enables citizen-centric, decentralized public service delivery, thereby building a resilient public service delivery system (Shen et al., 2023; Casalegno et al., 2023). Such solutions foster the development of public entrepreneurship and social innovation, and also increase opportunities for collaboration and learning. They enable the exchange of ideas on problem-solving, socialization, and the development of collective understanding (Nolte, Lindenmeier, 2024; Bhamra, Brodersohn, 2025). Thanks to digital technologies, employees of public organizations can discuss among themselves and with the community, exchanging ideas to solve current challenges, thereby building the organization's ability to adapt quickly and effectively to the situation. An agile approach to decision-making processes, robust stakeholder engagement mechanisms, democratic leadership, and flexible organizational structures are also important determinants of digital resilience (Bhamra, Brodersohn, 2025; Tremblay et al., 2023; Lin, Tao, 2024).

Furthermore, to bounce forward and beyond, a combination of static and dynamic digital resilience is necessary (Clement et al., 2023; Nolte, Lindenmeier, 2024; Sienkiewicz-Małyjurek, Zyzak, 2025b). Static digital resilience—defining a baseline—creates a robust foundation for organizational sustainability and development. In turn, a dynamic approach enables adaptation to changing conditions, drawing conclusions, and learning, which then inform innovation and change. Static and dynamic digital resilience complement each other, creating an integrated picture of capabilities.

6. Conclusions

This article aims to systematize knowledge about digital resilience. To achieve this goal, an interdisciplinary systematic literature review was conducted to answer the research questions presented in the Introduction.

To address the first research question, it was determined that the primary factors driving the development of digital resilience are policies that aim to use digital technologies in public governance, along with social innovations. Additionally, the COVID-19 pandemic has prompted public organizations to seek new ways to enhance resilience through digital technologies.

The findings related to the second research question reveal that digital resilience has evolved from the foundations of organizational resilience. Research on this topic is primarily conducted in China, the USA, Romania, and the Netherlands. Current studies emphasize how digital technologies can enhance public organizations' capacity to deliver effective public services in line with sustainable development principles.

The research areas about digital resilience, which are relevant to the third research question, comprise four main strands: the relationship between general resilience theory and the application of information and communication technologies in the digital transformation of the public sector; public policies and social innovations that contribute to the growth of digital governance; the extent of digitization and digitalization in public services aligned with sustainable development principles; and the interplay between organizational and digital factors. Together, these four areas provide a big picture of digital resilience.

Addressing the fourth research question, it can be concluded that digital resilience in public governance goes beyond mere bouncing back; it emphasizes moving forward and beyond. This concept requires both static elements—such as establishing robust foundations for organizational sustainability and development—and dynamic aspects involving adaptation, learning, and innovation. Additionally, digital resilience develops at both the individual and organizational levels. These levels are complementary; it is not possible to foster digital resilience at the organizational level without individual employees' competencies. Furthermore, digital resilience should not be viewed as an end goal, but rather as a capacity that bridges resources and actions with the effectiveness and sustainability of activities. By treating knowledge as a growing resource, digital resilience in public governance helps shape effective actions tailored to the current situation and context.

The identification of future research directions in digital resilience, as related to research question five, highlights the need to further explore the connections between organizational resilience and digital governance, particularly through the use of artificial intelligence. Additionally, it is crucial to establish the interrelationships between digital resilience and sustainable development within the public sector operations framework.

In summary, this article offers new insights into the development opportunities and impacts of digital resilience, thereby enhancing understanding of public governance and resilience theory in digital-era governance.

References

1. Aria, M., Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4), 959-975. <https://doi.org/10.1016/j.joi.2017.08.007>
2. Bartuseviciene, I., Butkus, M., Schiuma, G. (2024). Modelling organizational resilience structure: insights to assess resilience integrating bounce-back and bounce-forward. *European Journal of Innovation Management*, 27(1), 153-169. <https://doi.org/10.1108/EJIM-04-2022-0180>
3. Bhamra, R., Brodersohn, E. (2025). Understanding organizational dynamism: Fostering creativity and agility for resilience in social security institutions. *International Social Security Review*, 78(2-3), 37-54. <https://doi.org/10.1111/issr.70003>
4. Boh, W., Constantinides, P., Padmanabhan, B., Viswanathan, S. (2023). Special Issue Introduction: Building digital resilience against major shocks. *Mis Quarterly*, 47(1), 343-360.
5. Boin, A., Lodge, M. (2016). Designing resilient institutions for transboundary crisis management: a time for public administration. *Public Administration*, 94(2), 289-298. <https://doi.org/10.1111/padm.12264>
6. Casalegno, C., Civera, C., Cortese, D., Zardini, A. (2023). In search of the enabling factors for public services resilience: A multidisciplinary and configurational approach. *Journal of Innovation & Knowledge*, 8(1), 100337. <https://doi.org/10.1016/j.jik.2023.100337>
7. Casula, M., Pazos-Vidal, S. (2021). Assessing the multi-level government response to the COVID-19 crisis: Italy and Spain compared. *International Journal of Public Administration*, 44(11-12), 994-1005. <https://doi.org/10.1080/01900692.2021.1915330>
8. Clement, J., Esposito, G., Crutzen, N. (2023). Municipal pathways in response to COVID-19: a strategic management perspective on local public administration resilience. *Administration & Society*, 55(1), 3-29. <https://doi.org/10.1177/00953997221100382>
9. Colding, J., Colding, M., Barthel, S. (2020). Applying seven resilience principles on the Vision of the Digital City. *Cities*, 103, 102761. <https://doi.org/10.1016/j.cities.2020.102761>
10. Drăgoicea, M., Walletzký, L., Carrubbo, L., Badr, N. G., Toli, A.M., Romanovská, F., Ge, M. (2020). Service design for resilience: A multi-contextual modeling perspective. *IEEE Access*, 8, 185526-185543. <https://doi.org/10.1109/ACCESS.2020.3029320>
11. Duchek, S. (2020). Organizational resilience: a capability-based conceptualization. *Business Research*, 13(1), 215-246. <https://doi.org/10.1007/s40685-019-0085-7>
12. Duit, A., Galaz, V., Eckerberg, K., Ebbesson, J. (2010). Governance, complexity, and resilience. *Global Environmental Change*, 20(3), 363-368. <https://doi.org/10.1016/j.gloenvcha.2010.04.006>

13. Dunleavy, P., Margetts, H. (2025). Data science, artificial intelligence and the third wave of digital era governance. *Public Policy and Administration*, 40(2), 185-214. <https://doi.org/10.1177/09520767231198737>
14. Fischer, C., Siegel, J., Proeller, I., Drathschmidt, N. (2023). Resilience through digitalisation: How individual and organisational resources affect public employees working from home during the COVID-19 pandemic. *Public Management Review*, 25(4), 808-835. <https://doi.org/10.1080/14719037.2022.2037014>
15. Folke, C. (2016). Resilience (republished). *Ecology and Society*, 21(4), 44. <https://www.jstor.org/stable/26269991>
16. Głód, W., Ingram, T. (2025). Nurturing organizational resilience: Exploring the interplay of leadership and dynamic managerial capabilities. *Organizacja i Kierowanie*, 197(1), 103-129. <https://econjournals.sgh.waw.pl/OiK/article/view/4394>
17. Hillmann, J., Guenther, E. (2021). Organizational resilience: a valuable construct for management research? *International Journal of Management Reviews*, 23(1), 7-44. <https://doi.org/10.1111/ijmr.12239>
18. Hood, C. (1991). A public management for all seasons? *Public Administration*, 69(1), 3-19. <https://doi.org/10.1111/j.1467-9299.1991.tb00779.x>
19. Jonek-Kowalska, I., Wolniak, R. (2025). *Exclusion in Smart Cities: Assessment and Strategy for Strengthening Resilience*. Routledge. <https://doi.org/10.4324/9781003499992>
20. Kożuch, B., Sienkiewicz-Małyjurek, K. (2024). *Trust and Digital Transformation in the Public Sector*. New York: Routledge.
21. Lee, J.Y.H., Chou, C.Y., Chang, H.L., Hsu, C. (2024). Building digital resilience against crises: The case of Taiwan's COVID- 19 pandemic management. *Information Systems Journal*, 34(1), 39-79. <https://doi.org/10.1111/isj.12471>
22. Lin, J., Tao, J. (2024). Digital resilience: A multiple case study of Taobao village in rural China. *Telematics and Informatics*, 86, 102072. <https://doi.org/10.1016/j.tele.2023.102072>
23. Liu, Y., Xu, X., Jin, Y., Deng, H. (2023). Understanding the digital resilience of physicians during the COVID-19 pandemic: An empirical study. *MIS Quarterly*, 47(1), 391-422.
24. Luthans, F. (2002). The need for and meaning of positive organizational behavior. *Journal of Organizational Behavior*, 23, 695-706. <https://doi.org/10.1002/job.165>
25. Mahmood, S., Chadhar, M., Firmin, S. (2024). Digital resilience framework for managing crisis: A qualitative study in the higher education and research sector. *Journal of Contingencies and Crisis Management*, 32(1), e12549. <https://doi.org/10.1111/1468-5973.12549>
26. Mamedieva, G., Moynihan, D. (2023). Digital resilience in wartime: The case of Ukraine. *Public Administration Review*, 83(6), 1512-1516. <https://doi.org/10.1111/puar.13742>
27. Mamouni Limnios, E.A., Mazzarol, T., Ghadouani, A., Schilizzi, S.G.M. (2014). The resilience architecture framework: Four organizational archetypes. *European Management Journal*, 32(1), 104-116. <https://doi.org/10.1016/j.emj.2012.11.007>

28. Mongeon, P., Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: a comparative analysis. *Scientometrics*, 106(1), 213-228. <https://doi.org/10.1007/s11192-015-1765-5>
29. Nolte, I.M., Lindenmeier, J. (2024). Creeping crises and public administration: a time for adaptive governance strategies and cross-sectoral collaboration? *Public Management Review*, 26(11), 3104-3125. <https://doi.org/10.1080/14719037.2023.2200459>
30. Ostrom, E., Janssen, M.A. (2004). Multi-level Governance and Resilience of Social-ecological Systems. In: M. Spoor (Eds.), *Globalisation, Poverty and Conflict* (pp. 239-259). Dordrecht: Springer.
31. Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P., Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, n71. <https://doi.org/10.1136/bmj.n71>
32. Park, J., Son, Y., Angst, C. (2023). The Value of Centralized IT in Building Resilience During Crises: Evidence from U.S. Higher Education's Transition to Emergency Remote Teaching. *MIS Quarterly*, 47(1), 451-482.
33. Pranckutė, R. (2021). Web of Science (WoS) and Scopus: The titans of bibliographic information in today's academic world. *Publications*, 9(1), 12. <https://doi.org/10.3390/publications9010012>
34. Romanelli, M. (2021). Driving public organisations using information technology. *Modern Management Systems*, 16(1), 71-86. <https://doi.org/10.37055/nsz/134809>
35. Sagarik, D. (2024). How digital government capabilities strengthen public sector workforce resilience. *International Review of Public Administration*, 29(4), 353-362. <https://doi.org/10.1080/12294659.2024.2432096>
36. Shen, Y., Cheng, Y., Yu, J. (2023). From recovery resilience to transformative resilience: How digital platforms reshape public service provision during and post COVID-19. *Public Management Review*, 25(4), 710-733. <https://doi.org/10.1080/14719037.2022.2033052>
37. Sienkiewicz-Małyjurek, K. (2025). *Odporność cyfrowa w zarządzaniu publicznym: Perspektywa tworzenia wartości publicznej [Digital Resilience in Public Management: A Perspective on Creating Public Value]*. Gliwice: Wydawnictwo Politechniki Śląskiej.
38. Sienkiewicz-Małyjurek, K., Zyzak, B. (2025a). Digital Technologies in Public Administration Networks: Systematic Literature Review and Research Avenues. *Administration & Society*, 57(8-9), 1051-1087. <https://doi.org/10.1177/00953997251369090>
39. Sienkiewicz-Małyjurek, K., Zyzak, B. (2025b). Overcoming social and ethical challenges of AI through organizational resilience. A PLS-SEM approach. *Telematics and Informatics*, 96, 102210. <https://doi.org/10.1016/j.tele.2024.102210>

40. Sira, M., Kuzior, A. (2025). Digitalization of government management processes in the context of sustainable development. *Management Systems in Production Engineering*, 33, Article 2. <https://doi.org/10.2478/mspe-2025-0029>
41. Tangi, L., Janssen, M., Benedetti, M., Noci, G. (2021). Digital government transformation: A structural equation modelling analysis of driving and impeding factors. *International Journal of Information Management*, 60, 102356. <https://doi.org/10.1016/j.ijinfomgt.2021.102356>
42. Tremblay, M.C., Kohli, R., Rivero, C. (2023). Data is the New Protein: How the Commonwealth of Virginia Built Digital Resilience Muscle and Rebounded from Opioid and COVID Shocks. *MIS Quarterly*, 47(1), 423-450.
43. van Eck, N.J., Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* 84, 523538. <https://doi.org/10.1007/s11192-009-0146-3>
44. Weick, K.E. (1987). Organizational culture as a source of high reliability. *California Management Review*, 29(2), 112-127. <https://doi.org/10.2307/41165243>
45. Weick, K.E. (1993). The collapse of sensemaking in organizations: the Mann Gulch disaster. *Administrative Science Quarterly*, 38, 628-652. <https://doi.org/10.2307/2393339>
46. Weick, K.E., Sutcliffe, K.M. (2001). *Managing the unexpected*. San Francisco: Jossey-Bass.
47. Wildavsky, A.B. (1988). *Searching for safety*. Transaction publishers.
48. Wolniak, R., Grebski, W.W. (2025). Sustainable trends and determinants of wheat cultivation in Poland (2004-2023): a spatiotemporal analysis of productivity, resilience, and climate adaptation. *Sustainability*, 17, 5. <https://doi.org/10.3390/su17052225>
49. Zyzak, B., Sienkiewicz-Małyjurek, K., Jensen, M.R. (2024). Public value management in digital transformation: a scoping review. *International Journal of Public Sector Management*, 37(7), 845-863. <https://doi.org/10.1108/IJPSM-02-2024-0055>

Appendix 1.

The results of the Systematic Literature Review (chronological order)

Authors	Title	Year	Source title
G.C. Misuraca; G. Pasi; G. Viscusi	Social innovation and resilience: Exploring the dynamics and impacts on the digital transformation of governance & society	2018	ACM International Conference Proceeding Series, 91-100
G.C. Misuraca; G. Viscusi	AI-Enabled Innovation in the Public Sector: A Framework for Digital Governance and Resilience	2020	Lecture Notes in Computer Science, 12219, 110-120
M. Drăgoicea; L. Walletzky; L. Carrubbo; N.G. Badr; A.M. Toli; F. Romanovská; M. Ge	Service design for resilience: A multi- contextual modeling perspective	2020	IEEE Access, 8, 185526- 185543
N. Tcholtchev; I.K. Schieferdecker	Sustainable and reliable information and communication technology for resilient smart cities	2021	Smart Cities, 4(1), 156-176
D. Chatterjee; S. Chatterjee; S. Chatterjee	An Empirical Investigation of the Role of Information Technology in Fostering Organizational Resilience and Effectiveness	2021	ACIS 2021 Proceedings, 3
B.R. Fleron; J. Pries-Heje; R.L. Baskerville	Digital organizational resilience: A history of Denmark as a most digitalized country	2021	Proceedings of the Annual Hawaii International Conference on System Sciences, 2400-2409
Y. Tim; L. Cui; Z. Sheng	Digital resilience: How rural communities leapfrogged into sustainable development	2021	Information Systems Journal, 31(2), 323-345
B.R. Fleron; J. Pries-Heje; R.L. Baskerville	Becoming a Most Digitalized Country: A History of Digital Organizational Resilience in Denmark	2022	Communications of the Association for Information Systems, 51(1), 120-139
S.A. Apostu; V.A. Vasile; R. Vasile; J. Rosak-Szyrocka	Do Smart Cities Represent the Key to Urban Resilience? Rethinking Urban Resilience	2022	International Journal of Environmental Research and Public Health, 19(22), 15410
B. Faro; B. Abedin; D.K. Cetindamar	Hybrid organizational forms in public sector's digital transformation: a technology enactment approach	2022	Journal of Enterprise Information Management, 35(6), 1742-1763
I. Hasan; S.A.M. Rizvi	Knowledge Management Framework for Sustainability and Resilience in Next-Gen e-Governance	2022	Lecture Notes in Networks and Systems, 238, 191-203
G. Mamediiieva; D.P. Moynihan	Digital resilience in wartime: The case of Ukraine	2023	Public Administration Review, 83(6), 1512-1516
Y. Shen; Y. Cheng; J. Yu	From recovery resilience to transformative resilience: How digital platforms reshape public service provision during and post COVID-19	2023	Public Management Review, 25(4), 710-733
C.G. Casalegno; C. Civera; D. Cortese; A. Zardini	In search of the enabling factors for public services resilience: A multidisciplinary and configurational approach	2023	Journal of Innovation and Knowledge, 8(1), 100337
J. Clement; G. Esposito; N. Crutzen	Municipal Pathways in Response to COVID-19: A Strategic Management Perspective on Local Public Administration Resilience	2023	Administration and Society, 55(1), 3-29

C. Fischer; J. Siegel; I. Proeller; N. Drathschmidt	Resilience through digitalisation: How individual and organisational resources affect public employees working from home during the COVID-19 pandemic	2023	Public Management Review, 25(4), 808-835
Y. Tim; D.E. Leidner	Digital Resilience: A Conceptual Framework for Information Systems Research	2023	Journal of the Association for Information Systems, 24(5), 1184-1198
M.C. Chiarini Tremblay; R. Kohli; C. Rivero	Data is the new protein: how the commonwealth of Virginia built digital resilience muscle and rebounded from opioid and COVID shocks	2023	MIS Quarterly: Management Information Systems, 47(1), 423-450
Y. Liu; X. Xu; Y. Jin; H. Deng	Understanding the digital resilience of physicians during the COVID-19 pandemic: an empirical study	2023	MIS Quarterly: Management Information Systems, 47(1), 391-422
X. Yao; Z. Xu; M. Škare; X. Wang	Aftermath on COVID-19 technological and socioeconomic changes: A meta-analytic review	2024	Technological Forecasting and Social Change, 202, 123322
I.M. Nolte; J. Lindenmeier	Creeping crises and public administration: a time for adaptive governance strategies and cross-sectoral collaboration?	2024	Public Management Review, 26(11), 3104-3125
C.M. Proftiroiu; I.C. Negoită; A.V. Costea	Digitalization of public administration in EU member states in times of crisis: the contributions of the national recovery and resilience plans	2024	International Review of Administrative Sciences, 90(2), 336-352
D. Sagarik	How digital government capabilities strengthen public sector workforce resilience	2024	International Review of Public Administration, 29(4), 353-362
A.S.D. Santos; I. Gonçalves; A. Silva; R. Neves; I.C. Teixeira; E.M. Barbosa; V.L. Gava; O.S. Yoshida	Smart resilience through IoT-enabled natural disaster management: A COVID-19 response in São Paulo state	2024	IET Smart Cities, 6(3), 211-224
V.R. Levesque; K.P. Bell; E.S. Johnson	The role of municipal digital services in advancing rural resilience	2024	Government Information Quarterly, 41(1), 101883
Y.H. Zou	Urban resilience, digital technologies, and the economic recovery of a city from the pandemic	2024	Public Administration Review, 84(4), 637-650
J. Lin; J. Tao	Digital resilience: A multiple case study of Taobao village in rural China	2024	Telematics and Informatics, 86, 102072
J.Y.H. Lee; C.Y. Chou; H. Chang; C.W. Hsu	Building digital resilience against crises: The case of Taiwan's COVID-19 pandemic management	2024	Information Systems Journal, 34(1), 39-79
Q. Yuan; M.G. Hernandez; J.R. Gil-Garcia; M.E. Cook; T.A. Pardo	Continuity of Operations and Organisational Resilience during the COVID-19 Pandemic: Lessons from City Governments in the US Northeast Region	2025	Public Management Review, 27(1), 29-49
U. Abdullahi; A. Martadha Mohamed; V. Senasi	Digital orientation and organizational resilience: the contingent effect of dynamic capabilities	2025	Sustainable and Resilient Infrastructure, 10(4), 295-312
A. Holmström; C. Große	Not All Heroes Wear Capes: Cyber Resilience of the Social Administration at a Swedish Municipality	2025	Risk, Hazards and Crisis in Public Policy, 16, e70024
P. Horák; D. Špaček	Organizational Resilience of Public Sector Organizations Responding to the COVID-19 Pandemic in Czechia and Key Influencing Factors: Use of the Nograšek and Vintar Model	2025	International Journal of Public Administration, 48(8), 485-501

K.E. Sienkiewicz-Małyjurek; B. Zyzak	Overcoming social and ethical challenges of AI through organizational resilience. A PLS-SEM approach	2025	Telematics and Informatics, 96, 102210
L. Ha	Reconsider the role of digital revolution in public sector during the time of climate risk: Fresh insights from panel autoregression model	2025	Technological Forecasting and Social Change, 219, 124243
R.S. Bhamra; E. Brodersohn	Understanding organizational dynamism: Fostering creativity and agility for resilience in social security institutions	2025	International Social Security Review, 78(2-3), 37-54
S.A. Teo	Artificial intelligence, human vulnerability and multi-level resilience	2025	Computer Law & Security Review, 57, 106134
A.F. Crăciun; M. Umar; M. Qin; A.C. Nicolescu; O.R. Lobont	Digital Metamorphosis: Harnessing Transformation in the Public Sector for Sustainable Governance and Resilience	2025	Springer Proceedings in Business and Economics, 1-29

BANK DIVIDENDS: THE ROLE OF ECONOMIC ENVIRONMENT AND PERFORMANCE

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Purpose: The aim of this paper is to study trends in dividend payments in commercial banks from Central and Eastern Europe. Dividends are explored in the context of country differences as well as temporal developments throughout a long time period.

Design/methodology/approach: The analysis is based on a unique dataset, which includes hand-input data on dividend payments of listed and unlisted banks over the period 2006-2022. Banks in the sample are based in eleven EU countries, which have experienced strong economic growth, but also sizeable recessions in the study period. Dividend payments are studied using two measures, the propensity to pay dividends and the level of dividends. Dividends are explored in relation to the operating environment and to individual bank profitability and equity levels.

Findings: There is heterogeneity in the propensity to pay dividends, as well as the level of dividends, between eleven countries in the region. In general, economic growth is paired with more frequent and higher dividend payments. However, dividends in some countries do not largely differ under weak and strong economic environment. In line with existing literature, dividends are positively associated with profitability and capital. Banks that generate higher earnings and accumulate more equity are more likely to pay dividends and their dividends are higher than at their peers.

Originality/value: The paper shows trends of dividends in banks of Central and Eastern Europe, which have been very rarely studied in existing literature. Most empirical work relates to the US or cross-country samples that do not include Central and Eastern Europe. In addition, many studies base on listed banks, which may have different dividend payment patterns. This study uses banks from a rarely studied region and includes both listed and unlisted banks.

Keywords: dividend payouts, Central and Eastern Europe, commercial banks.

Category of the paper: Research paper.

1. Introduction

Decisions related to dividend payments are among the most significant choices made by managers and shareholders of firms. They play an especially important role in financial institutions. Banks are very heavily regulated, particularly in the area of capital requirements. Dividends directly affect the level of retained earnings that feed into capital, making the decision on dividend payment vital not only to shareholders, but also bank supervisors across the world. Low capital levels may endanger individual bank stability, especially during economic downturns, when new capital is limited and bank portfolios become more risky. Due to a high degree of interconnectedness in the banking sector, higher risk of individual banks is transferred to other banks and overall financial stability may decrease. In consequence, the decisions on dividend payments in banks, especially in turbulent times, are of high importance to individual banks but also banking sectors as a whole (Fahlenbrach et al., 2024). Meanwhile, empirical literature on bank dividends remains relatively limited, especially in terms of developing countries and unlisted banks.

The aim of this paper is to analyse dividend payments of banks in Central and Eastern Europe. We use a unique dataset of hand-input dividend data for a sample of listed and unlisted banks from eleven countries in the region over a period of 2006-2022. We study differences in dividends on the country level and their link with GDP growth. We compare whether banks under weak economic conditions have similar dividends to banks in strong environments. In addition, we consider the role of individual bank profitability and capital levels in dividend decisions across the whole period of analysis.

2. Review of empirical studies on bank dividends

Dividends have been broadly described in both theoretical and empirical literature, but the existing work has largely focused on non-financial entities. Empirical studies regarding banks are much more limited and usually refer to large, listed banks (Abreu, Gulamhussen, 2013; d'Udekem, 2021; Lepetit et al., 2018; Onali et al., 2016; Srivastav et al., 2014; Trinh et al., 2021; Trinh, 2022). There are many studies basing on U.S. bank samples (Abreu, Gulamhussen, 2013; d'Udekem, 2021; Floyd et al., 2015; Johari et al., 2020; Kanas, 2013; Srivastav et al., 2014) and earlier time periods, while cross-country analyses and more recent data remain relatively scarce. There is a limited number of cross-country studies investigating worldwide samples (Acharya et al., 2022; Ashraf et al., 2016; Lepetit et al., 2018), emerging economies (Forti, Schiozer, 2015; Trinh et al., 2021) and European banks (Lepetit et al., 2017; Onali et al., 2016; Belloni et al., 2023). The aim of our analysis is to shed more light on bank dividend

payments in Central and Eastern Europe, a region which has been rarely studied in this literature.

In existing literature regarding banks, dividend payouts are related to several groups of factors. These groups include bank-specific financial factors, the operating environment and the institutional environment. Bank-specific factors comprise bank profitability, general performance, bank size or risk levels. The link between dividend payments and bank profitability is among the most frequently analysed and shows the most consistent results. Dividend payouts are positively associated with bank profitability in a number of studies (Abreu, Gulamhussen, 2013; Belloni et al., 2023; Johari et al., 2020; Lepetit et al., 2018; Onali et al., 2016, Srivastav et al., 2014; Trinh et al., 2021). When banks record high earnings, they are more willing to pay dividends and the dividend level is more elevated than during periods of weak profits. Large banks are also found to pay higher dividends than smaller entities (Abreu, Gulamhussen, 2013; Belloni et al., 2023; Forti, Schiozer, 2015; Lepetit et al., 2018; Trinh et al., 2021). This may be due to the fact that large banks are usually listed and have numerous large shareholders, which expect regular dividend payments. They are also more closely monitored by capital market participants and the general public, so a reduction or avoidance of dividend payments in large banks is more discussed on the market and increases the pressure on payouts.

Higher dividend levels are observed for banks with more capital (Abreu, Gulamhussen, 2013; Belloni et al., 2023; Chronopoulos et al., 2023; Johari et al., 2020; Lepetit et al., 2018). When banks have higher equity levels, they do not need to further increase them through retained earnings and may distribute more income in the form of dividends. For weakly capitalised banks, paying dividends implies a further decrease in the capital base and may endanger a bank's financial stability. If losses materialise, the bank will not have a sufficient capital buffer to cover them. In consequence, banks with weak capital may be required by bank supervisors to withhold dividend payments, until they regain a sound capital cushion.

Banks relying more on uninsured debtholders, rather than insured depositors, pay more dividends (Lepetit et al., 2018) and an increase in insured deposits may be associated with lower dividends (Johari et al., 2020). Higher dividends are positively linked to institutional investor deposits (Forti, Schiozer, 2015). The link between bank risk and dividend payments is negative in most studies (Chronopoulos et al., 2023; Forti, Schiozer, 2015; Johari et al., 2020; Lepetit et al., 2017; Lepetit et al., 2018), although Onali (2014) finds a positive association. Dividends may also be related to bank shareholder structure, with a negative link identified between payouts and ownership concentration (Abreu, Gulamhussen, 2013), as well as government ownership (Onali et al., 2016) and foreign ownership (Forti, Schiozer, 2015). External factors in the banking environment also matter, such as the competition in the banking sector (Chronopoulos et al., 2023; De Cesari et al., 2024; Lepetit et al., 2018), the regulatory framework relating to investor protection and creditor rights (Lepetit et al., 2018) and the political situation (Fahlenbrach et al., 2024).

There is a number of studies that explore dividend payments under adverse economic conditions. High dividends reduce bank capital and may contribute to the fragility of the financial system, especially during economic downturns. Despite this, Acharya et al., (2022) and Floyd et al., (2015) demonstrate that some banks continued to pay high dividends during the global financial crisis (GFC). Floyd et al. (2015) find that during the GFC, banks were more prone to increase dividends and more reluctant to refrain from dividend payouts than industrial entities. Several potential reasons for this are put forward in the literature. Gambacorta et al. (2023) indicate that managers may not object to higher dividend payments, as they decrease the bank capital base and hence automatically increase return-on-equity, which managerial compensation may be based upon. In addition, dividend payouts boost short-term shareholder returns. Acharya et al. (2022) pose that if banks cut dividends, it could be seen as a signal of weakness and this could start a bank run, so dividends continue to be paid even when they should be decreased or stopped.

In parallel, decreasing or stopping dividend distributions increases bank capital and allows to sustain loan growth especially in crisis periods (Gambacorta et al., 2023). Dividend bans implemented in 2020 in the face of the Covid-19 crisis allowed to increase capital and boost loan growth in countries that implemented dividend payout restrictions (Hardy, 2021). A special role is played by minimum capital requirements. Onali (2014) shows that capital adequacy regulations may attenuate the observed positive link between bank risk taking and dividend payouts. Regulatory capital requirements limit dividend payouts, particularly in the case of undercapitalised banks during a financial crisis (Abreu, Gulamhussen, 2013). However, Ashraf et al. (2016) warn that while stringent capital requirements are linked with lower dividend payments and lower probability of excessive dividends in pre-crisis periods, their effectiveness in restricting dividends during the crisis may be limited. As a result, adequate capital requirements should be in place in periods of sound economic growth, to avoid the depletion of capital and increase of financial instability in crisis times.

3. Methodology and data

The aim of this paper is to study patterns of dividend payments in banks in Central and Eastern Europe. We take advantage of a large, hand-input database and use descriptive statistics to present the most important trends in bank dividends between 2006 and 2022. In our analysis, we use two dividend variables. First, we study the propensity to pay dividends, reflected in a binary variable, which equals one when a bank decides to pay a dividend in a given year. Second, we analyse the level of dividends, through an indicator of dividend to net income. This measure is commonly applied in empirical work and reflects the share of net income that banks decide to pay out as dividends. These two dividend proxies relate to similar,

but not identical dividend questions. The first indicates whether the bank decides to pay or withhold dividends, which is an important signal to market participants and investors. The second shows the level of dividends, which is likely to be a function of bank earnings and the operating environment.

In our study, we present dividends in the context of several areas. First, we analyse the heterogeneity of bank dividend payments across the region of Central and Eastern Europe, to show the geographical diversity of dividend policies. Second, we study dividend payment propensity and dividend levels in relation to the macroeconomic environment, proxied by GDP growth. In this part, we consider differences between dividends paid in strong and weak economic environments. We are interested to see if banks in various countries react to economic downturns and upturns similarly in terms of dividend payments. Third, we explore dividend payments in the context of bank performance, accounting for bank profitability and the level of capital. We compare banks with weak and strong performance, in order to observe whether they differ in terms of both the propensity to pay and the level of dividends.

In order to study bank dividends, we use a unique, hand-input dataset. The dataset is comprised of several building blocks. First, we use financial data of commercial banks from the Bureau van Dijk Orbis database for the period 2006-2022. We gather data on banks from eleven Central and Eastern European countries, including Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. The Orbis database includes only very fragmented data on dividend payments. Hence, in the second step, we hand-input the data on dividends, using bank financial reports, annual reports and result presentations available on official bank websites. Third, we merge this data with macroeconomic data taken from the World Bank. Our dataset includes data for commercial banks from eleven countries. The split of bank-year observations is shown in Table 1.

Table 1.

Sample description: countries and number of observations

Country	Number of observations, 2006-2022	
	bank-year observations	share in total sample (%)
Bulgaria	190	9.17
Czech Republic	283	13.66
Estonia	76	3.67
Croatia	263	12.69
Hungary	240	11.58
Lithuania	62	2.99
Latvia	214	10.33
Poland	233	11.25
Romania	137	6.61
Slovenia	195	9.41
Slovakia	179	8.64
SUM	2072	100

Note. The table shows bank-year observations for the whole period, per country.

Source: own elaboration.

The Central and Eastern European region shows some divergence in terms of the number of banks in various countries. Some countries have large banking sectors with more numerous banks (the Czech Republic, Croatia, Hungary and Poland), while other countries only have several banks and a smaller banking sector (Estonia and Latvia). The main variables used in our study are depicted in Table 2.

Table 2.

Descriptive statistics: the main variables

Variable	Number of observations	Mean	Standard deviation	Min.	Max.
Dividend payment (0 / 1)	2072	0.52	0.50	0	1
Dividend to income (%)	2072	30.52	38.29	0	102.55
ROA (%)	2072	0.75	1.24	-3.40	2.73
Equity to assets (%)	2072	10.79	4.25	4.20	23.85
Bank size (EUR mln)	2072	7.05	11.13	0.01	91.73
GDP growth (%)	2072	2.41	4.07	-16.04	12.83

Note. *Dividend payment* is a binary variable equal to one if there is a dividend payment in a given bank and year; *Dividend to income* is the relation of dividend to net income; *ROA* is the return on assets; *Equity to assets* is the relation of total equity to total assets.

Source: own elaboration.

Descriptive statistics shown in Table 2 indicate that the average dividend payment propensity (*Dividend payment*) is slightly over 50%, indicating that in over half bank-years there is a decision to pay out dividends. Dividends amount to around 30% of net income (*Dividend to income*) and their levels are highly diversified, which is reflected in a relatively high standard deviation. Banks in our sample differ in terms of both profitability and capital. Average return on assets (ROA) is 0.75%, but it varies between banks and years with relatively high losses and high earnings. Mean equity levels are just under 11%, but again we observe large differences throughout our sample. The region has mostly benefitted from sound economic growth in the sample period, but some countries witnessed very severe recessions, including the Baltic states in 2009 recording recessions of over 10%. Summing up, our sample includes a relatively diversified set of banks and countries, including periods of strong economic growth and bank performance, but also economic downturns and net losses in banks. Around half of banks in our sample pay dividends throughout the sample period, while the level of dividend constitutes around 30% of net income on average, with a significant variation of dividend levels across banks.

4. Results

In this section, we present the descriptive statistics, depicting the most important trends in dividend payment propensity and dividend levels in Central and Eastern European banks. First, we show the diversification of dividend payments across the region. Second, we depict dividends in relation to economic growth and third we account for the role of bank profitability and capital.

4.1. Bank dividends across the region

Bank dividends depend on numerous bank-specific and operating environment factors. However, the dividend policy of banks in a country's banking sector also matters for dividend decisions. When most banks in a given country regularly pay dividends and these dividends are high, an individual bank is less likely to refrain from dividend payments or to pay dividends much below the average. In consequence, we first explore differences between national dividend policy in our sample. We present country differences for average dividend payment propensity in Figure 1 and average dividend to income levels in Figure 2.

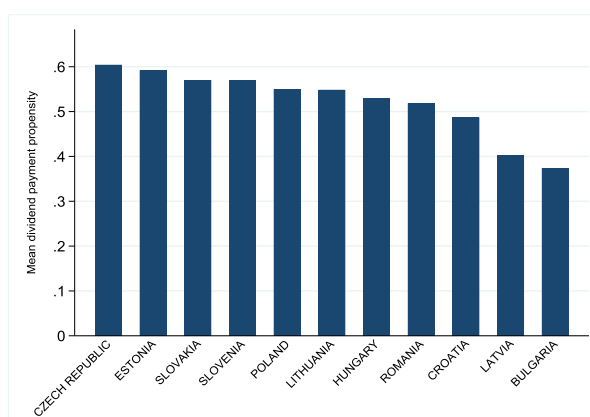


Figure 1. Dividend payment propensity in Central and Eastern European banks.

Source: own elaboration.

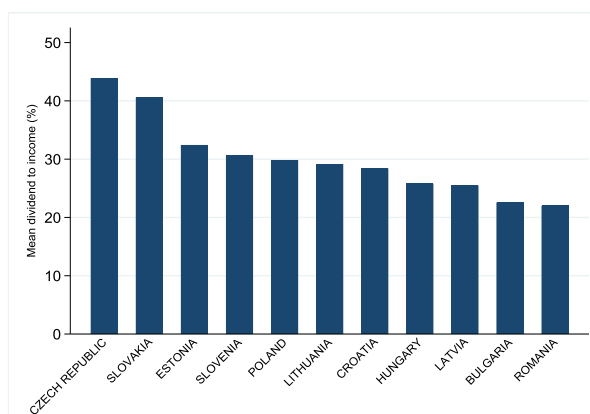


Figure 2. Dividend to income in Central and Eastern European banks.

Source: own elaboration.

We find that there are large differences across countries, when we consider dividend payment propensity (Figure 1). Banks in the Czech Republic and Estonia have an around 60% probability of paying dividends, while Bulgarian and Latvian banks pay dividends only in 40% of cases throughout our sample period. Banks in Slovakia, Slovenia, Poland, Lithuania, Hungary and Romania have an over 50% probability of dividend payments. When we consider the level of dividends (Figure 2), we find that banks in countries with high dividend payment probability have the highest level of dividends. Banks in Czech Republic and Slovakia have the most generous dividend payments, at over 40% of income on average. At the same time, Bulgarian and Romanian banks pay out only slightly over 20% of net income. In conclusion, we find that there is visible heterogeneity between countries in terms of dividend payments.

4.2. Dividends and the macroeconomic environment

In the next step, we explore dividends in terms of their links with economic growth for banks in our sample. We calculate median annual GDP growth for the eleven countries included in our sample. We use the median, instead of the mean, due to large differences in GDP growth between countries, especially in crisis periods. We present dividend payment propensity and GDP growth in Figure 3, while dividend to income and GDP growth is shown in Figure 4.

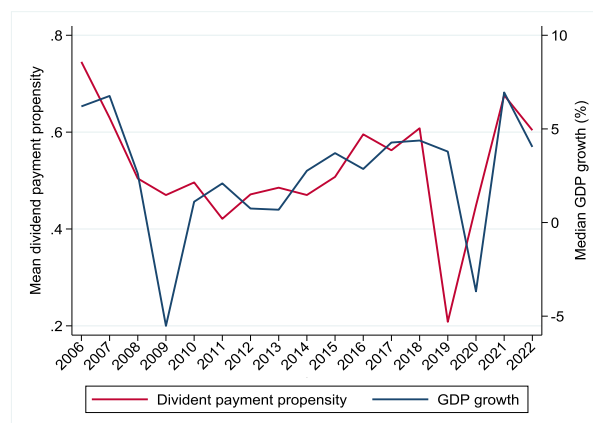


Figure 3. Dividend payment propensity and GDP growth in Central and Eastern European banks.

Source: own elaboration.



Figure 4. Dividend to income and GDP growth in Central and Eastern European banks.

Source: own elaboration.

In general, we find that trends in economic growth and dividend payments run in the same direction. Periods of economic downturns are linked with a lower propensity to pay dividends and a lower level of dividends, which is visible between 2007 and 2009 and also in 2019 and 2020. Importantly, the decline of dividends during the global financial crisis of 2007-2009 is different than the one seen during the Covid-19 pandemic. During the GFC, dividends decline in line with the economic downturn. In 2019, we observe that dividends seem to fall before the economic downturn takes place. This is due to the unique nature of the exogenous shock, such as the Covid-19 pandemic, and the timing of dividend decisions. The Covid-19 pandemic surfaced in Europe in the first quarter of 2020. The severity of the crisis became immediately visible and the GDP decline for the whole of 2020 was certain in the first quarter of 2020. Dividend decisions in banks regarding the previous financial year, in that case 2019, were taken in the first half of the next year. As a result, dividends for 2019 were drastically cut in the first half of 2020. Hence we observe a seemingly counter-intuitive results of dividends falling prior to the economic downturn.

The period between 2013 and 2019 shows dividends in a sound economic environment, when both the propensity to pay and the level of dividends are increasing. The strong decrease in dividends during the pandemic period is more than compensated after the pandemic, with dividends coming back to very high levels that were visible before the GFC.

In the next step, we consider whether changes in dividend payments during periods of high and low GDP growth are different in various countries. In order to study this, we calculate mean dividend payment propensity and dividend levels per country, for periods when GDP growth is above or below the (country) median for the whole period. In order to account for the lagged decisions regarding dividends, we consider dividends with a one-year lag. The results for dividend payment propensity are depicted in Figure 5, while dividend to income in Figure 6.

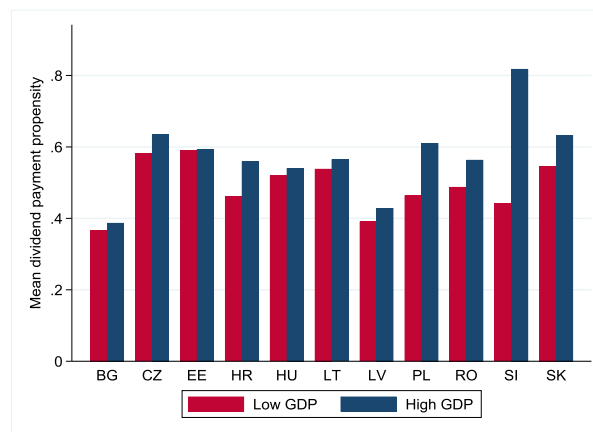


Figure 5. Dividend payment propensity and GDP growth above and below the median in Central and Eastern European banks.

Source: own elaboration.

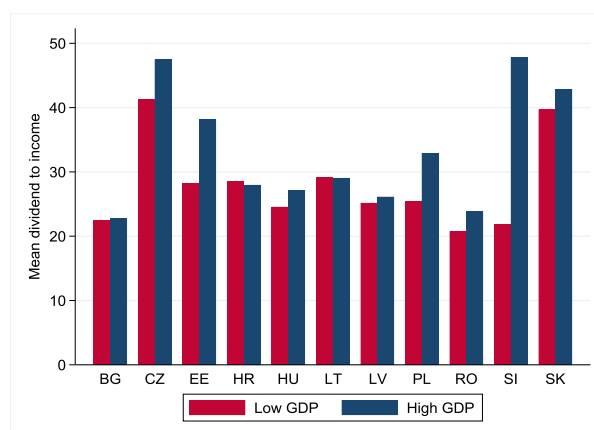


Figure 6. Dividend to income and GDP growth above and below the median in Central and Eastern European banks.

Source: own elaboration.

We find that there is heterogeneity between national banking sectors in terms of dividend payments under strong and weak economic conditions. In some countries, both the propensity to pay (Figure 5) and the level of dividends (Figure 6) are quite similar under low and high GDP growth. This is mostly visible for Bulgaria, Lithuania and Latvia. In other markets, such as the Czech Republic or Estonia, the propensity to pay is similar, but the average level of dividends differs under high and low growth. In Poland, Slovakia and especially Slovenia, the reaction of banks to GDP fluctuations is strongly visible in dividend payment propensity and levels. In periods of high growth, banks on these markets are much more likely to pay dividends and they are higher. During economic downturns, dividends decrease and banks are much less likely to pay them. Summing up, we observe that in Central and Eastern Europe there is heterogeneity in terms of bank dividends on the country level. In some markets, banks are more likely to pay dividends and dividends have a higher share in net income, than on other markets. At the same time, there are also country differences in dividend payments during high and low GDP growth, where some markets show relative stability of dividends, while in other countries dividends seem more dependent on the current economic environment.

4.3. Dividends and bank profitability and capital

Existing literature shows that bank dividends are frequently positive associated with bank profitability and capital levels. In this subsection, we analyse these links in our sample of Central and Eastern European banks. In the first step, we compare dividends of banks with profitability that is higher or lower than median profitability in a given country and year. Results for dividend payment propensity are shown in Figure 7, while dividend to income is presented in Figure 8.

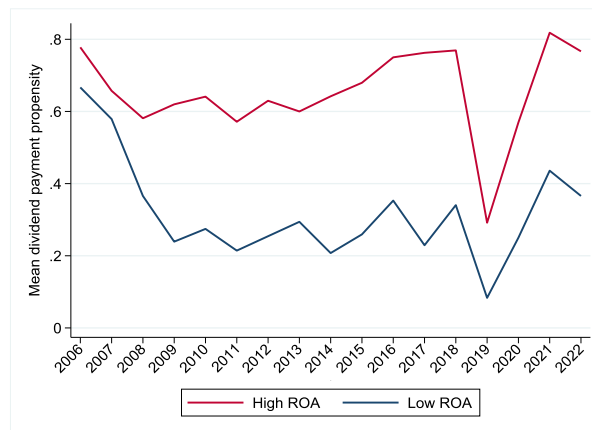


Figure 7. Dividend payment propensity for banks with high and low profitability in Central and Eastern Europe.

Source: own elaboration.

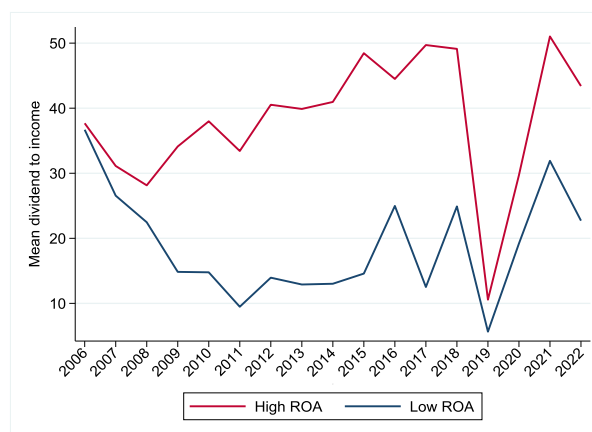


Figure 8. Dividend to income for banks with high and low profitability in Central and Eastern Europe.

Source: own elaboration.

We find that profitability is an important determinant of dividends, both in terms of propensity to pay (Figure 7) and the level of dividends (Figure 8). On average, banks with higher earnings are much more likely to pay dividends and their dividends are much higher than of banks with weak performance. Interestingly, differences in dividend payments between the two groups were relatively small before and in the beginning of the global financial crisis. Starting from 2009, banks with low and high profits start to strongly diverge in terms of dividend payments. Post financial crisis, the only period when the two groups converge in terms of dividends is 2019, when there is a sharp fall in dividends in both groups. The return to high dividends already seen in 2020 and continuing into 2021 is much quicker for highly performing banks, and the differences between the two groups again become more sizeable.

In the second step, we study bank dividends in the context of capital levels. In line with the procedure for bank profitability, we compare dividend payments of banks with equity that is higher or lower than the country median per year. We present results in Figure 9 for dividend payment propensity and Figure 10 for dividend to income.

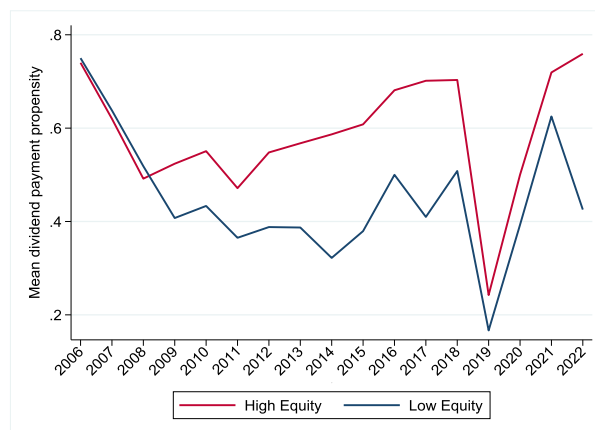


Figure 9. Dividend payment propensity for banks with high and low equity in Central and Eastern Europe.

Source: own elaboration.

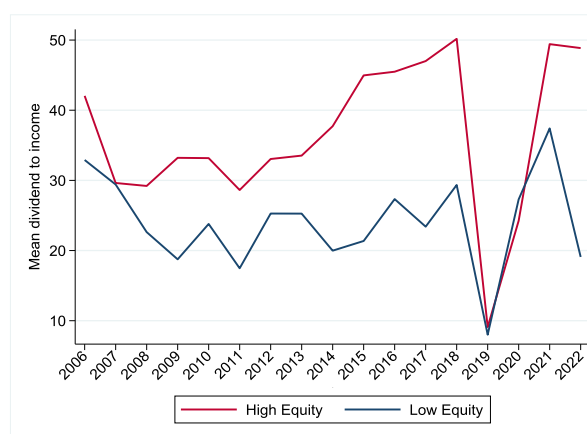


Figure 10. Dividend to income for banks with high and low equity in Central and Eastern Europe.

Source: own elaboration.

The results depicted in Figure 9 and 10 indicate that the level of capitalisation matters for dividend payments in banks. On average, banks with more generous equity cushions are more likely to pay dividends (Figure 9) and the dividends are higher (Figure 10) than of banks with below-median capital. The two groups diverge mostly between 2009 and 2018. Starting from 2019, differences are not so sizeable, indicating that profitability may be a more meaningful indicator to dividend payments than equity in the post-pandemic era. At the same time, it possible that bank regulators and supervisors were more strict about required capital levels in the pandemic period and differences between banks in terms of capital were smaller than before. This may have led to banks no longer determining dividends on the basis of capital, but rather making dividends dependent on profitability.

5. Conclusions

In this paper, we study trends in dividend payments of Central and Eastern European banks over the period 2006 to 2022. We use a unique, hand-input database of dividends for both listed and unlisted banks in eleven countries. We find that there is visible heterogeneity in dividend payment propensity and dividend levels between various countries. Dividends are linked with GDP growth, with higher dividends paid in strong economic environment. At the same time, banks in various countries react differently to changes in the macroeconomic environment. In some countries, dividends paid under strong and weak growth do not differ strongly, proving a consistent and stable dividend policy. In other markets, dividends paid in economic upheavals are much more likely to be paid and much higher than in economic downturns. This potentially shows that some banks in Central and Eastern Europe do not follow patterns of large US banks, which continued to pay dividends during the global financial crisis (Acharya et al., 2022; Floyd et al., 2015).

Dividends of banks in Central and Eastern Europe are positively linked to bank profitability and the level of capital. Banks with strong earnings and large capital buffers are more likely to pay dividends and dividends are higher than of banks with worse performance. The differences between the two groups become especially visible after 2008 and disappear only shortly in 2019. Performance is observed to drive dividend payments more than equity levels. After the COVID-19 pandemic, we find a sharp increase in dividends, regardless of profitability or equity levels. This dividend boost is similar to the observed rebound of dividends in US banks after the global financial crisis (Floyd et al., 2015). This poses an important task for bank regulators and supervisors, which should assure that adequate capital requirements are in place, to avoid dividend over-payment in good times, which may endanger financial stability during more turbulent periods (Ashraf et al., 2016).

In existing literature on bank dividends, studies relating to Central and Eastern Europe are rare. Empirical work on dividends most frequently bases on banks in developed markets, often limiting the samples to listed banks. We observe that on average, banks in Central and Eastern Europe have a much lower dividend payment propensity than listed banks in recent cross-country samples (Gambacorta et al., 2023), euro-area banks (Belloni et al., 2023) or earlier US samples (Chronopoulos et al., 2023). In addition, dividend to income levels are lower than in Western European banks (Belloni et al., 2023; Lepetit et al., 2017). Hence, more research is necessary on bank dividends in Central and Eastern Europe, to understand mechanisms underlying dividend payment decisions made by banks in the region. Possible explanations for different dividend levels, in relation to Western European and US banks, may include the prevalence of majority shareholders in Central and Eastern European banks, differences in bank performance and distinct bank regulation and supervision, especially regarding dividend policy.

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References

1. Abreu, J.F., Gulamhussen, M. A. (2013). Dividend payouts: Evidence from US bank holding companies in the context of the financial crisis. *Journal of Corporate Finance*, Vol. 22, pp. 54-65, doi:10.1016/j.jcorpfin.2013.04.001
2. Acharya, V.V., Gujral, I., Kulkarni, N., Shin, H.S. (2022). Dividends and bank capital in the global financial crisis of 2007-2009. *Journal of Financial Crises*, Vol. 4, No. 2, pp. 1-39.
3. Ashraf, B.N., Bibi, B., Zheng, C. (2016). How to regulate bank dividends? Is capital regulation an answer? *Economic Modelling*, Vol. 57, pp. 281-293, doi:10.1016/j.econmod.2016.05.005
4. Belloni, M., Grodzicki, M., Jarmuzek, M. (2023). Why European banks adjust their dividend payouts? *ECB Working Paper Series*, No. 2765.
5. Chronopoulos, D.K., Johari, E.E.C., Scholtens, B., Sobiech, A.L., Wilson, J.O., Yilmaz, M.H. (2023). Competition and bank dividends. *Journal of International Money and Finance*, Vol. 137, 102898, doi: 10.1016/j.jimonfin.2023.102898
6. d'Udekem, B. (2021). Agency conflicts and dividend persistence. *Journal of Financial Services Research*, Vol. 60, No. 2, pp. 207-234, doi: 10.1007/s10693-021-00348-x
7. De Cesari, A., Gilder, D., Huang, W., Onali, E. (2024). Competition and bank payout policy. *Journal of Money, Credit and Banking*, Vol. 56, No. 7, pp. 1738-1778, doi: 10.1111/jmcb.13028
8. Fahlenbrach, R., Ko, M., Stulz, R.M. (2024). Bank payout policy, regulation, and politics. *NBER Working Paper Series*, No. 32770.
9. Floyd, E., Li, N., Skinner, D.J. (2015). Payout policy through the financial crisis: The growth of repurchases and the resilience of dividends. *Journal of Financial Economics*, Vol. 118, pp. 299-316, doi: 10.1016/j.jfineco.2015.08.002
10. Forti, C., Schiozer, R.F. (2015). Bank dividends and signaling to information-sensitive depositors. *Journal of Banking and Finance*, Vol. 56, pp. 1-11, doi:10.1016/j.jbankfin.2015.02.011
11. Gambacorta, L., Oliviero, T., Shin, H.S. (2023). Low price-to-book ratios and bank dividend payouts: economic policy implications. *Economic Policy*, July, pp. 675-701.

12. Hardy, B. (2021). Covid-19 bank dividend payout restrictions: effects and trade-offs. *BIS Bulletins*, Vol. 38. Bank for International Settlements.
13. Johari, E.E.C., Chronopoulos, D.K., Scholtens, B., Sobiech, A.L., Wilson, J.O. (2020). Deposit insurance and bank dividend policy. *Journal of Financial Stability*, Vol. 48, 100745, doi: 10.1016/j.jfs.2020.100745
14. Kanas, A. (2013). Bank dividends, risk, and regulatory regimes. *Journal of Banking and Finance*, Vol. 37, No. 1, pp. 1-10, doi: 10.1016/j.jbankfin.2012.05.018
15. Lepetit, L., Meslier, C., Strobel, F., Wardhana, L. (2018). Bank dividends, agency costs and shareholder and creditor rights. *International Review of Financial Analysis*, Vol. 56, pp. 93-111, doi: 10.1016/j.irfa.2017.12.007
16. Lepetit, L., Meslier, C., Wardhana, L. (2017). Reducing agency conflicts through bank dividend payout decisions: the role of opacity and ownership structure. *Applied Economics*, Vol. 49, No. 49, pp. 4999-5026, doi: 10.1080/00036846.2017.1296556
17. Onali, E. (2014). Moral hazard, dividends, and risk in banks. *Journal of Business Finance and Accounting*, Vol. 41, No. 1-2, pp. 128-155, doi: 10.1111/jbfa.12057
18. Srivastav, A., Armitage, S., Hagendorff, J. (2014). CEO inside debt holdings and risk-shifting: Evidence from bank payout policies. *Journal of Banking and Finance*, Vol. 47, pp. 41-53, doi: /10.1016/j.jbankfin.2014.06.016
19. Trinh, V.Q., Elnahass, M., Salama, A. (2021). Board busyness and new insights into alternative bank dividends models. *Review of Quantitative Finance and Accounting*, Vol. 56, pp. 1289-1328, doi: 10.1007/s11156-020-00924-7
20. Trinh, V.Q., Kara, A., Elnahass, M. (2022). Dividend payout strategies and bank survival likelihood: A cross-country analysis. *International Review of Financial Analysis*, Vol. 81, 102129, doi: /10.1016/j.irfa.2022.102129

INTEGRATING DYNAMIC CAPABILITIES AND SUSTAINABLE INNOVATION DESIGN IN BUSINESS TRANSFORMATION

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Purpose: The purpose of this paper is to determine to what extent sustainable innovation drives the transformation of enterprises toward sustainable development and to assess its impact on local communities.

Design/methodology/approach: The study employs a literature review and analysis of two bioeconomy case studies a model integrating dynamic capabilities (sensing, seizing, reconfiguring) with sustainable innovation design.

Findings: Early identification of market and social signals enables precise targeting of innovation efforts; stakeholder engagement from the conceptual stage strengthens acceptance and addresses local needs; and flexible reconfiguration of production and business processes minimizes unintended negative impacts while building lasting competitive advantage.

Research limitations/implications: The research is based on two case studies in the bioeconomy sector, which may limit the generalizability of the findings. Future research should include quantitative analyses and cross-industry comparisons.

Practical implications: The proposed model serves as a practical guide for managers to effectively align economic, social, and environmental objectives during the design and implementation of innovations.

Social implications: The paper emphasizes the need for continuous stakeholder dialogue and monitoring to enhance social acceptance and mitigate adverse effects on the surrounding community.

Originality/value: This paper introduces a novel model that embeds dynamic capabilities into each phase of sustainable innovation design, bridging strategic, local, and global perspectives.

Keywords: dynamic capabilities; sustainable innovation; business transformation; stakeholder engagement; socio-environmental effects.

Category of the paper: Conceptual paper.

1. Introduction

The last three industrial revolutions were largely driven by the development of technology and the elevation of procedures. The fourth revolution, on the other hand, marks a change focused on appropriately aligned capabilities and sustainable performance. Under these

circumstances, there is a growing need for companies to develop appropriately aligned dynamic capabilities for sustainable performance (Primc, Čater, 2015). The main challenge for companies in developing such dynamic capabilities is to balance the relationship between economic benefits and environmental responsibility, and ultimately to achieve the strategic goal of sustainability (Chan et al., 2017; Li et al., 2019; Nguyen et al., 2017) while taking into account social requirements.

Companies, therefore, are increasingly under pressure to grow and maximise profits from their shareholders and, on the other hand, under pressure from society in terms of ecology and responsibility for the products and services they produce. The relationship between the company and its environment is based on the implicit expectation that the company's negative impact on the environment is reduced at each stage of production (Tatić Kasim, Haračić, 2018). Therefore, it is important to match the given business operations and their volume to the existing environmental conditions, to rationally manage natural resources and produce products, to use products in a way that does not endanger the environment and society and, at the same time, to provide a competitive advantage (Wu et al., 2019).

In order to meet these demands and achieve long-term sustainability, companies take actions that stem from entrepreneurship, which translates into finding new solutions and creating innovation or new value in economic, social and environmental dimensions in addition to solving existing problems (Johnson, Schaltegger, 2019; Muñoz, Cohen, 2018; Sarango-Lalangui et al., 2018). Innovation therefore creates new practices and leads to changes in organisational structures and people's actions.

As it were, sustainable innovations should be the answer and solution to the above challenges. These have their roots in sustainable development and are based on the principles of ethical, social, economic and environmental sustainability. Similar principles can be seen in eco-innovation (Boons, Lüdeke-Freund, 2013; Hall, Clark, 2003; Rennings, 2000), in frugal innovation and engineering (Bhatti, Ventresca, 2012), and in the development of shared value thinking (Porter, Kramer, 2011), but the broader concept of sustainable innovation needs to be thoroughly refined. Especially in the area of local impact. The impact stage of an innovation is often overlooked in innovation research because an innovation is considered ready when it is implemented.

Furthermore, there is a general assumption that innovations are always useful, valuable and positive in nature. These characteristics cannot be verified without considering the impact of the innovation. An innovation could be an economic success but socially a disaster because of its impact on social practices. Some researchers have pointed out that it is possible for an innovation to be detrimental or uneconomic from an individual or social system perspective (Rogers, 2003; Rogers, Schoemaker, 1971). As the author's research has shown, a negative effect of innovation activity in the bioeconomy area is odour nuisance. Success in the environmental area, has not translated into success in the social sphere. The principle, think globally act locally, did not work. The result of the innovation in the social area was an odour

nuisance for local residents. Another example is the product innovation in the production of biopolymers, an innovative material with unique ecological characteristics. Production at scale can shake up the food market. On the one hand, it is an innovation that responds to ecological challenges, while on the other it addresses the difficult question of what is more important: food or ecology. All this means that the delight of sustainable innovation can be temporary if we do not establish design principles that take into account all stakeholders right from the innovation design stage.

The selection of two examples from the bioeconomy sector was deliberate and exploratory in nature—both cases were chosen for their significance to Poland's sustainable development strategy and their visible impact on local communities. The example of innovation in biopolymer production reflects the global dimension of the challenges associated with balancing ecological and food needs, while the example of innovation causing odor nuisance shows the complexity of local impacts. In this way, both studies capture the contrast between the “global” and “local” perspectives, which was key to developing the proposed model.

The bioeconomy was chosen as the area of analysis due to its growing importance in sustainable development strategies at both the European and national levels. This sector combines three key perspectives:

- global – through innovations such as biopolymers, which respond to global environmental challenges,
- local – through projects related to bio-waste management, the effects of which are felt directly in communities,
- strategic – as an area for testing and implementing the dynamic capabilities of enterprises in the context of the transition to sustainable development.

As a result, the bioeconomy is a unique example of a sector in which the tensions between global trends and the local consequences of innovation are clearly visible. The following table presents a comparative analysis of two cases in the context of dynamic capabilities.

Table 1.
Comparative analysis

Criterion / Dimension	Case A: Biopolymer innovation	Case B: Innovation in bio-waste management (odour nuisance)
Sensing (signal recognition)	Early identification of global trends in ecology and the demand for alternatives to plastics.	Identification of local needs related to organic waste management.
Seizing (exploiting opportunities)	Investment in the development of a new material with unique ecological properties; commercialization on the international market.	Implementation of an innovative technological process on a local scale, supported by environmental policy.
Reconfiguring (transforming resources)	Adaptation of production lines to biopolymer production; creation of new partnerships in the supply chain.	Reorganisation of waste management processes; insufficient adaptation to social sensitivity.
Economic effect	Potential opening of new markets and sources of revenue; risk of disruption in the food market.	Reduction of waste storage costs; limited profitability in the absence of social acceptance.

Cont. table 1.

Environmental effect	Reduction of CO ₂ emissions by replacing conventional plastics with biopolymers.	Positive environmental effects (waste reduction), but accompanying odor nuisance reduces environmental value.
Social effect	Positive global image of the company; controversy over priorities (food vs. ecology).	Negative impact on the local community (nuisance effect); reduction of social acceptance of innovation.

With these assumptions in mind, the main objective of the article will be to determine to what extent sustainable innovation is a factor influencing the transformation of companies towards sustainability. A second complementary research objective will be to determine the impact effect of sustainable innovation. It will therefore be crucial to answer the following questions:

1. How companies shape sustainability policies: whether based on individual sustainable innovations or whether these actions are directed towards a strategic direction of sustainable transformation activities.
2. Whether sustainable innovation is instrumentally used consistently with the organisation's strategy, as well as whether it influences stakeholder engagement and who participates in the design process.
3. To what extent sustainable innovation impacts on the local community.

2. Transforming access to technology into green business practices: dynamic capabilities as an engine for sustainable development strategies

The rapid advances in technology over the past few decades have dramatically improved organisational efficiency, but at the same time created higher expectations for making business operations more sustainable (Ruiz-Mercader et al., 2006). Furthermore, unlike in the past, when only a few organisations had access to the latest technologies, today organisations have relatively wide access to technology (Chen et al., 2019). However, this state of affairs has led them to be sceptical of technology investments, as these do not achieve sustainable competitive advantage (Dubey et al., 2019).

Hence, the way to achieve this advantage seems to be through achieving sustainability by implementing green practices in strategy. Recent research findings indicate that companies can achieve a competitive advantage if they meet economic, social and environmental requirements (Jabbour et al., 2018). Its sustainability in turn depends on business operations (Pfeffer, 2010), which are largely driven by purpose and strategy. Green and transparent business practices are also crucial for developing adequate dynamic capabilities, which, properly developed, can ensure the sustainability of performance. Hence, researchers argue that business practices and performance are closely linked and influence organisational sustainability (Gupta et al., 2020).

The last three industrial revolutions were largely driven by the development of technology and the elevation of procedures (Gupta et al., 2020). The fourth revolution, on the other hand, marks a change focused on the right fit between capabilities and sustainable performance. According to Lin and Chen (2012), the initial application of these capabilities may be more expensive, but in the long run they will strengthen the organisation's structure and give it a competitive advantage. In these circumstances, there is a growing need for companies to develop dynamic capabilities that are properly aligned with sustainability (Primc, Čater, 2015).

Dynamic sustainability capabilities refer to the ability of firms to sense, acquire and reconstruct internal, and external organisational resources, including ecological (green) and technological resources, to cope with changing business environments and through the primary path - dependency and creation of new organisational resources and strategic practices (Eisenhardt, Martin, 2000; Wohlgemuth, Wenzel, 2016). These capabilities actively support circular strategies and ecological innovation practices in turbulent business environments and are one source of competitive advantage for firms (Dangelico et al., 2015).

The main objective of companies in developing this type of dynamic capability is to balance the relationship between economic benefits and environmental responsibility, ultimately achieving the strategic goal of sustainable development (Chan et al., 2017; Li et al., 2019; Nguyen et al., 2017).

The literature points out that there is a link between dynamic capabilities in the area of sustainability and innovation. For example, dynamic capabilities have been found to actively influence an organisation's green behaviour (Huang, Li, 2017). The dynamic capabilities of organisations dedicated to sustainability are not homogeneous. In their structure, one can distinguish between the ability to sense the environment, the ability to capture resources and the ability to reconfigure resources.

Environmental sensing capability can determine the future direction of a business by identifying and managing potential opportunities (or risks) in the current business environment (Teece, 2010). Environmental sensing capability requires businesses to identify opportunities (or risks) and exploit them by re-allocating organisational resources according to their strategic needs. This capability can be seen as most closely related to dynamic capability (Hartman et al., 2017). In particular, it refers to companies that are able to identify future development trends in their business environment through data collection (Salunke et al., 2019). This information includes information related to green customer preferences, market demand and the development of clean technologies.

The ability to capture resources enables a commercial growth strategy. Businesses need to assimilate and learn from the data, information and experience that creates and maintains a competitive resource base (Teece, 2010). On the one hand, the acquisition of resources highlights which information is worthy of being used by the enterprise, i.e. which has the greatest value (Dangelico, 2016). In addition, this capability requires the firm to use the newly acquired technological information for its routine activities, e.g. through the technology

commercialisation process. In summary, this capability can be defined as a firm's ability to absorb green growth-related information and use it for its technology commercialisation activities.

In turn, the ability to reconfigure resources enables a firm to maintain its competitive advantage in the market after successfully sensing and exploiting the opportunities (or risks) that exist in the business environment (Wang, Ahmed, 2007). However, the key to sustainable competitive advantage is having the ability to reconfigure resources as the firm grows and the environment changes (Lin, Wu, 2014). In this context, firms need to reconfigure resources to remain adaptable to the external business environment and, if obstacles arise, adopt alternative ways of business development.

In this strand, it is legitimate to pay attention to sustainable innovation. Taking the right perspective when analysing the idea of sustainable innovation, Boons, Montalvo, Quist and Wagner propose a general explanation stating that a sustainable innovation is an innovation that improves sustainability performance in terms of environmental, economic and social criteria (Boons et al., 2013, p. 4). In a similar vein, Bos-Brouwers and Calik and Bardudeen argue that a 'sustainable' innovation can be called an innovation where improvements in products, services, technological or organisational processes commercialised or implemented internally not only improve economic performance, but also improve environmental and social performance. In this way, both in the short and long term, sustainable innovation can generate positive social and environmental impacts (Bos-Brouwers, 2010; Horbach, 2005; Calik, Bardudeen, 2016). Furthermore, Tello and Yoon particularly emphasise the concern for resource use, pointing out that sustainable innovation can be defined as new products, processes, services and technologies that contribute to the development and well-being of human needs and institutions by respecting worlds.

In other words, the term 'sustainable innovation' refers to new products and processes that use fewer environmental resources, promote human health and are affordable for both consumers and producers. Secondly, the aforementioned author argues that sustainable innovation is also about building an organisation capable of maintaining the pace of innovation for several years (ten or more). He offers his second explanation with the observation that a single innovation will not support a company or cause fundamental changes in an industry (Hargadon, 2015). An interesting point of view is presented by Dyck and Silvestre, who distinguish between 'sustainable innovation 1.0' and 'sustainable innovation 2.0'. According to the aforementioned authors, the term 'sustainable innovation 1.0' refers to innovations that aim to both reduce the negative socio-ecological externalities of an organisation and enhance its financial interests. On the contrary, they describe as 'sustainable innovation 2.0' innovations that are driven by the social and environmental benefits they will bring. In other words, Dyck and Silvestre emphasise that the ultimate goal of 'sustainable innovation 2.0' is to improve overall social and environmental well-being. This type of innovation enables organisations to enhance positive socio-ecological externalities while maintaining financial viability, but without maximising financial returns (Dyck, 2018).

3. The complexity of sustainable development and the need for sustainable innovation

Sustainability is a complex issue and, despite many studies and publications in recent years, remains poorly recognised (Ramcilovic-Suominen, Pulzl, 2018; Johnson, Schaltegger, 2019; Muñoz, Cohen, 2018). Achieving the Sustainable Development Goals under the 2030 Agenda for Sustainable Development for the production and consumption of safe and healthy food and promoting sustainable business practices depends on research and innovation (Schutte, 2018). Therefore, the transition to a sustainable economy requires investments in technology, new business models and social and environmental innovations that help shape new business trends (Zilberman et al., 2018).

In order to achieve long-term sustainability, companies undertake actions driven by entrepreneurship, which translates into finding new solutions and creating innovation or new value economically, socially and environmentally in addition to solving existing problems (Johnson, Schaltegger, 2019; Muñoz, Cohen, 2018; Sarango-Lalanguí et al., 2018). Sustainability has been one of the drivers of innovation. Nidumolu, Prahalad and Rangaswami (2009) argue that there is no alternative to sustainability, and this principle has challenged companies to develop products and services for new cleantech markets, for better life-cycle control of products and services, for the use of recycled materials to increase energy efficiency and improve quality of life.

The relationship between the company and its environment is based on the implicit expectation that the company's negative impact on the environment is reduced at each stage of production (Tatić Kasim, Haračić, 2018).

Therefore, it is important to match the given business operations and their size to the existing environmental conditions, to rationally manage natural resources and produce products, to use products in a way that does not endanger the environment and society and, at the same time, to ensure competitive advantage (Wu et al., 2019). On the other hand, in order to meet demand, enterprises are producing more and more products, which in turn entails the need for more resources, materials, energy, water, fuel and other consumables necessary for production purposes.

The increased consumption and the huge number of new products appearing on the market each year, combined with the reduced life span of products, translates into increased consumption of raw materials, energy and more solid waste generated by agglomerations and other residential areas. Companies are therefore increasingly under pressure to grow and maximise profits from shareholders and, on the other hand, pressure from society to be environmentally friendly and responsible for the products and services they produce.

The solution may lie in sustainable innovation, rooted in sustainability, which is based on the principles of ethical, social, economic and environmental sustainability. Similar principles can be seen in eco-innovation (Boons, Lüdeke-Freund, 2013; Rennings, 2000), in frugal innovation and engineering (Bhatti, Ventresca, 2012), and in the development of shared value thinking (Porter, Kramer, 2011), but the broader concept of sustainable innovation needs to be thoroughly refined.

One of the challenges in innovation design is the impact stage, which is often overlooked in innovation research because an innovation is considered ready when it is implemented. In addition, there is a general assumption that innovations are always useful, valuable and of a good nature. These characteristics cannot be verified without considering the impact of the innovation. An innovation could be an economic success but socially a disaster because of its impact on social practices.

Some researchers have pointed out that it is possible for an innovation to be harmful or wasteful from an individual or social system perspective (Rogers, 2003; Rogers, Schoemaker, 1971), but the given nature of the innovation requires further research. When considering sustainable innovation, it can be argued, following Zeng et al. that this is difficult to achieve within a single organisation (Zeng et al., 2017). The aforementioned authors emphasise the need for sustainable innovation ecosystems created by continuous interactions between organisations, policies, society and the environment. Finally, some authors identify sustainable innovation as a concept consisting of several approaches to sustainability-related (sustainability-oriented) innovation, such as green innovation, eco-innovation, environmental innovation, bottom-up innovation, socially responsible innovation, etc. In business, innovation was created by the need to create superior competitiveness in the market. This has traditionally been achieved through two basic strategies: cost-cutting or creating products that are better than those of competitors (i.e. cost leadership or differentiation strategies) (Porter, 1980).

Sustainable innovation offers a third competitive strategy: creating products or processes with market-demanded characteristics such as sustainability, localisation or material and energy efficiency (Rennings, 2000). As consumers demand sustainable products and services and are willing to pay more for them, the market for sustainable innovation is growing. Sustainable innovations help customers and citizens manage their lifestyles, enabling them to live happier lives in ways that support sustainability. Sustainable innovation is the foundation of future business. The tasks that sustainable innovation serves are of global importance, but they start with the local community.

4. Final conclusions

Social pressures, concerns about resource depletion and legislation are driving companies to make the transition towards sustainability. An example of this is the chemical industry, which is hardly identified with a sustainable approach, yet has projects that are firmly in the sustainability strand, such as the conversion of glycerol to biopolymers. It is therefore crucial that attention is paid to the need for companies to develop dynamic capabilities that are properly aligned with sustainability. These capabilities refer to the ability of companies to sense, acquire and reconstruct internal, and external organisational resources, including environmental (green) and technological resources, in order to cope with changes in the business environment and through the primary path - dependency and creation of new organisational resources and strategic practices.

As indicated in the rationale for addressing the research problem, the impact phase is often overlooked in innovation. It is therefore necessary to determine the impact of an innovation taking into account the sustainability triad, i.e. the economic, environmental and social aspects. To this end, it is necessary to take into account all stakeholders (the quadruple helix). This will appeal to the gap signalled in the literature, about the need to create sustainable innovation ecosystems created by continuous interactions between organisations, policies, society and the environment.

The quadruple helix model (science – business – administration – civil society) allows us to capture the systemic nature of sustainable innovation. Incorporating this approach into the analysis emphasizes that:

- the ability to sense market and social signals is supported by cooperation with science and citizens,
- the ability to seize opportunities requires the involvement of business and public administration, which create regulatory and financial conditions,
- the ability to reconfigure resources is made possible by cooperation in networks involving various stakeholder groups.

The integration of the quadruple helix with the dynamic capabilities framework indicates that true sustainable transformation requires not only internal organizational efficiency, but also openness to cooperation within the innovation ecosystem. It is also crucial to treat sustainable innovation as a solution that responds to the local situation and the interests and values of the communities involved. There is an assumption that grassroots initiatives operate in the civil society arena and involve committed activists experimenting with social innovations as well as using greener technologies. This makes it possible to identify future customer needs. This will allow us to develop objective criteria for sustainable innovation.

It also makes sense to establish a so-called renewed balance between local and global approaches, i.e. a balance between local and global activities. If global trends influence local activities, but local or regional organisations do not have the capacity to influence these trends, alienation of these organisations can occur. So local solutions should be stimulated where possible and useful.

The above considerations can contribute to further research and will allow a better understanding of the mechanisms of the organisation.

They will enable the development of knowledge in the transformation of businesses towards sustainability. and the concept of dynamic capabilities in sustainability. The research will allow the adaptation of the concept of measuring dynamic capabilities, in terms of: the ability to sense the environment, the ability to capture resources, the ability to reconfigure resources.

In addition, traditionally the understanding of competitive advantage has consisted of two basic strategies: a cost leadership strategy or a differentiation strategy. The development of research in this area will advance the knowledge of sustainability-based strategy and the understanding of the extent to which strategy should reflect the variability and dynamics of the environment

It should also be noted that the public's high awareness of ecology makes consumers demand sustainable products and services. Further research will develop knowledge in the design of innovations taking into account all stakeholders. This will allow for a better understanding of the needs of the audience and thus negate the negative effects of innovations.

The case studies analyzed show that the success of sustainable innovations largely depends on the quality and nature of interactions with stakeholders:

- in the case of biopolymer innovation, cooperation with industry organizations, scientific institutions, and partners in the value chain was crucial, enabling both commercialization and social and environmental acceptance of the product;
- in the case of innovation in biowaste management, contacts with local authorities and neighboring communities were important; however, a lack of sufficient communication and participatory activities led to a decline in social acceptance, despite a positive environmental balance.

In conclusion, carrying out research in this area will contribute to the development of the scientific field, especially under the dynamic conditions of the fourth industrial revolution, which very much influences the need to redefine organisational structures in relation to a sustainable model of business management, defining strategic objectives based on the concept of sustainability and complementing innovation creation processes with stages relevant to all stakeholders, maintaining a balance of economic, social and environmental aspects.

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References

1. Bhatti, Y.A., Ventresca, M. (2012). *The emerging market for frugal innovation: Fad, fashion, or fit?* SSRN. <http://dx.doi.org/10.2139/ssrn.2005983>
2. Boons, F., Lüdeke-Freund, F. (2013). Business models for sustainable innovation: State of the art and steps towards a research agenda. *Journal of Cleaner Production*, 45, 9-19. <https://doi.org/10.1016/j.jclepro.2012.07.007>
3. Boons, F., Montalvo, C., Quist, J., Wagner, M. (2013). Sustainable innovation, business models and economic performance: An overview. *Journal of Cleaner Production*, 45, 1-8.
4. Bos-Brouwers, H.E.J. (2010). Corporate sustainability and innovation in SMEs: Evidence of themes and activities in practice. *Business Strategy and the Environment*, 19, 417-435.
5. Calik, E., Bardudeen, F.A. (2016). A measurement scale to evaluate sustainable innovation performance in manufacturing organizations. *Procedia CIRP*, 40, 449-454.
6. Charter, M., Clark, T. (2007). *Sustainable innovation: Key conclusions from sustainable innovation conferences 2003-2006 organised by the Centre for Sustainable Design*. University for the Creative Arts.
7. Chen, H.Y., Das, A., Ivanov, D. (2019). Building resilience and managing post-disruption supply chain recovery: Lessons from the information and communication technology industry. *International Journal of Information Management*, 49, 330-342.
8. Dangelico, R.M., Pujari, D., Pontrandolfo, P. (2017). Green product innovation in manufacturing firms: A sustainability-oriented dynamic capability perspective. *Business Strategy and the Environment*, 26(4), 490-506.
9. Dubey, R., Gunasekaran, A., Childe, S.J., Roubaud, D., Fosso Wamba, S., Giannakis, M., Foropon, C. (2019). Big data analytics and organizational culture as complements to swift trust and collaborative performance in the humanitarian supply chain. *International Journal of Production Economics*, 210, 120-136.
10. Dyck, B., Silvestre, B.S. (2018). Enhancing socio-ecological value creation through sustainable innovation 2.0: Moving away from maximizing financial value capture. *Journal of Cleaner Production*, 171, 1593-1604.

11. Eisenhardt, K.M., Martin, J.A. (2000). Dynamic capabilities: what are they? *Strategic Management Journal*, 21(10-11), 1105-1121.
12. Flipse, S.M., van der Sanden, M.C.A., Radstake, M., de Winde, J.H., Osseweijer, P. (2014). The DNA of socially responsible innovation: Social and natural scientists need to establish mutual understanding and a common language to efficiently work together. *EMBO Reports*, 15, 134-137.
13. Franceschini, S., Faria, L.G.D., Jurowetzki, R. (2016). Unveiling scientific communities about sustainability and innovation: A bibliometric journey around sustainable terms. *Journal of Cleaner Production*, 127, 72-83.
14. Gupta, S., Drave, V.A., Dwivedi, Y.K., Baabdullah, A.M., Ismagilova, E. (2020). Achieving superior organizational performance via big data predictive analytics: A dynamic capability view. *Industrial Marketing Management*, 90, 581-592.
15. Hargadon, A. (2015). *Sustainable innovation: Build your company's capacity to change the world*. Stanford University Press.
16. Hartman, P., Gliedt, T., Widener, J., Loram, R.W. (2017). Dynamic capabilities for water system transitions in Oklahoma. *Environmental Innovation and Societal Transitions*, 25, 64-81.
17. Horbach, J. (2005). Indicator systems for sustainable innovation. In: *Sustainability and Innovation* (pp. 1-27). Heidelberg: Physica-Verlag.
18. Huang, J.W., Li, Y.H. (2017). Green innovation and performance: The view of organizational capability and social reciprocity. *Journal of Business Ethics*, 145(2), 309-324.
19. Jabbour, C.J.C., de Sousa Jabbour, A.B.L., Filho, M.G., Roubaud, D. (2018). Industry 4.0 and the circular economy: A proposed research agenda and original roadmap for sustainable operations. *Annals of Operations Research*, 270, 273-286.
20. Johnson, M.P., Schaltegger, S. (2019). Entrepreneurship for sustainable development: A review and multilevel causal mechanism framework. *Entrepreneurship Theory and Practice*. Advance online publication. <https://doi.org/10.1177/1042258719885368>
21. Klemmer, P., Lehr, U., Lobbe, K. (1999). *Environmental innovation: Volume 3 of publications from a joint project on innovation impacts of environmental policy instruments; Synthesis report of a project commissioned by the German Ministry of Research and Technology (BMBF)*. Analytica-Verlag.
22. Konecki, K., Chomczynski, P. (2012). *Dictionary of qualitative sociology*. Difin.
23. Levy, Y., Ellis, T.J. (2006). A systems approach to conduct an effective literature review in support of information systems research. *Informing Science Journal*, 9, 181-211.
24. Lin, A., Chen, N.C. (2012). Cloud computing as an innovation: Perception, attitude, and adoption. *International Journal of Information Management*, 32(6), 533-542.
25. Lin, Y., Wu, L.-Y. (2014). Exploring the role of dynamic capabilities in firm performance under the resource-based view framework. *Journal of Business Research*, 67(3), 407-413.

26. Loya, M.I.M., Rawani, A.M. (2017). Adoption factors for green brick innovation: An empirical study of consumers in India. *International Journal of Innovation and Sustainable Development*, 11, 23-36.
27. Muñoz, P., Cohen, B. (2017). Sustainable entrepreneurship research: Taking stock and looking ahead. *Business Strategy and the Environment*, 27(3), 300-322. <https://doi.org/10.1002/bse.2000>
28. Nguyen, H.T., Skitmore, M., Gray, M., Zhang, X.L., Olanipekun, A.O. (2017). Will green building development take off? An exploratory study of barriers to green building in Vietnam. *Resources, Conservation and Recycling*, 127, 8-20.
29. Nidumolu, R., Prahalad, C.K., Rangaswami, M.R. (2009). Why sustainability is now the key driver of innovation. *Harvard Business Review*, 87(9), 56-64.
30. Pfeffer, J. (2010). Building sustainable organizations: The human factor executive overview. *Academy of Management Perspectives*, 24(1), 34-45.
31. Porter, M.E. (1980). *Competitive strategy: Techniques for analysing industries and competitors*. Free Press.
32. Porter, M.E., Kramer, M.R. (2011). Creating shared value. *Harvard Business Review*, 89(1/2), 62-77.
33. Primc, K., Čater, T. (2015). The influence of organizational life cycle on environmental proactivity and competitive advantage: A dynamic capabilities view. *Organization & Environment*, 29(2), 212-230.
34. Ramcilovic-Suominen, S., Pülzl, H. (2018). Sustainable development: A "selling point" of the emerging EU bioeconomy policy framework? *Journal of Cleaner Production*, 172, 4170-4180. <https://doi.org/10.1016/j.jclepro.2016.12.157>
35. Rennings, K. (2000). Redefining innovation-Eco-innovation research and the contribution from ecological economics. *Ecological Economics*, 32, 319-332.
36. Rogers, E.M. (2003). *Diffusion of innovations* (5th ed.). Free Press.
37. Rogers, E.M., Schoemaker, F.F. (1971). *Communication of innovations: A cross-cultural approach* (2nd ed.). Free Press.
38. Ruiz-Mercader, J., Merono-Cerdan, A., Sabater-Sanchez, R. (2006). Information technology and learning: Their relationship and impact on organizational performance in small businesses. *International Journal of Information Management*, 26(1), 16-29.
39. Salunke, S., Weerawardena, J., McColl-Kennedy, J.R. (2019). The central role of knowledge integration capability in service innovation-based competitive strategy. *Industrial Marketing Management*, 76, 144-156.
40. Sarango-Lalangui, P., Álvarez García, J., Rama, D. (2018). Sustainable practices in small and medium-sized enterprises in Ecuador. *Sustainability*, 10(6), 621. <https://doi.org/10.3390/su10062105>
41. Schiederig, T., Tietze, F., Herstatt, C. (2012). Green innovation in technology and innovation management-An exploratory literature review. *R&D Management*, 42, 180-192.

42. Schütte, G. (2017). What kind of innovation policy does the bioeconomy need? *New Biotechnology*, 40, 40-47. <https://doi.org/10.1016/j.nbt.2017.04.003>
43. Sekaran, U., Bougie, R. (2010). *Research methods for business: A skill-building approach* (5th ed.). Wiley.
44. Seyfang, G., Smith, A. (2007). Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environmental Politics*, 16, 584-603.
45. Silverman, D. (2010). *Conducting qualitative research*. PWN.
46. Tatić Kasim, M.U., Haračić, M. (2018). Corporate environmental responsibility and stakeholder expectations. *Journal of Business Ethics*, 149(3), 593-607.
47. Teece, D.J. (2010). Business models, business strategy and innovation. *Long Range Planning*, 43(2-3), 172-194.
48. Tello, S.F., Yoon, E. (2008). Examining drivers of sustainable innovation. *International Journal of Business Strategy*, 8, 164-169.
49. Wang, C.L., Ahmed, P.K. (2007). Dynamic capabilities: A review and research agenda. *International Journal of Management Reviews*, 9(1), 31-51.
50. Wohlgemuth, V., Wenzel, M. (2016). Dynamic capabilities and routinization. *Journal of Business Research*, 69(5), 1944-1948.
51. Zeng, D., Hu, J., Ouyang, T. (2017). Managing innovation paradox in the sustainable innovation ecosystem: A case study of ambidextrous capability in a focal firm. *Sustainability*, 9(11), 2091.
52. Zhang, J., Olanipekun, A.O., Lyu, S. (2019). Environmental impact assessment of transportation infrastructure in the life cycle: Case study of a fast track transportation project in China. *Energies*, 12(6), Article 2106.
53. Zilberman, D., Holland, T.G., Trilnick, I. (2018). Agricultural GMOs-What we know and where scientists disagree. *Sustainability*, 10(5), 1514. <https://doi.org/10.3390/su10051514>

ANALYSIS OF THE DIVERSITY OF EVALUATIONS OF CULTURAL SERVICES IN CZĘSTOCHOWA

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Purpose: The purpose of this article is to present research on the differences in evaluations of cultural services in Częstochowa among residents and tourists using the city's cultural services. The study analyzed aspects of service evaluation such as the availability of cultural offerings, the level of service, the quality of transportation, and the overall satisfaction of event attendees. The study was conducted on two groups of respondents. The first group comprised individuals who highly value cultural services, while the second group considered cultural services to be less important.

Design/methodology/approach: The study's objectives were achieved by conducting quantitative research and obtaining results in the form of conclusions. The primary research method was a survey conducted among Częstochowa residents and tourists using the city's cultural services. The Kolmogorov-Smirnov method was used in statistical research to determine differences between the surveyed groups of respondents. This method was used to determine similarities between two groups of people – those for whom cultural services are highly important and those for whom cultural services are less important. The hypothesis was that the surveyed groups do not differ in their assessment of the quality of cultural services. From this perspective, the hypothesis assumes similarity between the two groups. The alternative hypothesis assumes that the groups differ in their assessment of the quality of services in Częstochowa.

Findings: The study found that respondents who consider culture very important have higher expectations for cultural services. Their assessment of these services differs statistically from that of respondents less engaged in culture. In other cases, both groups have similar distributions. The study shows that some services have higher expectations among respondents. In the case of widely available services, these ratings are similar across different respondent groups. Only the introduction of less popular services (cultural events) reveals differences, with respondents divided into more and less demanding.

Research limitations/implications: In the future, research could be conducted on a larger research sample.

Practical implications: The research will improve the quality of cultural services. As a result, more demanding users of Częstochowa's cultural services should be provided with an appropriate offering, tailored to the preferences of cultural connoisseurs.

Social implications: The results of the study will have an impact on the satisfaction of users of cultural services in Częstochowa.

Originality/value: The value is that no previous research on cultural services has been conducted to determine the similarity of the two communities.

Keywords: cultural events, cultural services, diversity of services, satisfaction.

Category of the paper: Research paper.

1. Introduction

In most contemporary concepts of socio-economic development, improving the quality of life is one of the fundamental strategic goals and a key element of sustainable development (e.g., Borys, 2003, p. 19; Brol, 2001, p. 196; Szewczuk, 2011, pp. 32-33; Throsby, 2010, p. 69), and culture is a component of the quality of life in cities. Participation in culture, access to a wide and diverse cultural offering, high-quality public space, and historic urban monuments are essential elements of the quality of life in cities (Sanetra-Szeliga, 2017).

Analysis of research results on the impact of culture on the socio-economic environment allows us to present the potential role of culture as an element of quality of life. The most frequently occurring components of quality of life and the role of culture in their creation are presented in Table 1. According to Sanetra-Szeliga, culture can have the greatest influence on shaping three areas often included in quality of life indices: health, life satisfaction and sense of security (Sanetra-Szeliga, 2017). The culture as a component of the quality of life in the city presents Table 1.

Table 1.

Culture as a component of the quality of life in the city

	A component of quality of life	The potential of culture	The quality of life factor in the city
Health	subjective assessment of mental and physical health	active and passive participation in culture influences a positive assessment of one's own health.	Access to recreational areas. Access to culture. Good public spaces.
	feeling of stress	Active and passive participation in culture can reduce stress thanks to a break from everyday life, a sense of freedom, and the ability to "discharge negative energy". A properly designed public space influences a person's mental state.	

Cont. table 1.

Life satisfaction	education and learning	Opportunity to develop hobbies and interests by participating in various cultural activities.	Access to a diverse cultural offer as a form of education and development.
	own assessment of satisfaction with relationships with other people	Culture as a relational good can be a way to deepen interpersonal relationships.	Cultural institutions as "third places".
	own assessment of satisfaction with the way of spending time	Active and passive participation in culture is creative consumption, which, thanks to its diversity and the production of new goods and services, can combat the monotony of everyday life and provide a sense of development.	Access to a diverse cultural offering.
	job and income satisfaction	Opportunities for employment in culture (including creative industries), potentially offering interesting and creativity-developing work.	The breadth and depth of the cultural labor market.
Security	sense of security	Properly preserved and promoted cultural heritage (tangible and intangible) fosters a sense of belonging and builds identity. Immovable tangible heritage (e.g., historic urban fabric) that has shaped a given place for centuries influences an individual's psychological stability and sense of security. Well-designed urban spaces (architecture, public spaces) serve a similar function. Culture also influences the development of social capital, which can contribute to a sense of security.	Maintaining historic buildings and the high quality of public spaces, architecture, and urban planning. Cultural activities in degraded areas, among groups at risk of exclusion and criminal activity (vandalism, hooliganism, petty crime). Cultural activities focused on understanding the Other, intercultural dialogue, and the integration of local communities.

Source: Sanetra-Szeliga, 2017.

Table 1 demonstrates not only the potential role of culture in building quality of life, but also how this role can translate into quality of life factors in the city. The third column of the table can be treated as a list of elements of the city's policy aimed at creating a good quality of life through culture. The table demonstrates, among other things, why access to a diverse cultural offering is crucial for quality of life. This offering, while serving as entertainment and a way to spend free time, also offers opportunities for education and personal development. For residents to feel good in the city, they must have opportunities and possibilities that, if utilized, will impact their well-being. Creating a good (i.e., friendly, accessible, aesthetically pleasing, and flexible) public space is crucial (Sanetra-Szeliga, 2017).

Cultural services are a specific type of public service whose purpose is not only to meet recreational needs but also to develop cultural, social, and identity capital (Hausner, Karwińska, Purchla, 2007).

Cultural institutions – such as theaters, museums, galleries, community centers, and libraries – serve not only educational and social functions but also integrational ones, influencing the development of local communities.

Unlike commercial services, cultural institutions typically operate under a public financing model, which requires addressing social expectations and ensuring universal access to services. This, in turn, necessitates systematic monitoring of the quality of services provided and their reception across various social groups.

Cultural marketing, understood as the process of building relationships with audiences and tailoring offerings to their needs, is an essential element of the functioning of contemporary institutions (Kotler, Scheff, 1997; Colbert, 2012). Research indicates that effective cultural marketing should combine artistic goals with audience expectations (Boorsma, 2006; Fillis, 2011). Differences in audience evaluations may result from socio-demographic characteristics such as age, education, and financial situation, but also from the frequency of cultural participation (Bennett et al., 2009; Brosz, Lewandowska, 2020). In the local context, the specific nature of a medium-sized city like Częstochowa means that the accessibility of institutions, their programming, and communication with residents play a special role (Hausner, Karwińska, Purchla, 2007).

Cultural audiences constitute a key element in the functioning of cultural institutions. Their needs, preferences, and expectations determine the offerings and the institutions' communication strategies. The literature emphasizes that participation in culture is diverse in social and demographic terms and also depends on the cultural capital of individuals (Bourdieu, 1984; Bennett et al., 2009). Cultural capital—including education, competencies, and patterns learned in the family—influences the way cultural offerings are used and the hierarchy of preferences. Research indicates that cultural audiences are divided into various segments, including "active participants" who regularly use cultural institutions, "occasional participants" who attend selected events, and "non-participants" who remain outside the institutional culture (Throsby, 2001; Kolb, 2013). In recent years, the importance of digital audiences, who utilize online offerings, has also grown, reflecting the development of new technologies and changing lifestyles (Jenkins, 2006). From a marketing perspective, understanding the audience structure and their expectations enables more effective offer design and building long-term relationships (Kotler, Scheff, 1997; Colbert, 2012). Audience analysis also allows for tailored promotional and educational activities, which can contribute to increased participation in culture, especially among groups that have previously been less active (Rentschler, Hede, 2007). The table 2 presents a typology of cultural audiences.

Table 2.

Typology of culture recipients

Recipient type	Characteristics
Active participants	They regularly use cultural institutions and participate in many events.
Occasional	They attend selected events, often related to fashion or occasion.
Non-participant	They remain outside the institutional culture, lacking regular contacts.
Digital audiences	They take advantage of online cultural offerings (streaming, broadcasts, social media).

Source: (own study based on: Throsby, 2001; Kolb, 2013).

The presented typology of cultural audiences highlights the diversity of ways in which institutions participate in cultural life. Active participants are a key group for institutions, generating consistent interest and establishing a foundation for attendance. Occasional participants are characterized by selective participation, which may depend on trends, recommendations, or unique events – this group requires effective promotional efforts to increase the frequency of cultural exposure. Non-participants pose a challenge for institutions – their lack of interest in institutional culture may stem from financial or educational barriers, or a lack of participation habits. Digital audiences are a relatively new group, whose importance is growing with the development of technology and the digitization of culture. Understanding their needs allows institutions to develop online offerings and reach new audience segments. Service quality is most often defined as the degree to which a given service meets the expectations of the audience (Parasuraman, Zeithaml, Berry, 1985). It is a complex concept that encompasses both the substantive aspect of the offer and the method of its delivery (Parasuraman, Zeithaml, Berry, 1985; Zeithaml, Bitner, Gremler, 2018). One of the most commonly used tools for its assessment is the SERVQUAL model, based on five dimensions of quality: reliability, responsiveness, assurance, empathy, and tangible elements (Parasuraman, Zeithaml, Berry, 1985).

In the context of cultural services, audiences' assessment of quality encompasses both elements related to the artistic content (e.g., attractiveness of the repertoire, artistic quality of the performance) and customer service (staff friendliness, ticket availability, comfort of attendance). Furthermore, the institution's infrastructure (quality of the venues, accessibility for people with disabilities, location) and the method of communication with audiences, especially regarding promotion and event information, play a significant role (Kotler, Scheff, 1997; Rentschler, Hede, 2007). Research indicates that cultural consumers often use subjective criteria related to emotions, satisfaction, and a sense of value from the cultural experience (Colbert, 2012; Hill, O'Sullivan, O'Sullivan, 2018). Therefore, in assessing the quality of services, it is important not only to meet expectations but also to create an element of surprise, a sense of uniqueness, and the enrichment of an individual's cultural capital (Bourdieu, 1984; Bennett et al., 2009). The ways in which consumers assess the quality of cultural services can take various forms, from simple rating scales in surveys, through opinions expressed on social media, to participation in qualitative research (interviews, focus groups). The literature indicates that it is important for cultural institutions not only to monitor ratings but also to systematically analyze them, which allows them to adapt their offerings to diverse expectations (Kotler, Kotler, Kotler, 2008; Brosz, Lewandowska, 2020).

A review of the literature on the subject shows that participation in culture is not a homogeneous phenomenon – it depends on many socio-demographic factors, such as age, level of education, place of residence, financial status, and professional activity (Bennett et al., 2009; Ziółkowski, 2013). This diversity also translates into the assessment of the quality of

cultural services, as different social groups may be guided by different evaluation criteria: some value high artistic standards, others ease of access, and still others a friendly atmosphere.

2. Diversity of Cultural Audiences and the Perception of Quality

The diversity of cultural audiences poses challenges for institutions related to diversifying offerings, flexible communication, and personalizing services. Therefore, quality perception analysis should take these variables into account, allowing for the identification of gaps in service adaptation to the needs of various social groups.

Diversification of cultural services refers to a broad spectrum of offerings, encompassing both traditional forms of participation, such as theater, opera, and museum exhibitions, as well as new, hybrid forms of activity, such as online broadcasts, interactive multimedia exhibitions, and participatory projects. This diversity of services stems from dynamic social, technological, and economic changes that shape the way culture is consumed (Throsby, 2001; Boorsma, 2006).

The literature indicates that diversity of cultural services serves several functions. First, it responds to the diverse needs and expectations of audiences – from those seeking high-quality artistic experiences to those who view cultural participation as a form of recreation and entertainment (Kolb, 2013; Hill, O’Sullivan, O’Sullivan, 2018). Second, it increases the inclusiveness and accessibility of culture, enabling participation by groups with different cultural capital, social status, and financial means (Bourdieu, 1984; Bennett et al., 2009). Third, it supports the development of innovative forms of artistic expression that attract new audiences, especially younger generations (Jenkins, 2006; Fillis, 2011).

Cultural institutions, when introducing a diverse offering, must maintain a balance between preserving tradition and opening up to modern forms of participation. Too much emphasis on entertainment can lead to commercialization, while an excessive focus on high art can lead to limited access and the exclusion of some audiences (Kotler, Scheff, 1997; Colbert, 2012). Therefore, a key challenge is to skillfully manage the diversity of services, allowing institutions to meet the expectations of a broad audience while maintaining their culture-building mission.

3. Local Context – Culture in Częstochowa

Research analyzing the diversity of cultural service ratings was conducted using the district city of Częstochowa as an example. Częstochowa is a city with a strong religious and historical identity, but also a diverse social and cultural structure. Numerous cultural institutions operate here – including the Adam Mickiewicz Theatre, the Częstochowa Museum, the Municipal Art

Gallery, and the Częstochowa Philharmonic – as well as non-governmental organizations and grassroots initiatives. Local cultural policy has for years been focused on increasing accessibility and activating communities. Despite this, differences in the perception of cultural services exist – both between age and professional groups, and between the city center and its outskirts (Brosz, Lewandowska, 2020). Assessing the quality of services from a diverse perspective is therefore an important step towards a more equitable, inclusive, and needs-based cultural policy. Analyzing the development of cultural services in Częstochowa, it can be observed that older Częstochowa residents and families with children are highly active in cultural services, tending to participate in traditional forms such as philharmonics and museums. Low participation in these forms is also observed among youth and young adults. Cultural services compete with commercial entertainment options such as multiplex cinemas and other entertainment events.

4. Methods

The study was quantitative in nature and conducted as a standardized online and paper survey. The questionnaire included questions about services, cultural participation, and sociodemographic data. To verify the research assumptions, an analysis was conducted using the Kolmogorov-Smirnov test. This is a nonparametric test used to assess the conformity of the distribution of analyzed variables to a normal distribution. It tests the null hypothesis that the distribution approximates a normal distribution. This means that p values > 0.05 (at the alpha threshold = 0.05) confirm the assumption of a normal distribution. Therefore, a statistically significant result for this test indicates a lack of conformity to a normal distribution (pogotowiestatystyczne.pl). The Kolmogorov-Smirnov test (K-S test) is a nonparametric statistical test used to compare empirical distributions. It can be used to:

- check the consistency of an empirical distribution with a theoretical distribution (e.g., the normal distribution),
- compare two empirical distributions in independent samples.

In this article, it is used as a test of similarity between two independent groups of respondents. The first group consists of people who declare that culture and the use of cultural services in Częstochowa are important to them. The second group consists of people who declare these services to be less important in their lives.

The test is based on calculating the maximum absolute value of the difference between the empirical distribution function and the theoretical distribution function (or between two empirical distribution functions). This maximum difference (denoted by the letter D) constitutes the test statistic.

The Kolomogorov-Smirnov test therefore allows us to determine whether a sample is likely to have come from a specific distribution, such as the normal distribution, which is important when choosing appropriate methods for further data analysis (e.g., parametric or nonparametric tests). Assumptions of the K-S test:

- variables must be continuous,
- observations must be independent,
- data must be ordered in ascending order.

In the context of assessing the quality of cultural services, the Kolmogorov-Smirnov test can be used, for example, to check whether the distribution of respondents' ratings falls within the normal range, which determines the use of parametric tests.

5. Results

The Kolmogorov-Smirnov method was used in statistical research to determine similarity between two groups. The first group consisted of individuals who considered culture to be very important in their lives. The second group declared that culture was important in their lives. To determine the impact of service quality in Częstochowa, the hypothesis was formulated that declarations regarding the importance of culture are statistically insignificant for quality assessment. From this perspective, the hypothesis assumes similarity between the two groups. The alternative hypothesis assumes that the groups differ in their assessment of service quality in Częstochowa. To test this hypothesis, a table was constructed for the group of individuals declaring culture to be very important in their lives and for those for whom this role was less important. For clarity, the group of respondents for whom culture is important is considered "Group A", and those for whom culture is less important are considered "Group B". Table 3 presents evaluation of services by "group A".

Table 3.
Evaluation of services by "group A"

Cultural Services/Assessments	0	1	2	3	4	5
Cinema	9	0	2	7	28	28
Theatre	6	0	3	18	25	22
Philharmonic	10	0	1	18	21	24
Art gallery	9	0	5	14	19	27
Museum	17	0	7	14	22	14
Literary meetings	23	0	8	12	14	17
Library	25	0	5	11	16	17
Meetings with artists	17	0	8	18	14	17
Concerts	16	0	8	17	21	12
Travel festivals	33	0	10	16	8	7
Other	57	0	5	7	4	1

Source: Own study based on research.

Table 4 presents evaluation of services by “group B”.

Table 4.

Evaluation of services by "group B"

Cultural Services/Assessments	0	1	2	3	4	5
Cinema	3	0	3	5	36	22
Theatre	8	0	1	15	26	19
Philharmonic	12	0	3	13	29	12
Art gallery	14	0	7	16	22	10
Museum	16	0	13	17	15	8
Literary meetings	22	0	14	15	10	8
Library	19	0	9	13	14	14
Meetings with artists	20	0	10	20	11	8
Concerts	9	0	10	21	18	11
Travel festivals	23	0	16	15	13	2
Other	38	0	13	7	10	1

Source: Own study based on research.

In the course of further calculations, the result tables were adjusted to values and a distribution table was created for both communities and cultural services in Częstochowa.

Table 5 presents distribution of the evaluation of cultural services for group A.

Table 5.

Distribution of the evaluation of cultural services for group A

	0	1	2	3	4	5
Cinema	0,12	0,12	0,15	0,24	0,62	1,00
Theatre	0,08	0,08	0,12	0,36	0,70	1,00
Philharmonic	0,14	0,14	0,15	0,39	0,68	1,00
Art gallery	0,12	0,12	0,19	0,38	0,64	1,00
Museum	0,23	0,23	0,32	0,51	0,81	1,00
Literary meetings	0,31	0,31	0,42	0,58	0,77	1,00
Library	0,34	0,34	0,41	0,55	0,77	1,00
Meetings with artists	0,23	0,23	0,34	0,58	0,77	1,00
Concerts	0,22	0,22	0,32	0,55	0,84	1,00
Travel festivals	0,45	0,45	0,58	0,80	0,91	1,00
Other	0,77	0,77	0,84	0,93	0,99	1,00

Source: Own study based on research.

Table 6 presents distribution of the evaluation of cultural services for group B.

Table 6.

Distribution of the evaluation of cultural services for group B.

	0	1	2	3	4	5
Cinema	0,04	0,04	0,09	0,16	0,68	1
Theatre	0,12	0,12	0,13	0,35	0,72	1
Philharmonic	0,17	0,17	0,22	0,41	0,83	1
Art gallery	0,20	0,20	0,30	0,54	0,86	1
Museum	0,23	0,23	0,42	0,67	0,88	1
Literary meetings	0,32	0,32	0,52	0,74	0,88	1
Library	0,28	0,28	0,41	0,59	0,80	1
Meetings with artists	0,29	0,29	0,43	0,72	0,88	1
Concerts	0,13	0,13	0,28	0,58	0,84	1
Travel festivals	0,33	0,33	0,57	0,78	0,97	1
Other	0,55	0,55	0,74	0,84	0,99	1

Source: Own study based on research.

In the next step, the highest difference between the distributions in each respondent group and in each cultural services group was determined ($D_{\max}$). The next part of the calculation was then determined using the following formula:

$$n = \frac{n_1 * n_2}{n_1 + n_2} \quad (1)$$

where:

n_1, n_2 - number of observations in the first and second sample,

n - total number of observations in the combined sample after summing both groups.

In this case, the n index was 35.71.

On this basis, the lambda index was calculated for each group of cultural services using the following formula:

$$\lambda = D * \max \sqrt{n} \quad (2)$$

where:

$D_{\max}$ (maximum difference): The greatest distance between the empirical distribution function (the graph of the cumulative distribution of sample observations) and the theoretical distribution function (the distribution to which our sample is compared). It is calculated as the maximum absolute value of the difference between these two distribution functions for all values in the data set.

n (sample size): The number of observations in the sample.

λ (test statistic): The value of λ is calculated based on a formula and is used to determine whether the difference between the distributions tested is statistically significant.

The obtained results were compared with the theoretical value obtained from the Kolmonogorov-Smirnoff distribution tables. A significance level of 0.10 was adopted. With this statistic, the theoretical index is 1.23. The results of the comparison of empirical and theoretical statistics of the given types of cultural services are presented in figure 1.

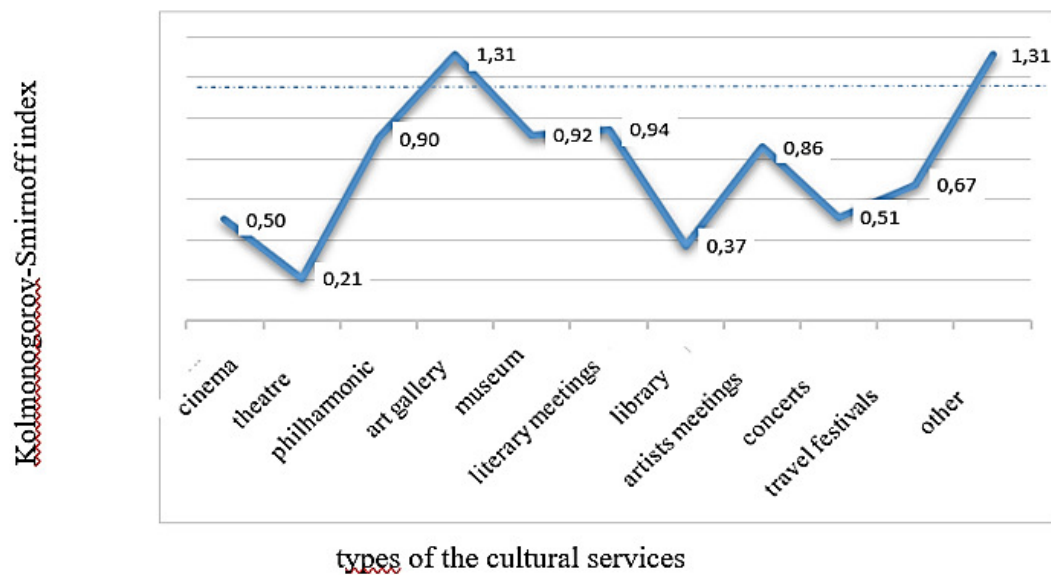


Figure 1. Comparison of the empirical and theoretical statistics.

Source: Source: Own study based on research.

As the data presented in the graph indicates, we are dealing with a situation where two types of services, namely an art gallery and services from the "other" category, indicate that the hypothesis of homogeneity of distributions should be rejected at a loyalty level of 0.1. This means that respondents who consider culture very important to them have higher expectations of cultural services. Their assessment of these services differs statistically from respondents who are less engaged in culture. In other cases, both groups have similar distributions. However, here too, we are dealing with a situation where some services are close to the critical value, such as the philharmonic hall, literary meetings, and meetings with artists. The latter services, namely cinema, theater, library services, concerts, and travel festivals, do not approach the critical value, meaning their assessment is not dependent on respondents' declarations of the importance of culture. The above studies show that some services have higher expectations. In the case of widely available services, this assessment is similar across different groups of respondents. Only when less common services are introduced (cultural events) can differences be noticed and respondents are divided into more or less demanding ones.

6. Discussion

To date, research on cultural services and their audiences has focused solely on general segmentation schemes. Consumer groups for these services have been examined from the perspective of marketing management. The examples provided in the literature review identified types of cultural consumers, and the overall management focused on typological

studies and the quality of reception of presented cultural products. The research presented in this article does not contradict the schematic approach to marketing management in culture. However, it goes further, as it aims to assess the individual elements influencing respondents as consumers of cultural services as a whole. These studies demonstrate that the level of expectations for cultural services is not uniform and depends on the type of services analyzed and the level of respondents' engagement in culture. The main finding of this research is that in the case of widely available services, such as basic forms of cultural participation (e.g., visits to the cinema, libraries, or popular museums), the ratings of different customer groups remain relatively similar. This may be due to the fact that these services are socially familiar, have an established place in residents' daily lives, and are less variable in quality. The situation is completely different for less common services, such as artistic events or services offered by specialized institutions. These services allow for the identification of differences in quality perception and allow for the division of respondents into more and less demanding groups. These results confirm observations from the literature, according to which, in the case of unique and more niche services, customers express different attitudes and preferences (Kotler, Scheff, 1997; Kieźel, 2010). A particularly interesting group consists of respondents who declare that culture plays a very important role in their lives. These individuals demonstrate significantly higher expectations for cultural services, and their ratings differ statistically significantly from those expressed by those less engaged in culture. This phenomenon can be interpreted in light of Bourdieu's (1986) theory of cultural capital, which states that the greater the importance attributed to culture, the more critical and demanding attitudes toward its institutions and offerings become. It is worth noting, however, that even in the area of cultural services, which were rated similarly by both groups of respondents, some results fell close to the critical threshold. This indicates a potential risk of reduced customer satisfaction if the quality of offerings does not improve further. Cultural institutions should therefore treat these results as a warning sign and strive to improve quality even in areas that currently do not significantly differentiate their audiences. In summary, the discussion of the results indicates that a key factor differentiating the ratings of cultural services is the importance individuals assign to culture in their lives. The greater the role of culture, the more demanding the expectations become, and the greater the differences in the assessment of service quality. The research results confirm the need to segment recipients and adapt the offer to diverse needs, which is consistent with the modern approach to cultural management and marketing in cultural institutions (Kolb, 2013).

7. Conclusion

This article presents the results of research on the differences in the evaluation of cultural services in Częstochowa among residents and tourists using its cultural services. The study analyzed aspects of service evaluation such as the availability of cultural offerings, the level of service, the quality of transportation, and the overall satisfaction of event attendees. The study was conducted on two groups of respondents. The first group comprised individuals for whom cultural services were highly important, while the second group was less so. The Kolmogorov-Smirnov method was used to statistically determine differences between the surveyed groups. This method was used to determine similarity between two groups of people – those for whom cultural services were highly important and those for whom cultural services were less important. The hypothesis was that the surveyed groups did not differ in their evaluation of the quality of cultural services. From this perspective, the hypothesis assumed similarity between the two groups, while the alternative hypothesis assumed that the groups differed in their evaluation of the quality of services in Częstochowa.

The main result of this article is that the research shows that certain services have higher expectations. In the case of widely available services, this assessment is similar across different respondent groups. Only the introduction of less common services (cultural events) allows us to see differences and divide respondents into more or less demanding ones.

Respondents who consider culture very important have higher expectations of cultural services. Their assessment of these services differs statistically from that of respondents less engaged in culture. In other cases, both groups have similar distributions. However, here too, we are dealing with a situation in which some services approach a critical value.

References

1. Bennett, T., Savage, M., Silva, E.B., Warde, A., Gayo-Cal, M., Wright, D. (2009). *Culture, Class, Distinction*. Routledge.
2. Boorsma, M. (2006). A strategic logic for arts marketing: Integrating customer value and artistic objectives. *International Journal of Cultural Policy*, 12(1), 73-92.
3. Borys, T. (2003). Jakość życia jako integrujący rodzaj jakości. In: J. Tomczyk-Tołkacz (ed.), *Jakość życia w perspektywie nauk humanistycznych, ekonomicznych i ekologii* (pp. 9-20). Jelenia Góra: Akademia Ekonomiczna im. O. Langego we Wrocławiu.
4. Bourdieu, P. (1984). *Distinction: A Social Critique of the Judgement of Taste*. Harvard University Press.

5. Bourdieu, P. (1986). *The Forms of Capital*. In: J. Richardson (ed.), *Handbook of Theory and Research for the Sociology of Education*. Greenwood.
6. Brol, R. (2001). Rozwój miasta. In: R. Brol (ed.), *Ekonomika i zarządzanie miastem* (pp. 201-246). Wrocław: Wydawnictwo Akademii Ekonomicznej im. Oskara Langego we Wrocławiu.
7. Brosz, A., Lewandowska, A. (2020). *Kultura w miastach średnich – szanse i wyzwania*. Narodowe Centrum Kultury.
8. Colbert, F. (2012). *Marketing Culture and the Arts* (4th ed.). HEC Montréal.
9. Fillis, I. (2011). The evolution and development of arts marketing. *Arts Marketing: An International Journal*, 1(1), 11-25.
10. Hausner, J., Karwińska, A., Purchla, J. (Eds.) (2007). *Kultura a rozwój*. Narodowe Centrum Kultury.
11. Hill, L., O'Sullivan, C., O'Sullivan, T. (2018). *Creative Arts Marketing* (3rd ed.). Routledge.
12. <https://pogotowiestatystyczne.pl/slovniki/test-kolmogorowa-smirnowa/>
13. Jenkins, H. (2006). *Convergence Culture: Where Old and New Media Collide*. NYU Press.
14. Kieźel, E. (2010). *Konsument i konsumpcja we współczesnej gospodarce*. Warszawa: PWE.
15. Kolb, B.M. (2013). *Marketing for Cultural Organizations: New Strategies for Attracting Audiences* (3rd ed.). Routledge.
16. Kotler, N.G., Kotler, P., Kotler, W.I. (2008). *Museum Marketing and Strategy: Designing Missions, Building Audiences, Generating Revenue and Resources* (2nd ed.). Jossey-Bass.
17. Kotler, P., Scheff, J. (1997). *Standing Room Only: Strategies for Marketing the Performing Arts*. Harvard Business School Press.
18. Parasuraman, A., Zeithaml, V.A., Berry, L.L. (1985). A Conceptual Model of Service Quality and Its Implications for Future Research. *Journal of Marketing*, 49(4), 41-50.
19. Rentschler, R., Hede, A.-M. (2007). *Museum Marketing: Competing in the Global Marketplace*. Butterworth-Heinemann.
20. Sanetra-Szeliga, J. (2017). Kultura jako element składowy jakości życia w mieście. *Kultura i Rozwój*, 1(2).
21. Szewczuk, A. (2011). Rozwój lokalny i regionalny – główne determinanty. In: A. Szewczuk, M. Kogut-Jaworska, M. Ziolo (eds.), *Rozwój lokalny i regionalny. Teoria i praktyka*. Warszawa: C.H. Beck.
22. Throsby, D. (2001). *Economics and Culture*. Cambridge University Press.
23. Throsby, D. (2010). *Ekonomia i kultura*. Warszawa: Narodowe Centrum Kultury.
24. Zeithaml, V.A., Bitner, M.J., Gremler, D.D. (2018). *Services Marketing: Integrating Customer Focus Across the Firm* (7th ed.). McGraw-Hill Education.
25. Ziolkowski, M. (2013). *Tożsamość, uczestnictwo i polityka kulturalna*. Wydawnictwo Naukowe UAM.

DECISION-MAKING MECHANISMS IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT: A BEHAVIORAL ECONOMICS PERSPECTIVE

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Purpose: The aim of this paper is to identify cognitive biases that humans may commit in actions related to sustainable development. These biases can influence decision-making processes, stakeholder engagement, and the implementation of sustainability strategies. By highlighting these cognitive distortions, the paper seeks to support the development of more resilient and inclusive sustainability frameworks.

Design/methodology/approach: The analysis was based on a systematic literature review according to PRISMA principles. Peer-reviewed articles from multidisciplinary databases were screened and selected based on predefined inclusion and exclusion criteria. The review process focused on identifying patterns of cognitive bias across environmental, economic, and social dimensions of sustainable development.

Findings: The systematic literature review allowed for the identification of the most common cognitive biases. This demonstrated that the decision-making mechanisms inherent in behavioral economics are directly relevant to decisions made in the context of sustainable development.

Research limitations/implications: The identified research gap indicates the need for in-depth analyses that will allow for a better understanding of how cognitive biases influence economic decisions in the area of sustainable development. Only by systematically identifying and minimizing them will it be possible to design effective educational, diagnostic, and implementation tools that support the transition towards more responsible economic practices.

Originality/value: This paper contributes to the development of practices related to sustainable development, based on a realistic model of human cognition identified as cognitive biases.

Keywords: cognitive biases, sustainable development, systematic literature review.

Category of the paper: Research paper.

1. Introduction

Human actions are selfish and directed towards self-interest, and in economics, towards maximizing utility. This orientation is based on the concept of economic rationality (the "Homo Oeconomicus" paradigm). An alternative approach is the behavioral approach. Behavioral economics, combining psychological and economic concepts, analyzes how human decision-making biases and cognitive limitations influence choices and behaviors, including environmental ones. The analysis of decision-making mechanisms, heuristics, and cognitive biases, known in behavioral economics' approach to sustainable development, takes a cognitive perspective. Understanding this relationship is crucial for developing effective policies and interventions aimed at increasing sustainable development in a world grappling with serious environmental problems.

The research problem addressed is framed by the question: what cognitive biases can be committed in sustainable development activities?

The aim of this study is to identify cognitive biases that can be committed by humans in sustainable development activities.

The topic of sustainable development is broad and widely presented in the literature, so this work does not include a detailed description. It is assumed that sustainable development meets the needs of the current generation without compromising the chances of future generations to meet them. It combines concern for future generations. It promotes a balance between three dimensions: economic, taking into account growth and efficiency; social, promoting quality of life, equality, and education; and environmental, paying attention to the protection of natural resources and the climate (Florczak 2020). This is a broad topic, so the identification of behavioral mechanisms was based on general assumptions. The rationale for addressing this issue is the interest of behavioral economists in the topic of sustainable development. These works shed new light on traditional theories of economic behavior, based on theoretical constructs and experimental methods drawn from psychology. The relationship between sustainable development and behavioral economics is a dynamic and evolving area of research. The work hypothesizes that despite the complex and interdisciplinary nature of sustainable development, cognitive biases accompanying actions can be effectively identified and analyzed. The text focuses on cognitive biases that occur when making decisions related to sustainable development in its broadest sense. The first part of the paper presents the assumptions of behavioral economics. This is followed by a description of the methodology. The next chapter presents the cognitive biases identified in the analyzed documents as part of a systematic literature review. After a discussion of the paper's assumptions, the conclusion is presented.

2. Behavioral tendencies in the decision-making process

Behavioral economics examines and describes systematic errors, challenging the classical paradigm of rationality and supplementing it with a series of limitations inherent in human nature. Behaviorists strive to portray humans as truly rational, yet imperfect, and sometimes erroneous. As Richard Thaler aptly put it, they strive to "rehumanize" *homo oeconomicus* (Thaler, 2000, 2018). Behavioral economics allows us to understand anomalies occurring in market participants' decision-making, unexplained by the assumptions of rational choices. The core concept of behavioral economics is cognitive bias. A cognitive bias is a systematic error in thinking that occurs when we incorrectly process and interpret information in the world around us, which influences decisions and judgments. There is evidence of at least sixty cognitive biases that influence thinking and decision-making (Patent, 2022). Cognitive biases can be classified into two groups: individual and social. Individual biases are rooted in intuition and are related to habits that have evolved to shorten and accelerate the decision-making process. Group biases are related to social norms, to established patterns of behavior in society (Aaron, 1999; Zalega, 2015). They are related to the course of cognitive processes. Cognitive processes and emotions simultaneously shape our decisions; their roles in shaping investor actions and market behavior should be viewed as complementary (Baker, Filbeck, Nofsinger, 2021; Zygan, 2015).

3. Methodology

A systematic literature review was conducted using the PRISMA guidelines to ensure a transparent, structured, and comprehensive approach (Kitchenham, 2004). The Web of Science database was selected for analysis due to its broad and interdisciplinary scope. The search included all articles related to sustainable development and behavioral economics. A keyword identification process was used to identify and create search terms using the wildcards "behavioral economics" and "sustainable development". PRISMA (2020) recommendations, a globally recognized and widely followed set of guidelines for reporting systematic reviews and meta-analyses, were used. Data extraction and quality assessment identified articles, followed by a selection, eligibility, and inclusion process. The total number of articles retrieved from the database using keywords in the title, abstract, and keywords was 736. Of these, 15 were excluded because they did not fall within the selected subject areas (economics, econometrics and finance, environment), were not articles or reviews published in peer-reviewed journals or conference proceedings, or were not written in English. After exclusion, 551 papers remained. Due to the large number of papers, the additional criteria

of "cognition bias" were added, yielding 19 papers. Their content was fully analyzed. Only four papers addressed sustainable development, cognitive biases, and behavioral economics. This was deemed too few. The search was repeated, rewording the query by combining the terms "cognitive biases (All Fields)" and "sustainable development (All Fields)". 121 papers were retrieved. The exclusion criteria outlined above were applied, and 52 papers were excluded. The remaining 68 papers related to economics, econometrics and finance, and the environment were mapped. This approach allowed for the evaluation of papers in terms of the SDGs, available on Web of Science (Table 1).

Table 1.

Distribution of publications by SDG (n = 68)

SDG	Number of publications	% z 68
13. Climate Action	17	25.000%
03. Good Health and Well-Being	14	20.588%
12. Responsible Consumption and Production	14	20.588%
02. Zero Hunger	13	19.118%
04. Quality Education	11	16.176%
14. Life Below Water	11	16.176%
15. Life on Land	11	16.176%
11. Sustainable Cities and Communities	9	13.235%
09. Industry, Innovation and Infrastructure	8	11.765%
07. Affordable and Clean Energy	5	7.353%
08. Decent Work and Economic Growth	3	4.412%
10. Reduced Inequality	3	4.412%
01. No Poverty	2	2.941%
05. Gender Equality	2	2.941%
06. Clean Water and Sanitation	1	1.471%
17. Partnerships for the Goals	1	1.471%
No SDG data in the record	20	29.412%

Source: Web of Science.

This activity is related to the popularity of analyses related to the SDGs (Grzebyk et al., 2023; Grzebyk et al., 2025). After quantitative mapping of the papers, abstract analysis was initiated, followed by an in-depth content analysis. In the final phase, 22 publications were included, which—in the authors' opinion—most clearly and substantively addressed the identified cognitive mechanisms in the context of sustainable development. This selection was based on content compliance with analytical criteria and interpretative potential for classifying cognitive biases.

4. Obtained Results

To organize the literature analysis, clustering was performed. Mapping all the topics generated four clusters (Figure 1, Table 2). Clusters facilitate the identification of correlations between different topics, facilitating the interpretation of the obtained results. The strength of keywords was indicated by the thickness of the connecting lines. The size of the nodes also revealed the frequency of the keyword or topic, in addition to the clusters and lines.

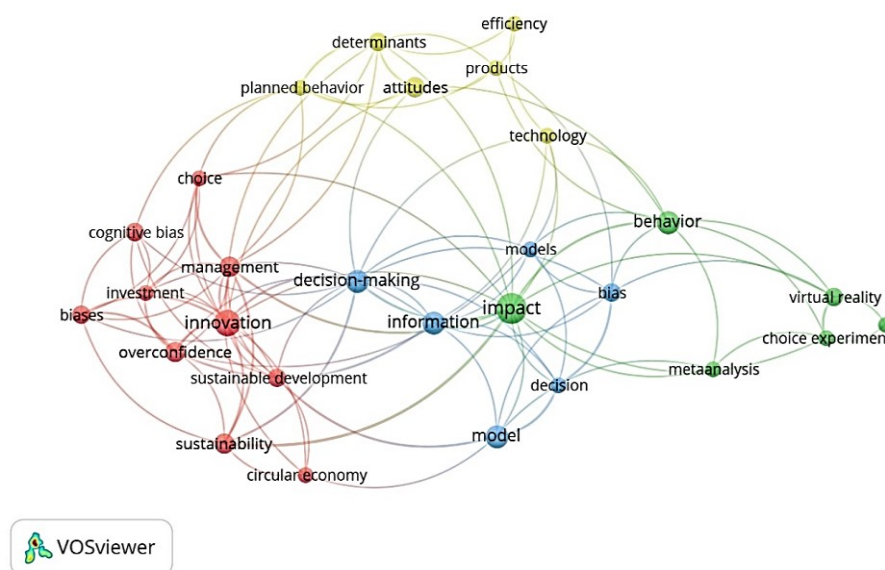


Figure 1. Keyword Map (occurrences).

Source: Own work using VOSviewer.

Table 2.
Clusters by keyword

Cluster red	Cluster green	Cluster blue	Cluster yellow
Biases	Behavior	Bias	Attitudes
Choice	Choice experiment	Decision	Determinants
Circular economy	Climate change	Decision – making	Planer behavior
Cognitive bias	Impact	Information	Products
Innovation	Metaanalysis	Model	Technology
Investment	Virtual reality	Models	
Management			
Overconfidence			
Sustainability			
Sustainable developmemnt			

Source: Own work.

The cluster map shows a network of co-occurrences of terms (e.g., keywords) grouped based on the strength of their interconnectedness. Each node represents a single term, and the lines between them indicate co-occurrences in the same document or dataset. Colors indicate thematic clusters, i.e., groups of terms with strong semantic connections. The red cluster can be labeled "Management, Innovation, Sustainability". This cluster combines

research on innovation implementation with 13 other nodes, including sustainability strategy and the impact of cognitive biases on managerial decisions. Its central location in the map suggests a significant role in the network structure. It is characterized by a high frequency of words such as innovation and sustainability. The blue cluster can be labeled "Decisions, Models, Information". It is characterized by a high frequency of decision-making and information. Strong connections exist between terms related to decision-making and modeling (e.g., model ↔ impact from the green cluster). The nodes are densely connected, indicating thematic coherence. The cluster focuses on decision analysis, the impact of information, and the application of models in the context of efficiency and sustainability. The green cluster can be defined as "Behavior, Technology". It is characterized by a moderate frequency of occurrence but a high strength of association for the word "behavior". It is less centrally located but clearly distinguished thematically. The cluster encompasses experimental research on user behavior, technology, and cognitive effectiveness. The yellow cluster can be defined as "Attitudes, Planned Behavior, Determinants". It is characterized by a moderate frequency of occurrence but strong associations between psychological and consumer terms. The nodes are more dispersed, which may indicate interdisciplinarity. The cluster focuses on theories of planned behavior, consumer attitudes, and factors influencing purchasing decisions. A detailed text analysis of the publications was based on identifying the names of errors according to the findings of the literature. Table 3 presents a brief description of the cognitive errors. This intention stemmed from the occurrence of descriptive errors in most cases.

After distinguishing errors, we identified which clusters they belonged to. The identified errors were assigned to the red cluster: overconfidence (Wang et al., 2021; Joseph et al., 2023), overestimation, comparison bias (Joseph et al., 2023), and confirmation bias (Cristofaro et al., 2024; Oliveira et al., 2025).

Publications assigned to the green cluster focused on topics related to behavior, technology, virtual reality, and efficiency. The identified cognitive biases included emotional bias (Vassilopoulos et al., 2024; Pandey, Pandey, 2025), information processing bias (Pandey, Pandey, 2025), and illusion of control (Borowa et al., 2023).

The blue set was dominated by cognitive biases such as status quo bias (Huang, 2026; Cristofaro et al., 2024), anchoring bias (Kaenzig, Wüstenhagen, 2010; Vargas-Lama, Osorio-Vera, 2020), and framing bias (McGowan et al., 2023; Vassilopoulos et al., 2024; Kaenzig, Wüstenhagen, 2010). The papers assigned to this yellow cluster identified biases such as awareness bias (Giordano et al., 2019), herd bias (Shantha, 2019), and cognitive reflection bias (Shantha, 2019). Assigning cognitive biases to specific thematic clusters allows for a better understanding of the decision-making and research contexts in which specific cognitive bias mechanisms occur. Although not all publications clearly identify biases, their presence can be inferred based on descriptions of behaviors, decisions, and research results.

This approach not only allows for the classification of biases within a thematic structure but also provides a starting point for further diagnostic analyses.

Table 3.
Selected behavioral errors identified in the analyzed works

Cognitive Bias	Description	Authors of Analyzed Studies
Anchoring bias	Basing decisions on the first available information, even if irrelevant.	Kaenzig, Wustenhagen (2010), Vargas-Lama, Osorio-Vera (2020)
Authority bias	Accepting authority opinions as valid regardless of actual competence.	Almeida-Silva et al. (2024)
Availability heuristic	Excess of negative information distorts perception.	Xu et al. (2018)
Awareness bias	Discrepancy between declarations and actual behavior.	Giordano et al. (2019)
Bounded rationality	Limited information processing leads to simplified decisions.	Frör (2008)
Cognitive reflection bias	Preference for fast, intuitive answers over deeper analysis.	Shantha (2019)
Comparison bias	Comparing oneself to others leads to flawed decisions or scaling.	Joseph et al. (2023)
Confirmation bias	Interpreting information in line with one's own beliefs.	Cristofaro et al. (2024), Oliveira et al. (2025)
Framing effect	Decisions depend on how the same information is presented.	McGowan et al. (2023), Vassilopoulos et al. (2024), Kaenzig, Wustenhagen (2010)
Herd bias	Following others without independent analysis.	Shantha (2019)
Illusion of control	Overestimating one's influence over a situation.	Borowa et al. (2023)
Information processing bias	Preferences in how information is processed (e.g., visual vs textual).	Pandey, Pandey (2025)
Overconfidence	Overestimating one's skills leads to risky decisions.	Wang et al. (2021), Joseph et al. (2023)
Overestimation	Inflating values, capabilities, or impact of actions.	Joseph et al. (2023)
Perception bias	Distorted perception of reality due to prejudice.	Xu et al. (2018)
Present bias	Favoring immediate rewards over long-term benefits.	McGowan et al. (2023), Kaenzig, Wustenhagen (2010)
Recall bias	Inaccurate recollection of past events.	Giordano et al. (2019)
Status quo bias	Preferring the current state despite better alternatives.	Huang (2026), Cristofaro et al. (2024)

Source: prepared by the authors (*the description of errors is general and can be found in the works of Chaira et al., 2020; Cossette, 2014; French et al., 2023; Kaheneman, 2012; Kahneman, Tversky, 1973; Szara, 2024).

5. Discussion

The literature on the subject provides numerous confirmations of the occurrence of cognitive biases in the context of sustainable development. The analyzed publications cover diverse areas, such as the economy, employee behavior, and respondent attitudes. Due to their differing methodological approaches, direct comparison is not possible, but they constitute significant examples of the presence of cognitive biases in various contexts related to the concept of sustainable development (Kapsalis, Kapsalis, 2020).

It is worth emphasizing that in many cases, cognitive biases were not clearly identified in the articles. They were often presented descriptively or hidden under the general term "cognitive bias". Selected examples from the content analysis of the publications are presented below.

Xu et al. (2018) indicate that "tourists' perceived safety can be severely biased", which the authors attribute to the availability of media information. This description corresponds to the availability heuristic, exacerbated by the phenomenon of "media panic caused by the publication of excessive negative reports," meaning an excess of negative media reports leading to a distorted perception of risk.

Giordano et al. (2019) present a classic example of awareness bias, pointing to respondents' lack of awareness of the actual scale of food waste. The authors note that self-assessment bias can be reinforced by other cognitive mechanisms, such as the positive illusion—the belief that "I'm not doing so badly".

Fror (2008) highlights respondents' cognitive limitations stemming from limited time, resources, and information-processing capacity. He also points to a tendency to use simplified decision rules (heuristics), which impacts the quality of project evaluations and their benefits.

The identified cognitive limitation bias is a form of unintentional cognitive bias resulting from respondents' limited ability to process complex information, understand product attributes (e.g., insurance), and logically compare alternatives in choice experiments.

Consequently, individuals with lower cognitive competences are more likely to make decision errors, use simplified strategies (e.g., omitting attributes), and their declarations of "willingness to pay" are less consistent and more susceptible to hypothetical bias.

Veetil et al. (2025) indicate that hypothetical bias is more pronounced in individuals with lower cognitive abilities, and its intensity decreases with increasing cognitive abilities: "We show that the magnitude of the hypothetical bias is higher at a lower level of cognitive ability and that bias diminishes with an increase in cognitive ability". The authors also emphasize that motivational stimuli can increase cognitive effort, especially in individuals with lower competences, for whom the cognitive cost is higher. This phenomenon is the core of cognitive limitation bias, a distortion resulting from a limited ability to process information and make rational decisions.

Cognitive reflection bias, although not explicitly mentioned, can be inferred from the analysis of the concept of self-reflection—understood as the cognitive processing of experiences. The authors emphasize that experience itself does not automatically lead to learning: "Past trading experiences do not directly produce learning. Rather, the experiences are to be cognitively reflected (that is, self-reflection) to yield learning to reduce behavioral biases". A lack of cognitive reflection leads to the perpetuation of decision-making errors, including herd bias, the occurrence of which is fully mediated by the level of reflection: "Self-reflection fully mediates the relationship between trading experience and herd bias" (Shanta, 2019).

Comparison bias in the context of entrepreneurial cognition appears as a distortion resulting from social, market, or strategic comparisons. Joseph et al. (2023) indicate that entrepreneurs compare the growth trajectories of their startups with companies with different resources and contexts: "They compare their startup's growth trajectory with that of successful peers or industry benchmarks". Such comparisons lead to excessive optimism and poor strategic decisions, reinforced by the cognitive pressure resulting from success narratives: "Narratives of rapid scaling in startup ecosystems create cognitive pressure to conform".

Confirmation bias has been identified in studies by Cristofaro et al. (2024) and Oliveira et al. (2025), where the authors analyze the impact of cognitive biases on the decisions of managers of medium-sized enterprises implementing sustainable performance management systems. Managers tend to confirm their own beliefs by selectively treating information: "Managers tend to rely on familiar performance indicators and disregard sustainability metrics that challenge their existing mental models".

The framing effect is a key element of the experiment described by McGowan (2023). The author manipulates the presentation of fuel savings, demonstrating that respondents are willing to pay more for a more fuel-efficient car when the savings are presented over a one- or three-year period, rather than a month—even though the total remains the same.

Overconfidence bias is described in detail by Wang et al. (2021), who analyze the impact of managers' overconfidence on business transformation decisions. Overestimating one's own abilities leads to an expansion of the scope of activities, disregarding real resource and market constraints, which is often associated with the illusion of control—the belief in the ability to predict and control complex processes. It is also worth mentioning the work by Kapsalis & Kapsalis (2020), in which the authors attempt to monitor and minimize cognitive biases in the process of social change. The publication contains references to mechanisms such as status quo bias, confirmation bias, optimism bias, and anchoring bias, although they are not always clearly identified.

The authors of the analyzed works often cite biases that are most widely known in the literature (Almeida-Silva et al., 2020; Liu, 2017, Dumbura Eyupoglu, 2025; Hietschold, Voegtlin, 2021).

Such efforts are confirmed by the work of other authors rooted in behavioral economics. Popular biases mentioned in the works of other authors include: framing effects (Fetherstonhaugh, Rose, 1999), confirmation bias (Pericherla, Rachuri, Rao, 2018), conformist herding bias (e.g. "herd behavior", social proof, social norms) (Sharma 2024), overoptimism (Schaupp, Carter, 2010), anchoring heuristic (Vermeer, 2016; Palombi, Nonino, Borgatti, 2024), conservatism bias (Castelo, Ward, 2020), affirmation bias (Grillo, Pizzutti, 2020), group effect (Friedrich et al., 2019), illusion of control (Yarritu, Matute, Vadillo, 2014), contribution bias (Calanchini et al., 2022), overconfidence (Sharma, 2024; Gudmundsson, Lechner, 2013). The presentation of cognitive biases as decision-making mechanisms can also be found in the

works of Katsamakos, Madany (2019), Miłaszewicz, Borawska (2021), Morné et al. (2024), Peters (2022), Szara (2020), and Śliwowski, Wincewicz-Price, (2019).

The review included publications available in the Web of Science database, and their selection and interpretation of descriptions are subjective, despite the use of a procedure consistent with PRISMA guidelines. Detailed content analysis and the assignment of specific cognitive biases based on descriptions may raise interpretational questions—not all texts allow for a clear classification.

The main premise of the study was to identify cognitive biases, and this was achieved. The hypothesis was confirmed: Despite the complex and interdisciplinary nature of sustainable development, cognitive biases accompanying undertaken actions can be effectively identified and analyzed. A systematic literature review allowed for the identification of the most common cognitive biases.

This demonstrated that the decision-making mechanisms inherent in behavioral economics are directly relevant to decisions made in the context of sustainable development.

The identified cognitive biases influence not only the perception of sustainable development goals but also the effectiveness of implementing ESG strategies, the selection of assessment indicators, and the interpretation of environmental and social data. The results of the analysis indicate the need to design diagnostic and educational tools that take into account decision-makers' cognitive limitations and support debiasing processes. These conclusions contribute to the development of sustainable development practices based on a realistic model of human cognition.

Further work is recommended in specific areas of sustainable development, so that the bias occurring within an industry, phenomenon, or other parameter can be compared.

This work should analyze cognitive biases and their determinants in each area of sustainable development. Another research area could be the assessment of the social impact on cognitive biases when making decisions related to sustainable development.

6. Conclusion

According to the basic assumption of classical economics, humans are rational beings, meaning that their actions are guided by the principle of maximizing their own utility. Among various options, they choose the one that is most beneficial to them. The focus on rational, economically driven human behavior is a source of criticism for mainstream economics, which is often described as "desocialized". The development of behavioral economics has led to a challenge to existing paradigms in economics. Behavioral economics allows us to understand anomalies occurring in market participants' decision-making, unexplained by normative approaches.

In the context of sustainable development, behavioral economics reveals that the decisions of individuals and organizations are often burdened by cognitive biases—such as the status quo bias, overconfidence, the availability heuristic, and others. Awareness of these mechanisms and their impact on consumer, investment, and strategic choices is crucial for the effective implementation of sustainable policies.

The identified research gap indicates the need for in-depth analyses that will allow for a better understanding of how cognitive biases influence economic decisions in the area of sustainable development. Only by systematically identifying and minimizing them will it be possible to design effective educational, diagnostic, and implementation tools that support the transition towards more responsible economic practices.

References

1. Aaron, H. (1999). Retirement, Retirement Research, and Retirement Policy. In: H. Aaron (ed.), *Behavioral Dimensions of Retirement Economics* (pp. 60-61). Washington D.C., New York.
2. Almeida-Silva, M., Andrade, G., Luis, T., Santos, M., Grilo, A. (2024). Influence of cognitive factors on adherence to social distancing and the use of masks during the COVID-19 pandemic by young adults: A systematic review. *Social Sciences–Basel*, 13(5). <https://doi.org/10.3390/socsci13050275>
3. Baker, H., Filbeck, G., Nofsinger, J. (2021). *Finanse behawioralne. Co każdy powinien wiedzieć*. Warszawa: PWN, p. 114.
4. Borowa, K., Kamoda, S., Ogrodnik, P., Zalewski, A. (2023). Fixations in agile software development teams. *Foundations of Computing and Decision Sciences*, 48(1), 3-18. <https://doi.org/10.2478/fcds-2023-0001>
5. Calanchini, J., Schmidt, K., Sherman, J., Klein, S. (2022). The contributions of positive outgroup and negative ingroup evaluation to implicit bias favoring outgroups. *PNAS*, 119(40), e2116924119. <https://doi.org/10.1073/pnas.2116924119>
6. Castelo, N., Ward, A.F. (2021). Conservatism predicts aversion to consequential Artificial Intelligence. *PLoS ONE*, 16(12), e0261467. <https://doi.org/10.1371/journal.pone.0261467>
7. Chaira, A., Brunetta, F., Boccardelli, P. (2020). Cognitive biases and decision-making strategies in times of change: a systematic literature review. *Management Decision*, 59(3). <https://doi.org/10.1108/MD-07-2019-1006>
8. Cossette, P. (2014). Heuristics and cognitive biases in entrepreneurs: a review of the research. *Journal of Small Business & Entrepreneurship*, 27(5), 471-496. <https://doi.org/10.1080/08276331.2015.1105732>

9. Cristofaro, M., Giardino, P.L., Camilli, R., Hristov, I. (2024). Unlocking the sustainability of medium enterprises: A framework for reducing cognitive biases in sustainable performance management. *Journal of Management & Organization*, 30(3), 490-520. <https://doi.org/10.1017/jmo.2023.55>
10. Dumbura, A., Eyupoglu, S. (2025). The role of affective commitment in promoting knowledge sharing in Zimbabwean higher education. *South African Journal of Business Management*, 56(1). <https://doi.org/10.4102/sajbm.v56i1.4690>
11. Fetherstonhaugh, D., Rose, L. (1999). Framing Effects and Income Flow Preferences in Decisions about Social Security. In: H. Aaron (ed.), *Behavioral Dimensions of Retirement Economics* (pp. 187-209). Washington D.C., New York/
12. Florczak, E. (ed.) (2022). *Zrównoważony rozwój jako trend kształtujący współczesną gospodarkę*. Warszawa: C.H. Beck.
13. French, A.M., Storey, V.C., Wallace, L. (2023). The impact of cognitive biases on the believability of fake news. *European Journal of Information Systems*, 1-22. <https://doi.org/10.1080/0960085X.2023.2272608>
14. Friedrich, M.P.A., Basso, K., Espartel, L.B., Dalla Corte, V.F. (2019). The effect of groups on trust violation and recovery. *ReMark – Revista Brasileira De Marketing*, 18(3), 1-25. <https://doi.org/10.5585/remark.v18i3.16364>
15. Frör, O. (2008). Bounded rationality in contingent valuation: Empirical evidence using cognitive psychology. *Ecological Economics*, 68(1-2), 570-581. <https://doi.org/10.1016/j.ecolecon.2008.05.021>
16. Giordano, C., Alboni, F., Falasconi, L. (2019). Quantities, determinants, and awareness of households' food waste in Italy: A comparison between diary and questionnaires quantities. *Sustainability*, 11(12). <https://doi.org/10.3390/su11123381>
17. Grillo, T., Pizzutti, C. (2020). Recognizing and Trusting Persuasion Agents: Attitudes Bias Trustworthiness Judgments, but not Persuasion Detection. *Personality and Social Psychology Bulletin*, 47(5). <https://doi.org/10.1177/0146167220946197>
18. Grzebyk, M., Stec, M., Hejdukova, P. (2023). Implementation of sustainable development goal 8 in European Union countries – A measurement concept and a multivariate comparative analysis. *Sustainable Development*, 31(4), 2758-2769. <https://doi.org/10.1002/sd.2545>
19. Grzebyk, M., Stec, M., Stec, B. (2025). An Evaluation of the Implementation of Sustainable Development Goal 7 in European Union Countries in 2013 and 2022 Using the Ward's Method. *Humanities and Social Sciences*, 32(1), 47-59. <https://doi.org/10.7862/rz.2025.hss.04>
20. Gudmundsson, S., Lechner, Ch. (2013). Cognitive biases, organization, and entrepreneurial firm survival. *European Management Journal*, 31(3), 278-294. <https://doi.org/10.1016/j.emj.2013.01.001>

21. Hietschold, N., Voegtlin, C. (2021). Blinded by a Social Cause? Differences in Cognitive Biases between Social and Commercial Entrepreneurs. *Journal of Social Entrepreneurship*, 13(3), 431-452. <https://doi.org/10.1080/19420676.2021.1880466>
22. Huang, S.Y.B. (2026). Asking fintech voice chatbots: Explaining consumer switching intention by status quo bias theory. *Journal of Retailing and Consumer Services*, 88. <https://doi.org/10.1016/j.jretconser.2025.104457>
23. Joseph, G.C., Aboobaker, N., Zakkariya, K.A. (2023). Entrepreneurial cognition and premature scaling of startups: A qualitative analysis of determinants of start-up failures. *Journal of Entrepreneurship in Emerging Economies*, 15(1), 96-112. <https://doi.org/10.1108/JEEE-11-2020-0412>
24. Kaenzig, J., Wustenhagen, R. (2010). The effect of life cycle cost information on consumer investment decisions regarding eco-innovation. *Journal of Industrial Ecology*, 14(1), 121-136. <https://doi.org/10.1111/j.1530-9290.2009.00195.x>
25. Kahneman, D. (2012). *Pułapki myślenia. O myśleniu szybkim i wolnym*. Warszawa: Media Rodzina.
26. Kahneman, D., Tversky, A. (1973). Availability: A Heuristic for Judging Frequency and Probability. *Cognitive Psychology*, 5(2), 207-232. [https://doi.org/10.1016/0010-0285\(73\)90033-99](https://doi.org/10.1016/0010-0285(73)90033-99)
27. Kapsalis, T.A., Kapsalis, V.C. (2020). Sustainable development and its dependence on local community behavior. *Sustainability*, 12(8). <https://doi.org/10.3390/su12083448>
28. Katsamakas, E., Madany, H. (2019). Effects of user cognitive biases on platform competition. *Journal of Decision Systems*, 28(2), 138-161. <https://doi.org/10.1080/12460125.2019.1620566>
29. Kitchenham, B. (2004). *Procedures for Performing Systematic Reviews*. Keele: Keele University.
30. Liu, Y., Segev, S., Villar, M.E. (2017). Comparing two mechanisms for green consumption: Cognitive-affect behavior vs theory of reasoned action. *Journal of Consumer Marketing*, 34(5), 442-454. <https://doi.org/10.1108/JCM-01-2016-1688>
31. McGowan, F.P., Denny, E., Lunn, P.D. (2023). Looking beyond time preference: Testing potential causes of low willingness to pay for fuel economy improvements. *Resource and Energy Economics*, 75. <https://doi.org/10.1016/j.reseneeco.2023.101404>
32. Miłaszewicz, D., Borawska, A. (2021). Zastosowania koncepcji ekonomii behawioralnej w celu zwiększenia skuteczności kampanii społecznych. *Ekonomia XXI Wieku*, 24, p. 131.
33. Morné, O., Flowerday, S., van der Schyff, K. (2024). Optimism bias in susceptibility to phishing attacks: an empirical study. *Information and Computer Security*. <https://doi.org/10.1108/ICS-02-2023-0023>
34. Oliveira, A.Y., Mendes, J.A.J., Zanon, L.G., Gerolamo, M.C., Zeidler, V.G.Z. (2025). Sustainable development: Prioritizing attributes and validating factors for the success of

- green startups in Brazilian and German entrepreneurial ecosystems. *Business Strategy and Development*, 8(1). <https://doi.org/10.1002/bsd2.70083>
35. Palombi, G., Nonino, F., Borgatti, S.P. (2024). The effect of social network structure on group anchoring bias. *Journal of Organization Design*, 13, 33-44. <https://doi.org/10.1007/s41469-023-00162-w>
 36. Pandey, P.K., Pandey, P.K. (2025). Unveiling the transformative power of augmented reality in retail: A systematic literature analysis. *Journal of Strategy and Management*. <https://doi.org/10.1108/JSMA-05-2023-0101>
 37. Patent, V. (2022). Dysfunctional trusting and distrusting: Integrating trust and bias perspectives. *Journal of Trust Research*, 12(1), 66-93. <https://doi.org/10.1080/21515581.2022.2113887>
 38. Pericherla, S.R., Rachuri, R., Rao, S. (2018). *Modeling Confirmation Bias Through Egoism and Trust in a Multi Agent System*. IEEE International Conference on Systems, Man, and Cybernetics (SMC), Miyazaki, Japan, 1162-1168. <https://doi.org/10.1109/SMC.2018.00205>
 39. Peters, U. (2022). What Is the Function of Confirmation Bias? *Erkenntnis*, 87(3), 1351-1376.
 40. Schaupp, L.C., Carter, L. (2010). The impact of trust, risk and optimism bias on E-file adoption. *Information Systems Frontiers*, 12, 299-309. <https://doi.org/10.1007/s10796-008-9138-8>
 41. Shantha, K.V.A. (2019). Individual investors' learning behavior and its impact on their herd bias: An integrated analysis in the context of stock trading. *Sustainability*, 11(5). <https://doi.org/10.3390/su11051448>
 42. Sharma, P.Ch. (2024). Influence of Behavioural Biases on Market Investment Behaviour – Mediating Role of Brand Trust. *Interdisciplinary Journal of Management Studies (IJMS)*, 17(1), 1-19. <https://doi.org/10.22059/ijms.2022.331497.674780>
 43. Śliwowski, P., Wincewicz-Price, A. (2019). *Prościej, taniej i skuteczniej, czyli jak ekonomia behawioralna wspiera polityki publiczne w Polsce*. Warszawa: Polski Instytut Ekonomiczny.
 44. Szara, K. (2020). Behaviours towards creativity of SMEs employees. *Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie*, 45(1), 123-135. <https://zn.mwse.edu.pl/index.php/zn/article/view/690/667>
 45. Szara, K. (2024). Behavioral aspects of investments in renewable energy sources on the example of Podkarpackie Province. *Economic and Regional Studies [Studia Ekonomiczne i Regionalne]*, 17(1), 164-180. <https://doi.org/10.2478/ers-2024-0009>
 46. Thaler, R. (2000). From Homo Economicus to Homo Sapiens. *Journal of Economic Perspectives*, 14(1), 133-141.
 47. Thaler, R. (2018). *Zachowania niepoprawne. Tworzenie ekonomii behawioralnej*. Poznań: Media Rodzina.

48. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. (2021). *BMJ*. <https://doi.org/10.1136/bmj.n71>
49. Vargas-Lama, F., Osorio-Vera, F. (2020). The Territorial Foresight for the construction of shared visions and mechanisms to minimize social conflicts: The case of Latin America. *Futures*, 123, 102625. <https://doi.org/10.1016/j.futures.2020.102625>
50. Vassilopoulos, A., Papadaki, L., Koundouri, P. (2024). Can virtual reality nudge toward green investing? An experiment with small business entrepreneurs. *Review of Behavioral Finance*, 16(2), 322-340. <https://doi.org/10.1108/RBF-01-2023-0005>
51. Veettil, P.C., Yashodha, Y., Vecchi, J. (2025). Hypothetical bias and cognitive ability: Farmers' preference for crop insurance products. *American Journal of Agricultural Economics*, 107(3), 888-924. <https://doi.org/10.1111/ajae.12506>
52. Vermeer, N. (2016). Age Anchors and the Expected Retirement Age: An Experimental Study. *De Economist*, 164(3), 255-279.
53. Wang, D.L., Wang, Y.D., Yang, J.Y., Huang, Z.Y., Cui, R. (2021). Managerial cognitive bias, business transformation, and firm performance: Evidence from China. *SAGE*, 11(1). <https://doi.org/10.1177/2158244021999156>
54. Xu, F., Lin, X.J., Li, S.S., Niu, W.X. (2018). Is Southern Xinjiang really unsafe? *Sustainability*, 10(12). <https://doi.org/10.3390/su10124639>
55. Zalega, T. (2015). Ekonomia behawioralna jako nowy nurt ekonomii – zarys problematyki. *Studia i Materiały. UW*, 1(18).
56. Zygan, M. (2013). Ekonomia behawioralna – wprowadzenie do problematyki. *Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania Uniwersytetu Szczecińskiego*, 32, 9-22.

ASSESSMENT OF OCCUPATIONAL SAFETY AT SELECTED WORKSTATIONS IN A FOOD PROCESSING PLANT

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Purpose: The purpose of this article is to conduct a comprehensive assessment of occupational safety at selected workstations in a food processing plant by identifying hazards and evaluating occupational risks.

Design/methodology/approach: The analysis was carried out using the RISK SCORE method, which takes into account the probability of hazard occurrence and the severity of its consequences. The study covered four workstations: production line operator, packer, warehouse worker, and cold storage employee. Data were collected based on observations, company documentation, and consultations with employees.

Findings: The highest risk level was recorded at the production line operator workstation, primarily due to contact with moving machine parts ($R = 15$). The remaining workstations were classified as medium risk ($R = 4-8$), where the most common hazards included noise, slippery surfaces, physical overload, and low temperatures. Preventive recommendations were developed regarding technical, organizational, and training solutions.

Originality/value: The study results provide practical guidelines enabling effective preventive actions and support decision-making processes related to occupational safety management in the food industry sector.

Keywords: occupational safety, food processing, occupational risk, RISK SCORE, ergonomics, hazard assessment.

Category of the paper: research paper.

1. Introduction

Occupational health and safety (OHS) is a fundamental component of management policy in every manufacturing enterprise, particularly in the food processing industry. Due to the specific nature of this sector - which involves intensive use of machinery, work in high-humidity environments, low temperatures, and strict sanitary requirements - the food industry is classified as a high-risk work environment. In such conditions, ensuring an adequate level of safety not only protects the health and lives of employees but also directly affects the quality and continuity of production processes (Raditsela et al., 2025). In recent years, there has been

an increase in incidents involving mechanical injuries, accidents caused by slippery surfaces, musculoskeletal overload, and excessive noise exposure. These factors are particularly prevalent at workstations where employees perform repetitive tasks in a fixed position, often in close proximity to production lines. This issue is structural in nature and applies to both large automated plants and smaller, manually operated enterprises. Insufficient preventive measures, lack of regular risk assessments, or neglect of ergonomic principles in workstation design can lead to serious health and economic consequences.

The ability to analyze such factors using computer simulations supports decision-making at the organizational level (Pawlak, 2025). Protecting employees from occupational exposures should be based on a systematic approach to safety management that goes beyond reactive responses to incidents, focusing instead on preventive measures—hazard identification, risk assessment, and the implementation of effective control strategies.

In the context of industrial modernization, Agriculture 4.0 technologies are gaining increasing importance. These enable remote monitoring of working conditions, automation of control processes, and more effective identification of potential hazards in the work environment (Pilarczyk, Ulewicz, 2024). Organizational tools such as the SDCA cycle and the DACI matrix can further support the standardization of processes and assignment of responsibilities. In production settings, they help shorten approval times for changes and reduce process deviations (Leby, 2024). Although not designed specifically for risk assessment, these tools play a significant role in strengthening OHS systems and change management practices.

In parallel, the 5S method, as part of lean management, can also have a positive impact on safety and work organization. Its implementation facilitates the elimination of unnecessary items from the workspace, improves ergonomics, and reduces errors and hazards arising from disorder and lack of standardization. A study by Mazur et al. (2024) demonstrated that systematic use of the 5S method contributed to improved workstation organization and reduced accident risk in a production environment. Similarly, Chwist and Ingaldi (2025), in their study of a manufacturing enterprise, demonstrated that applying the 5S method led to improved workplace organization and cleanliness, contributing to enhanced production efficiency.

For the analysis conducted in this article, the RISK SCORE method was applied due to its clarity and alignment with the operational conditions of the studied facility. However, it is worth noting that both academic literature and industrial practice employ more advanced tools for risk assessment and management, such as FMEA analysis, which enables the systematic identification of failure modes and prioritization of corrective actions (Sahin, 2024; Szyszka, Ulewicz, 2024). The use of such methods – along with tools like SDCA and DACI in advanced safety management—requires greater resource investment and a higher level of organizational maturity. Nevertheless, they represent a potential direction for the development of the OHS system in the studied enterprise.

Modern risk assessment approaches also align with international standards such as ISO 45001:2018, which provide an integrated and measurable framework for analyzing the work environment (International Organization for Standardization, 2018; Pacana, Czerwińska, 2025). These standards support the identification of key risk areas and prioritization of corrective actions based on real data rather than subjective judgment.

Against this background, the objective of the present study was to conduct a comprehensive assessment of occupational risk at selected workstations in a food processing plant. The analysis covered four key positions characteristic of production activities in this industry: production line operator, packer, warehouse worker, and cold storage employee. The goal was to identify mechanical, physical, environmental, and chemical hazards and evaluate the level of risk using the Risk Score method. The assessment considered both technological and organizational factors as well as environmental parameters, such as noise, temperature, humidity, and the presence of harmful substances.

As a result, the risk level for each workstation was determined, and possible preventive and modernization measures were proposed that could significantly improve occupational safety. These findings can serve as an analytical resource for those responsible for OHS management in food processing facilities, supporting investment decisions, training planning, and development of risk management systems. The study also has practical value – the conclusions drawn may be adapted by other enterprises with similar operational profiles.

2. Characteristics of the Food Processing Plant

The analyzed production facility is one of the largest enterprises in the food processing sector located in central Poland. It specializes in the manufacture of ready-made meals, canned meat and vegetable products, as well as soups and frozen goods. Its portfolio includes over 80 product lines, distributed both domestically and internationally.

The plant is equipped with a modern technological infrastructure that enables comprehensive processing operations – from the intake of raw materials, through thermal processing and packaging, to storage and distribution. Production is carried out on automated technological lines, ensuring high efficiency and consistency across processes. The company employs approximately 1000 workers, representing various occupational groups including machine operators, warehouse staff, packers, technical personnel, and administrative employees. The organizational structure is divided into production, logistics, quality, occupational health and safety (OHS), and maintenance departments. The facility operates under internal occupational health and safety regulations, and follows procedures compliant with national labor law as well as international standards.

The enterprise operates as part of a larger corporate group, which facilitates the integration of procurement, sales, and logistics processes and supports the implementation of unified safety and quality standards. The plant is certified under recognized food quality and safety management systems and undergoes regular internal and external audits. Ongoing investments in equipment modernization and staff training help maintain high standards in terms of ergonomics, work organization, and occupational risk management. Nevertheless, the nature of food production inherently involves various environmental and organizational hazards, the identification and evaluation of which constitute the core focus of this study.

3. Risk Assessment Methodology

Occupational risk assessment constitutes a fundamental component of occupational health and safety (OHS) management systems. Its primary objective is the systematic identification of hazards present in the work environment and the determination of their potential impact on the health and safety of employees (Rączkowski, 2024; Klimecka-Tatar et al., 2023). The approach adopted in this study complies with the requirements of Directive 89/391/EEC of the European Parliament and of the Council of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work (Council of the European Communities, 1989). Additionally, the methodology was aligned with the international standard ISO 45001:2018, which promotes a systematic and continuous approach to OHS management.

Risk management is an iterative and cyclical process involving the systematic repetition of risk identification, assessment, control, and monitoring stages, as illustrated by Figure 1.

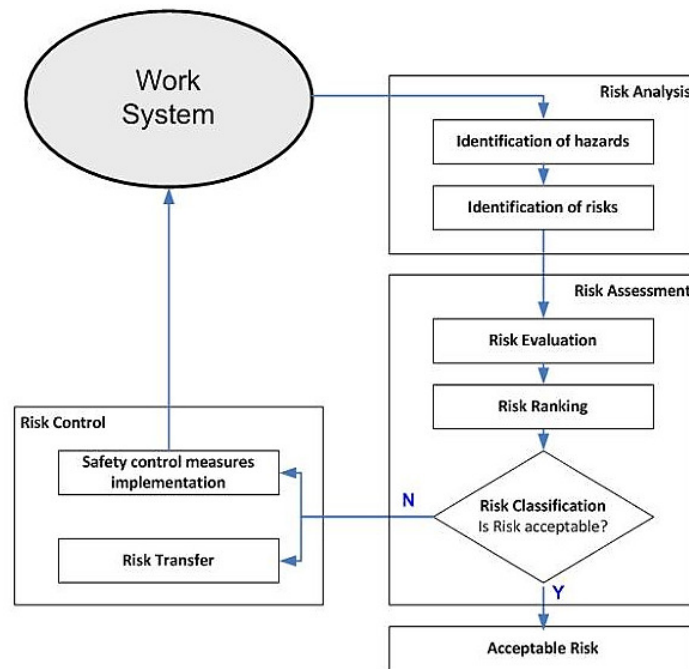


Figure 1. The cyclical process of risk management.

Source: European Agency for Safety and Health at Work, *Occupational safety and health risk assessment methodologies* (retrieved July 21, 2025).

In this study, a simplified version of the Risk Score method was applied. This method is based on the determination of two core parameters for each identified hazard:

- P – the probability of hazard occurrence,
- S – the severity of consequences should the hazard materialize.

Both parameters are rated on a five-point scale (Tab. 1).

Table 1.
Risk Score Method – Assessment Scales

Scale	P – Probability	S – Severity
1	Very unlikely	No injury or negligible harm
2	Unlikely	Minor injury, short-term absence
3	Possible	Injury requiring outpatient medical treatment
4	Likely	Serious injury requiring hospitalization
5	Very likely	Permanent disability or fatality

Source: author's own elaboration.

The risk index (R) is calculated as the product of the two values (1):

$$R = P \times S \quad (1)$$

Based on the results, the risk level is classified according to the following scheme:

- $R < 4$ – Low risk (acceptable, but should be monitored),
- $4 \leq R < 10$ – Medium risk (requires preventive and control measures),
- $R \geq 10$ – High risk (requires immediate intervention and workplace modifications).

The assessment process was conducted in stages. Initially, hazards were identified based on an analysis of internal company documentation, direct observation, and interviews with employees and OHS personnel. Subsequently, the environmental parameters of each

workstation (temperature, noise, humidity), as well as ergonomic and organizational factors, were evaluated. Separate analyses were conducted for the following workstations: production line operator (Fig. 2a), packer (Fig. 2b), warehouse worker (Fig. 2c), and cold storage worker (Fig. 2c), taking into account the nature of the tasks performed and the use of personal and collective protective equipment.



Figure 2. Workstations covered by the study.

Source: author's own elaboration.

Additional aspects assessed included the degree of work automation, employee rotation, exposure time to adverse environmental conditions, and the frequency of physically demanding activities. Particular attention was given to evaluating hazards related to contact with moving machine parts, operation of transport equipment, work in high-humidity environments, and exposure to noise and low temperatures. The compliance of existing safety measures with technical standards and labor law regulations was also verified. The results enabled the creation of a risk profile for each specific workstation and identified areas requiring either immediate corrective actions or long-term safety improvements. The adopted methodology allowed not only for the evaluation of the current safety status but also for the formulation of actionable recommendations for facility managers.

4. Hazard Analysis and Occupational Risk Assessment Results

The study involved a detailed evaluation of hazards (Table 2) associated with four key workstations in the food processing facility: production line operator, packer, warehouse worker, and cold storage worker. The analysis covered various types of risk factors, including mechanical, environmental, physical, and chemical hazards, all of which significantly impact employee health and safety. The highest level of occupational risk was identified at the production line operator workstation. This employee is constantly exposed to moving parts of machinery and production line components, posing a direct threat of mechanical injuries such as cuts, crush injuries, or amputations. Continuous proximity to equipment necessitates heightened vigilance, technical safeguards, and the consistent use of personal protective equipment (PPE).

At the packer workstation, the primary hazard identified was the risk of slips and falls due to wet and slippery surfaces in the packaging area. These conditions are typical in food processing environments, where moisture arises from cleaning production lines or transporting raw materials. Slips and falls can lead to serious injuries, making this a critical area of concern.

The warehouse worker is exposed to noise generated by transport equipment as well as the physical strain of lifting and carrying loads. Repetitive movements and manual handling tasks contribute to musculoskeletal overload, potentially leading to chronic pain and occupational diseases.

The cold storage worker, on the other hand, is exposed to low temperatures, which may adversely affect the human body during prolonged exposure. The specific microclimate of cold storage areas requires appropriate thermal protective clothing and organizational strategies such as workforce rotation to mitigate the effects of cold stress and related health risks.

Table 2.
Identified Occupational Hazards by Workstation

Workstation	Main Hazard	Description of Hazard and Consequences
Production Line Operator	Moving machine parts	Direct contact with active machinery; high risk of severe mechanical injuries; constant alertness required.
Packer	Slippery surfaces	Wet and slippery floors increase the risk of slips and falls, possibly leading to injuries or fractures.
Warehouse Worker	Noise, physical overload	Excessive noise, repetitive lifting/carrying tasks cause musculoskeletal strain and joint overload.
Cold Storage Worker	Low temperature (microclimate)	Prolonged exposure to cold may lead to hypothermia; requires protective clothing and shift rotation.

Source: Based on on-site observation and internal documentation.

Data from Table 3, further illustrated in Figure 3, clearly demonstrate the variation in occupational risk levels across the examined workstations in the facility. According to the results, the highest risk index ($R = 15$) was recorded for the production line operator, classifying this position as high risk. The high probability parameter ($P = 5$) reflects the frequent contact with moving machinery, coupled with a dynamic and demanding production environment. Although the severity ($S = 3$) does not reach the maximum, the potential consequences – such as limb injuries – are serious and may lead to temporary incapacity for work. This underscores the necessity for advanced collective protective measures and strict adherence to machine operation procedures. Conversely, the packer, warehouse worker, and cold storage worker positions were classified as medium risk, with R values of 8, 6, and 4, respectively. While these differences may appear subtle, each arises from job-specific characteristics. The packer ($R = 8$) faces increased risk of slipping due to moisture on surfaces and repetitive movements, which can strain the musculoskeletal system. Standard preventive measures should include anti-slip mats, appropriate footwear, and ergonomic workstation design. For the warehouse worker ($R = 6$), key risks stem from manual material handling and improper lifting techniques. While the risk level is moderate, it may lead to chronic musculoskeletal disorders, necessitating ergonomic training and the use of assistive devices such as carts and lifts. The cold storage worker ($R = 4$) had the lowest risk level among the analyzed positions. The main concern – exposure to cold – can cause health issues over time, such as rheumatic changes or hypothermia. However, this risk is effectively mitigated by employee rotation and thermal protective clothing.

Table 3.
Occupational Risk Index (R) for Selected Workstations (Risk Score Method)

Workstation	P (Probability)	S (Severity)	$R = P \times S$	Risk Class
Production Line Operator	5	3	15	High
Packer	4	2	8	Medium
Warehouse Worker	3	2	6	Medium
Cold Storage Worker	2	2	4	Medium

Source: Based on on-site observation and internal documentation.

Figure 3 provides a visual comparison of the risk levels, clearly highlighting the production line operator as the most hazardous position. The graphical representation allows for the quick identification of roles requiring urgent technical and preventive interventions.

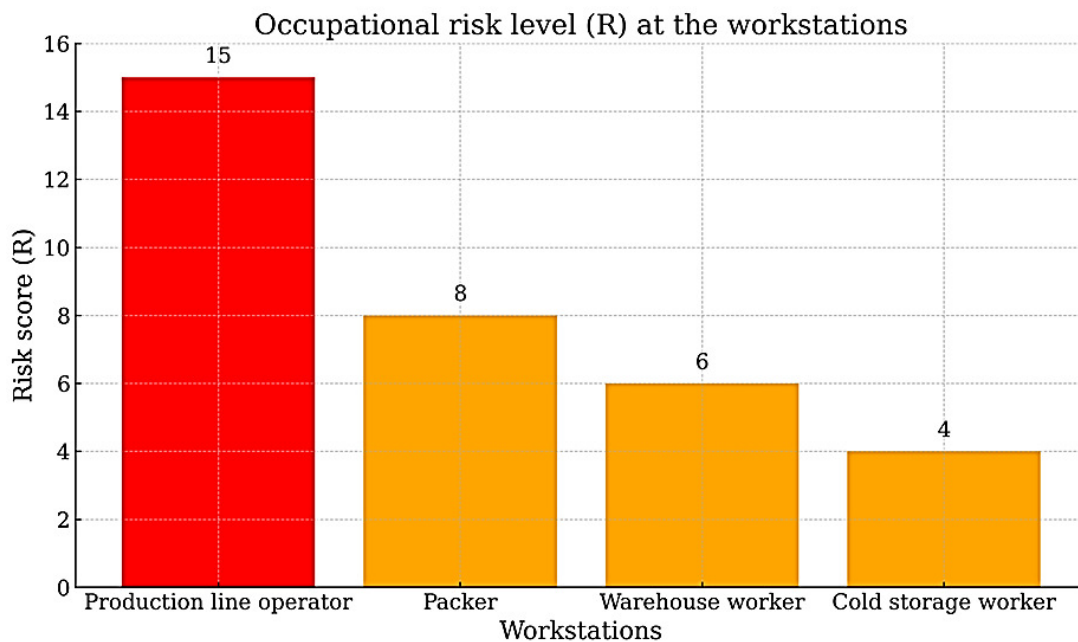


Figure 3. Occupational risk level at the workstations covered by the study.

Source: Based on on-site observation and internal documentation.

Figure 4 shows the distribution of risk classes among the assessed positions. Notably, 75% of positions fell within the medium risk category, indicating that while the overall safety standards are relatively sound, there is still room for improvement in ergonomic solutions, technical safeguards, and preventive training programs. Only 25% of positions (1 out of 4) were categorized as high risk, warranting immediate attention from OHS management.

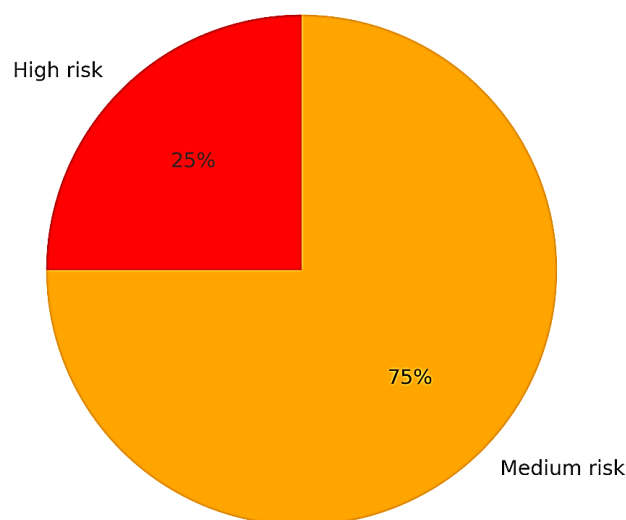


Figure 4. Distribution of risk classes among the analyzed workstations.

Source: Based on on-site observation and internal documentation.

To deepen the analysis, a further assessment was conducted to examine the relationship between the risk index (R) and its two components: probability (P) and severity (S). The findings revealed a stronger correlation between R and P, suggesting that the frequency of hazard occurrence has a more significant impact on the overall risk level than the magnitude of potential consequences.

This is particularly evident in the case of the production line operator, where despite a moderate severity rating ($S = 3$), the very high probability ($P = 5$) of hazardous contact with machinery elevates the total risk index to a high level ($R = 15$). In contrast, for the cold storage worker, even though long-term cold exposure may result in serious conditions, the low probability ($P = 2$) and moderate severity ($S = 2$) keep the R value at a medium level ($R = 4$).

This relationship provides practical guidance for developing preventive strategies – reducing exposure frequency (through automation, minimizing direct contact, or workforce rotation) yields a more significant reduction in risk than solely focusing on mitigating the consequences of potential injuries.

5. Discussion of Results

The results of the occupational risk assessment conducted for four selected positions in a food processing facility allow for the formulation of several key conclusions. Most notably, despite a relatively uniform working environment, there are clear differences in risk levels between the analyzed positions. These differences stem both from the nature of the tasks performed and from the degree of process automation. The highest risk level was recorded for the production line operator. The high risk score ($R = 15$) confirms the presence of significant hazards associated with contact with moving machinery. This necessitates not only the use of effective technical safeguards and safety interlocks, but also a high level of employee training and continuous monitoring of compliance with operating procedures.

The remaining positions – packer, warehouse worker, and cold storage worker – were classified as medium-risk. However, each is characterized by distinct dominant risk factors. For packers, the primary concern is slips on wet surfaces; for warehouse workers, physical strain and noise exposure; and for cold storage workers, exposure to low temperatures. Recommended preventive measures include: the use of anti-slip mats, ergonomic workstation improvements, implementation of appropriate personal protective equipment, and organizational changes aimed at reducing exposure time to adverse environmental conditions.

The analysis indicates that the most significant factor influencing the overall risk level was parameter P – the frequency of exposure to a given hazard. It is the regular and repeated contact with dangerous factors, rather than their mere presence, that most strongly increases the risk

index (R). The findings also underscore the importance of an integrated approach to occupational health and safety, which incorporates both technical and organizational aspects. The analysis can serve as a decision-support tool for investment planning and the implementation of preventive programs in other manufacturing facilities with similar operational profiles.

Moreover, the conclusions drawn from this analysis form the basis for proposing specific preventive and modernization measures, which are presented in the final section of this article.

6. Conclusion and Recommendations

Risk assessment is a fundamental process for identifying hazards, evaluating risks, and implementing measures to control and mitigate those risks (Rausand, Haugen, 2020).

This study focused on assessing occupational risk at a limited number of production workstations within a single food processing plant, which constitutes a notable constraint of the research. The analysis did not encompass all roles present in the facility, nor did it account for seasonal variations or extended shifts in working conditions over time. These factors may influence the overall accuracy and completeness of the risk evaluation. However, the results serve as a solid foundation for recognizing critical hazards and guiding more comprehensive future assessments and targeted safety interventions.

The occupational risk assessment carried out for selected job positions in the analyzed production facility revealed that the level of occupational risk is not uniform and depends on the nature of the tasks performed, the working environment, and the organization of processes. The highest risks were identified for machine operators, while supporting roles – such as packers, warehouse workers, and cold storage workers – were classified as medium risk, though still requiring constant monitoring and preventive measures.

The use of the Risk Score method enabled a transparent classification of hazards and the identification of areas needing improvement. Furthermore, the correlation analysis demonstrated that the frequency of exposure (P) has a stronger impact on the overall risk level than the severity of consequences (S). This suggests that preventive efforts should focus on limiting exposure, e.g., through automation, employee rotation, or organizational changes.

It is worth emphasizing that the evaluated company maintains a high standard of occupational safety, in line with current regulations and occupational health and safety (OHS) guidelines. The identified risks – such as contact with moving machine parts, slips on wet surfaces, or musculoskeletal overload – are continuously monitored and effectively managed. Nevertheless, there is potential for further optimization of the safety system through the implementation of the following recommendations:

- Enhancing preventive measures through regular training and educational campaigns, particularly focused on workplace ergonomics and safe operation of machinery.
- Modernizing technical safeguards at high-risk workstations by implementing advanced solutions that complement existing protective measures.
- Systematic monitoring of microclimatic conditions, especially in cold storage areas, along with the introduction of flexible organizational solutions such as employee rotation or shortened shifts.
- Continuing investment in new technologies and process automation to minimize direct worker exposure to hazardous environmental factors.

Implementation of the above actions will not only further reduce occupational risk levels, but also improve work comfort and efficiency, reduce sickness-related absenteeism, and enhance the competitiveness of the analyzed facility in the market.

It is also worth emphasizing that effective occupational health and safety management relies not only on technical safeguards, but also on organizational learning from past incidents. Systematic reflection on accident occurrences constitutes one of the pillars of modern approaches to risk control, supporting the prevention of their recurrence (Patel, Ansari, 2022). This perspective further underlines the need for continuous development and improvement of safety management systems also in the food industry.

Although the analyzed company demonstrates a high level of compliance with national OHS regulations and effectively implements preventive measures, a critical reflection reveals that its safety management system is also strongly aligned with the ISO 45001:2018 principles. The organization applies a systemic approach to risk management, combining technical safeguards with procedural control, employee engagement, and ongoing monitoring of safety indicators. This alignment confirms that the company's practices are not limited to formal compliance, but reflect the continuous improvement philosophy promoted by ISO 45001, integrating safety management into every stage of production and organizational decision-making.

While the present study confirmed a strong alignment with ISO 45001:2018, future research could include a structured gap analysis to identify specific areas for further optimization and to verify the full extent of conformity between documented procedures and day-to-day operational practices. Such an approach would provide valuable input for management, supporting evidence-based decision-making and reinforcing the continuous improvement cycle within the occupational health and safety management system.

References

1. Chwist, K., Ingaldi, M. (2025). Improving a manufacturing enterprise through the implementation of 5S – a practical approach. *Scientific Journals of the Maritime University of Szczecin*, 82(154), 58-68. <https://doi.org/10.17402/642>
2. European Agency for Safety and Health at Work. *Occupational safety and health risk assessment methodologies*. OSHwiki. Retrieved from: <https://oshwiki.osha.europa.eu/en/themes/occupational-safety-and-health-risk-assessment-methodologies>, July 21, 2025.
3. International Organization for Standardization (2018). *ISO 45001:2018 – Occupational health and safety management systems – Requirements with guidance for use*. ISO.
4. Klimecka-Tatar, D., Ulewicz, R., Ingaldi, M. (2023). Minimizing occupational risk by automation of the special processes – Based on occupational risk assessment. *Procedia Computer Science*, 217, 1145-1152. <https://doi.org/10.1016/j.procs.2022.12.313>
5. Leby, C.L. (2024). Stabilization of operational processes through the application of the SDCA and the DACI matrix. *Archives of Engineering Knowledge*, 10(1), 137-141. <https://doi.org/10.30657/aek.2024.10.19>
6. Mazur, M., Korenko, M., Zitnak, M., Shchur, T., Kielbasa, P., Dostal, P., Dzhidzhora, O., Idzikowski, A. (2024). Implementation and benefits of the 5S method in improving workplace organisation – A case study. *Management Systems in Production Engineering*, 32(4), 498-507. <https://doi.org/10.2478/mspe-2024-0047>
7. Pacana, A., Czerwińska, K. (2025). Validation of the use of KPIs to measure information security management system performance in manufacturing companies. *Production Engineering Archives*, 31(2), 266-275. <https://doi.org/10.30657/pea.2025.31.26>
8. Patel, R., Ansari, M.F. (2022). *Occupational health and safety management system: Occupational health and safety management system performance improvement (BOP)*. LAP Lambert Academic Publishing. ISBN 978-620-55119-16
9. Pawlak, S. (2025). Computer simulations in planning production processes as a tool of decision making. *Production Engineering Archives*, 31(2), 183-189. <https://doi.org/10.30657/pea.2025.31.18>
10. Pilarczyk, M., Ulewicz, R. (2024). Agriculture 4.0 – Modern technologies in occupational health and safety management. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarządzanie*, 205, 471-491. <https://doi.org/10.29119/1641-3466.2024.205.29>
11. Rączkowski, B. (2024). BHP w praktyce. *Ośrodek Doradztwa i Doskonalenia Kadr*. ISBN 978-83-7804-945-6
12. Rada Wspólnot Europejskich (1989, 12 czerwca). *Dyrektywa Rady 89/391/EWG w sprawie wprowadzenia środków mających na celu ulepszenie warunków BHP pracowników podczas pracy* [Dyrektywa]. *Dziennik Urzędowy Wspólnot Europejskich*, L 183.

- Pobrano z Sejm.gov.pl: <https://orka.sejm.gov.pl/Drektywy.nsf/all/31989L0391/%24File/31989L0391.pdf>
13. Raditsela, R., Sharp, K.-L., Bevan-Dye, A.L. (2025). Safety culture in focus: Comparing employee perceptions across small and medium-sized manufacturing SMEs in South Africa. *Production Engineering Archives*, 31(2), 238-246. <https://doi.org/10.30657/pea.2025.31.24>
 14. Rausand, M., Haugen, S. (2020). *Risk assessment: Theory, methods, and applications* (2nd ed.). John Wiley & Sons. <https://doi.org/10.1002/9781119377351>
 15. Sahin, A. (2024). Application of FMEA in quality control: minimizing risk and enhancing reliability in watch production. *Archives of Engineering Knowledge*, 10(1), 56-64. <https://doi.org/10.30657/aek.2024.10.8>
 16. Szyszka, M., Ulewicz, R. (2024). Quality improvement in bottle production: a case study on FMEA and Pareto-Lorenz methodologies. *Archives of Engineering Knowledge*, 10(1), 148-152. <https://doi.org/10.30657/aek.2024.10.21>

BANK CHARACTERISTICS AND THE TRANSMISSION OF MONETARY POLICY: PANEL EVIDENCE FROM THE GERMAN SAVINGS BANK SECTOR

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Purpose: This study assesses the transmission of ECB monetary policy to credit supply within Germany's savings-bank sector. A central aim is to quantify how bank-level balance-sheet features – such as size or capital – shape real loan growth.

Design/methodology/approach: We assemble an annual bank-level panel of 491 Sparkassen (4103 observations, 2000-2019) from Bankscope/Orbis, which is winsorized and deflated. Our empirical strategy employs fixed-effects regressions of real loan growth on lagged policy-rate changes and control variables. To uncover heterogeneity, we complement this with median-split and a detailed 4×4 size-by-capital quartile analysis.

Findings: On average, a one percentage point (p.p.) monetary policy rate increase reduces real loan growth by approximately 0.6 p.p. We find that equity growth and deposit inflows mitigate this contraction, whereas higher capital ratios and provisioning amplify it. The heterogeneity is pronounced: capital strength dominates bank scale as a determinant of sensitivity. A quartile analysis reveals a U-shaped pass-through pattern, with the strongest effects at the low- and high-capital tails. The cushioning effect of size is primarily evident when capital is scarce. These asymmetries imply a regionally uneven transmission of monetary policy, a critical concern given Sparkassen's statutory local lending mandates.

Research limitations/implications: The annual frequency and pre-2020 coverage of our data limit direct inference for the recent monetary tightening cycle. We acknowledge the potential endogeneity of funding and equity dynamics. Future research should extend the sample period and exploit higher-frequency supervisory data to confirm these dynamics.

Practical implications: Our findings suggest that credible guidance on the usability of capital buffers and carefully calibrated reserve-tiering can dampen excessive credit contraction where liability costs are binding. Furthermore, a closer coordination of macro-prudential tools with the monetary policy cycle can help reduce the regional disparities in credit availability.

Social implications: The heterogeneous pass-through of monetary policy risks widening existing regional inequalities in credit access, investment, and employment. A targeted design of prudential regulation can therefore serve as a tool to support broader local economic development objectives.

Originality/value: This paper provides long-horizon, micro-econometric analysis of the bank lending channel for the German Sparkassen sector. Its multi-layer heterogeneity design uncovers a U-shaped pass-through pattern relative to capital levels. The results yield concrete, evidence-based policy design insights for one of Europe's most important decentralized, deposit-funded banking pillars.

Keywords: Bank lending channel, Monetary policy, Sparkassen (German savings banks).

Category of the paper: Research paper.

1. Introduction

The prolonged period of exceptionally low interest rates that followed the global financial crisis fundamentally reshaped the economics of banking across advanced economies. In the euro area, the European Central Bank (ECB) lowered its deposit facility rate below zero in June 2014 and maintained a negative policy stance for more than eight years – marking the longest such episode among major monetary jurisdictions. Empirical studies have examined how this regime affected the behavior of commercial banks, particularly through margin compression and altered lending patterns (Heider, Saidi, Schepens, 2019). By contrast, Germany's public savings banks (Sparkassen) – despite their systemic importance – have received comparatively limited academic attention. Notable exceptions include Köhler (2018), who analyses the role of non-traditional income sources in enhancing Sparkassen's profitability, and Michaelis (2023), who provides micro-level evidence on deposit pricing responses to negative policy rates. Nonetheless, comprehensive evaluations of how these institutions adapted to sustained monetary accommodation remain scarce.

Sparkassen constitute the largest component of Germany's three-pillar banking system. As of end-2023, they accounted for approximately 40% of loans to domestic companies and self-employed individuals, and around 36% of mortgage lending to private households, reflecting their systemic importance in regional credit provision (Moody's Investors Service, 2025). Their public mandate obliges them to promote regional economic development, with a governance structure characterized by municipal trusteeship that insulates them from shareholder pressure while embedding political objectives through local oversight (Hardie, Howarth, 2009; Puri, Rocholl, Steffen, 2011). This combination of significant market share, decentralized risk-taking, and a developmental remit positions Sparkassen as a natural conduit for the transmission of monetary policy, particularly when policy ventures into unconventional territory.

The study examines how Sparkassen respond to monetary accommodation and how their behavior contributed to monetary transmission through the lending channel. This question is salient for several reasons. Sparkassen account for approximately 30% of total banking-sector assets in Germany; any systematic shift in their behavior has macroeconomic implications. Their public-interest mandate may induce responses to interest rate cuts that differ meaningfully from those of profit-maximizing commercial banks, potentially amplifying or dampening regional credit cycles. A clearer understanding of how Sparkassen adapted during the accommodation phase is essential for anticipating the effects of policy reversal.

This study contributes to the literature in three key ways. First, it provides the first long-horizon, micro-econometric assessment of how Sparkassen adjusted lending, in response to successive phases of ECB monetary accommodation between 2000 and 2019, using a granular panel dataset of 491 institutions. While retrospective in scope, this historical perspective offers a valuable benchmark for evaluating the resilience and policy sensitivity of decentralized, deposit-funded banks under tightening conditions. Second, by interacting policy shocks with quartile-based and median-split heterogeneity structures, the analysis reveals significant within-pillar variation – particularly across capitalization and size profiles – that would be masked in standard specifications. Third, the findings have direct policy implications for the design of interest-rate tools and countercyclical buffers in a banking system characterized by public ownership, local political accountability, and structural exposure to margin compression.

The remainder of the paper is structured as follows. Section II reviews the relevant literature. Section III outlines the data sources and econometric methodology. Section IV presents the baseline results and explores heterogeneity across Sparkassen characteristics. Section V concludes.

2. Monetary Policy, Bank Heterogeneity and the German Savings Bank Sector

A broad base of empirical and theoretical research agrees that extended periods of very low or negative policy rates diminish the net-interest margins, which serve as a key income stream for banks funded primarily by retail deposits. Cross-country studies by Altavilla, Canova, and Ciccarelli (2016) and Demiralp, Eisenschmidt, and Vlassopoulos (2021), alongside ECB analysis, show that from 2014 to 2019, net-interest margins were mechanically compressed because deposit rates failed to adjust in line with declining policy rates. Brunnermeier and Koby (2018) introduced the 'reversal rate' concept, which captures how excessive monetary easing can paradoxically tighten financial conditions once it crosses a critical threshold, primarily by squeezing bank margins.

The distributional effects of negative interest rates depend critically on banks' liability structures. Heider, Saidi, and Schepens (2019) exploit the 2014 introduction of the ECB's negative deposit facility rate to show that institutions with large, sticky retail-deposit bases experienced a quasi-exogenous increase in relative funding costs. These banks responded by curtailing lending and reallocating portfolios toward riskier borrowers. Their findings resonate with the broader literature on the risk-taking channel of monetary policy (Dell'Ariccia, Laeven, Suárez, 2017; Bottero et al., 2022), which posits that accommodative policy incentivizes greater risk-taking, especially among banks facing compressed margins. Capital-based heterogeneity further shapes these responses: Kishan and Opiela (2000) and Jiménez et al. (2012) document

that well-capitalized banks are better positioned to absorb monetary shocks, whereas poorly capitalized peers either contract credit or raise their risk profile in an effort to restore balance sheet strength. However, Gropp and Heider (2010) caution that banks may refrain from deploying capital buffers – even in downturns – due to reputational concerns, thus potentially blunting the intended countercyclical function of prudential regulation.

Since Sparkassen typically earn around 75% of their income through maturity transformation and operate with deposit-to-loan ratios close to one, reduced interest margins pose a direct risk to the sustainability of their core business strategy. Following the ECB's move into negative policy territory in 2014, micro-level evidence shows that many German savings banks responded by introducing account maintenance fees and applying negative interest rates on large corporate deposits, thereby limiting the pass-through of policy accommodation to depositors (Michaelis, 2023). Simultaneously, Sparkassen have ramped up efforts to diversify their income streams. According to Köhler (2018), expanding fee and commission revenues, especially from payments and brokerage services, enhances their profitability on a risk-adjusted basis and stabilizes earnings.

The distinctive public mandate and governance model of Sparkassen introduces an additional institutional layer into the transmission of monetary policy. Local government trustees, who prioritize regional development over shareholder returns, promote long-term relationship lending with SMEs – a feature that contributes to the stronger credit supply sensitivity to conventional monetary tightening identified by De Santis and Surico (2013). While the traditional literature on German banking structures has emphasized the resilience of Sparkassen in such regimes, the post-2014 environment of persistently negative policy rates introduced novel pressures that these earlier studies did not fully anticipate. More recent contributions, including Heider, Saidi, and Schepens (2019) and Bottero et al. (2022), have begun to unpack how liability structures and risk-taking behavior adapt under such conditions, highlighting incomplete pass-through and heightened incentives for portfolio rebalancing. Rating-agency reports suggest that the partial normalization of interest rates since late 2022 has provided relief on margin pressure. Yet they also point to mounting challenges related to valuation losses on securities holdings and increased credit risk, as fixed-rate assets accumulated during the low-rate period are progressively repriced in a steeper yield environment (Moody's Investors Service, 2025).

Taken together, the literature suggests that any rigorous assessment of how ECB monetary accommodation has affected Sparkassen must account for several interrelated mechanisms. First, the direct mechanical compression of net-interest income – arising from the inability to pass negative rates onto retail depositors – posed a structural challenge to their income model. Second, heterogeneity in funding cost pressures, particularly among institutions heavily reliant on core deposits, altered the distributional impact of negative rates across the sector. Third, the interaction between monetary policy and capital adequacy influenced risk-taking behavior, as thinly capitalized banks faced stronger incentives to curtail lending or rebalance

toward higher-yield assets to restore buffers. Finally, many Sparkassen strategically expanded their reliance on fee and commission income, particularly in payments and brokerage services, thereby partially insulating profits from interest-rate shocks.

3. Data and Econometric Methodology

The empirical analysis is based on an annual unconsolidated financial statements for Public Sparkassen/Landesbanken Banks from Germany over the period 2000-2019. The database was created by joining BankScope with the Orbis/BankFocus files. This allowed us to obtain long enough time-series to observe both the macro backdrop – policy rates, unemployment, GDP growth – and balance-sheet dynamics – total assets, loans, deposits, loan-loss provisions and profitability. The database was winsorized using 1st and 99th percentile for each bank-level variable. Finally the cleaned unbalanced panel contained 491 banks and 4103 observations suited to testing the bank-lending channel and its conditioning factors.

The macroeconomic environment in Germany after 2000 is presented below.

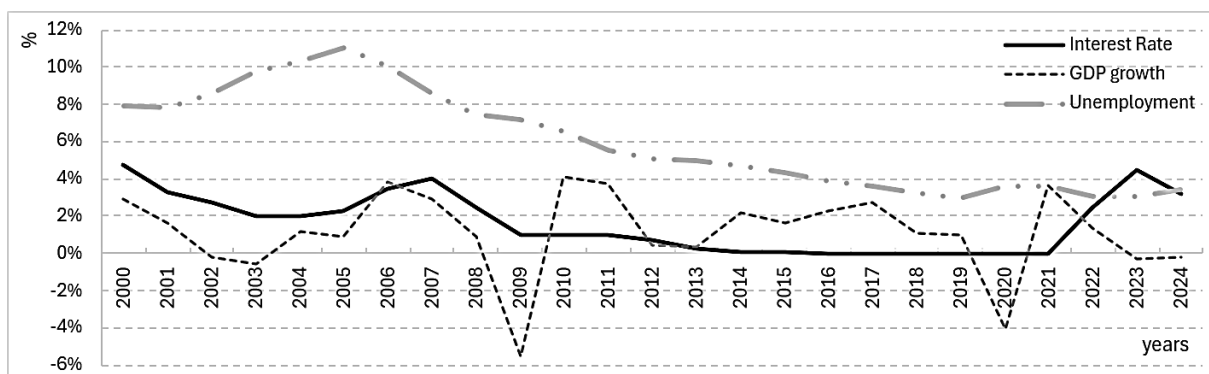


Figure 1. Interest rates, GDP growth and unemployment rate in Germany.

Source: ECB, IMF.

The distribution on histogram of main variables used in the studies showing the banks characteristics is illustrated in the appendix. The main descriptive characteristics of the variables used in the model are outlined in the Table 1 below. The average loan growth in the examined group of banks amounted to 2.96% over the sample period, although the results were highly dispersed (Std. Dev. = 3.64 percentage points). During the same period, the average annual growth of equity was only 0.06%, compared with an average annual growth of customer deposits of 3.25%. The average ROA indicates low profitability, while the mean LLP stood at 0.12%.

Table 1.
Descriptive statistics of variables used in the model

Variable	Obs	Banks	Median	Mean	Std.dev	Min	Max
ΔLoans	4103	491	2.43	2.96	3.64	-8.49	35.41
ΔEquity	4103	491	0.05	0.06	0.06	-0.05	0.45
$\Delta\text{CustDep}$	4103	491	2.55	3.25	3.43	-8.21	41.60
ROA	4103	491	0.17	0.15	0.10	0.00	0.77
Size	4103	491	14.22	14.44	1.00	11.72	18.16
CAP	4103	491	16.26	17.03	4.02	9.61	33.83
LLP	4103	491	0.50	0.12	0.74	-3.49	3.03
GDPG	4103	491	1.57	1.32	2.20	-5.55	4.15
Unempl	4103	491	7.61	4.87	1.44	2.98	11.01
ΔIR	4103	491	0.00	-0.27	0.57	-1.50	1.75

Note: ΔLoans – real loan growth rate, calculated as the log difference of bank loans (percentage points); ΔEquity – real equity growth rate (percentage points); $\Delta\text{CustDep}$ – real growth rate of customer deposits (percentage points); ROA – return on assets, defined as net income divided by total assets (percentage points); Size – logarithm of total assets; CAP – Tier 1 capital ratio, measuring core equity relative to risk-weighted assets (percentage points); LLP – loan-loss provisions ratio, calculated as loan-loss provisions divided by total assets (percentage points); GDPG – annual GDP growth rate in Germany (percentage points); Unempl – unemployment rate in Germany (percentage points); ΔIR – ECB interest rate change (percentage points). Real values deflated by author from nominal based on country inflation.

Source: Author's calculations made in StataSE19.

The baseline econometric specification used to capture the bank-lending channel's sensitivity to monetary policy, moderated by bank characteristics, is formulated as:

$$\begin{aligned} \Delta\text{Loans}_{i,t} = & \alpha_1 + \alpha_2 \Delta\text{Loans}_{i,t-1} + \alpha_3 \Delta\text{Equity}_{i,t-1} + \alpha_4 \Delta\text{DepCust}_{i,t-1} + \alpha_5 \text{ROA}_{i,t} \\ & + \alpha_6 \text{Size}_{i,t} + \alpha_7 \text{CAP}_{i,t} + \alpha_8 \text{LLP}_{i,t} + \alpha_9 \text{GDPG}_t + \alpha_{10} \text{unempl}_t \\ & + \Delta\text{IR}_{t-1} + \vartheta_{i,t} + \varepsilon_t \end{aligned} \quad (1)$$

Here, $\Delta\text{Loans}_{i,t}$ represents the real growth rate of loans calculated as the log difference of bank loans (expressed in percentage points), $\Delta\text{Equity}_{i,t}$ represents real equity growth rate (in p.p.), $\Delta\text{CustDep}_{i,t}$ represents real growth rate of customer deposits (in p.p.), $\text{ROA}_{i,t}$ is return on assets, defined as net income divided by total assets (in p.p.), $\text{Size}_{i,t}$ is calculated as logarithm of total assets; $\text{CAP}_{i,t}$ means Tier1 capital ratio, measuring core equity relative to risk-weighted assets (in p.p.); $\text{LLP}_{i,t}$ (loan-loss provisions ratio) is calculated as loan-loss provisions divided by total assets (in p.p.). The model contains also macroeconomic variables: GDPG_t – annual GDP growth rate (in p.p.), Unempl_t – unemployment rate (in p.p.); ΔIR_{t-1} – ECB interest rate change (in p.p.). The indexes are marked: i – bank, t – year. Real values were deflated by author from nominal based on country inflation.

To minimize interpretational ambiguity, we verified that all flow variables are expressed as real annual percentage-point changes and that levels (e.g., the Tier-1 ratio) are likewise in percentage points. This distinction matters for elasticities: the estimated policy coefficient is read as a semi-elasticity of real loan growth with respect to a one-percentage-point change in the policy rate, whereas coefficients on ΔEquity and $\Delta\text{Customer Deposits}$ capture the marginal contribution of funding and capital generation to credit supply at the annual horizon. Variable winsorization at the 1st/99th percentiles reduces the influence of extreme tails, and results are read in that metric throughout, which limits the scope for outlier-driven inferences.

The deposit-facility rate is the preferred stance indicator for deposit-funded institutions because it most directly maps into liability remuneration; nevertheless, the qualitative interpretation we offer relies on policy stance rather than any one operational rate. The macro block (GDP growth and unemployment) functions as a parsimonious guardrail against conflating aggregate demand conditions with bank-supply responses.

The baseline standard errors are clustered at the bank level, reflecting serial correlation in bank-specific shocks. Given that the policy variable varies primarily over time, one could also contemplate two-way clustering (bank $\times$ year); however, because we already include macro controls and fixed effects, and because the inference is not driven by marginal t-statistics near conventional thresholds, our qualitative conclusions are not sensitive to reasonable choices of clustering. We therefore retain bank-level clustering for transparency and comparability with the related literature.

4. Empirical Results

We estimate pooled OLS, random-effects, and (benchmark) bank fixed-effects specifications. A Hausman test strongly favors fixed effects ($\chi^2 = 888.15$, $p = 0.000$ presented in Table 2), and all inference is based on bank-clustered standard errors. Reporting OLS and RE alongside FE (models 1-2 and 3-5 in Table 2, respectively) aids comparability and shows that our qualitative conclusions are not an artefact of model choice.

The final fixed-effects estimates (model 5, Table 2), confirm that the transmission of ECB policy to Sparkassen credit supply is strongly mediated by balance-sheet characteristics. In the fixed-effects specification, a 1 p.p. rise in the deposit-facility rate is associated with a 0.61 p.p. fall in real loan growth. Increases in real equity growth are associated with markedly higher loan growth, consistent with internally generated capital providing headroom to sustain lending under tighter policy – a pattern consistent with the balance-sheet channel documented by Kishan & Opiela (2000) and, for euro area banks, Jiménez et al. (2012). Likewise, deposit inflows matter: a 1 p.p. rise in real customer deposits lifts lending by 0.22 p.p., echoing the liability-structure mechanism stressed by Heider, Saidi & Schepens (2019). By contrast, thicker regulatory capital buffers dampen credit: every additional percentage-point of the capital ratio lowers loan growth by 0.17 p.p., consistent with evidence that better-capitalized banks lend more cautiously (Gropp & Heider 2010). Higher provisioning is likewise associated with lower loan growth. Dell’Ariccia, Laeven & Suárez (2017) document a related risk-taking channel for U.S. banks. Size and contemporaneous profitability (ROA) are not statistically significant once unobserved heterogeneity is absorbed, implying that it is the dynamic flow variables – equity and deposits – rather than static levels that condition Sparkassen’s sensitivity to monetary policy. Together, the results corroborate the literature’s core insight: bank-level capital

generation, funding mix and risk provisioning crucially shape how monetary policy changes propagate to the real economy.

Table 2.
OLS, FE and RE estimation

VARIABLES	(1) reg	(2) re	(3) fe	(4) re vce bank robust	(5) fe vce bank robust
$\Delta \text{Loans}_{t-1}$	0.294*** (0.013)	0.294*** (0.013)	0.132*** (0.014)	0.294*** (0.024)	0.132*** (0.022)
$\Delta \text{Equity}_{t-1}$	12.718*** (1.211)	12.718*** (1.211)	9.988*** (1.353)	12.718*** (2.148)	9.988*** (2.612)
$\Delta \text{CustDep}_{t-1}$	0.239*** (0.015)	0.239*** (0.015)	0.216*** (0.015)	0.239*** (0.034)	0.216*** (0.036)
ROA_t	0.464 (0.512)	0.464 (0.512)	-0.688 (0.882)	0.464 (0.578)	-0.688 (0.962)
Size_t	-0.000 (0.050)	-0.000 (0.050)	0.696 (0.732)	-0.000 (0.058)	0.696 (0.797)
CAP_t	0.007 (0.013)	0.007 (0.013)	-0.170*** (0.031)	0.007 (0.015)	-0.170*** (0.043)
LLP_t	0.093 (0.104)	0.093 (0.104)	-0.205* (0.116)	0.092 (0.167)	-0.205 (0.206)
GDPG_t	-0.027 (0.024)	-0.027 (0.024)	0.016 (0.023)	-0.027 (0.026)	0.016 (0.026)
Unempl_t	-0.428*** (0.043)	-0.428*** (0.043)	-0.488*** (0.063)	-0.428*** (0.050)	-0.488*** (0.078)
ΔIR_{t-1}	-0.510*** (0.099)	-0.510*** (0.099)	-0.612*** (0.100)	-0.510*** (0.120)	-0.612*** (0.130)
Constant	2.437*** (0.825)	2.437*** (0.825)	-3.443 (10.864)	2.437*** (0.938)	-3.443 (11.787)
Observations	4,103	4,103	4,103	4,103	4,103
Number of Banks	491	491	491	491	491
Hausman Chi2 test			888.15		
Hausman test p-value			0.000		
R ² within	0.260	0.154	0.177	0.154	0.177
R ² between		0.686	0.143	0.686	0.143
R ² overall		0.260	0.158	0.260	0.158

Note. Definitions of variables used in the model are presented below Table 1. Standard errors in parentheses below the coefficient estimates. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels respectively.

Source: Author's estimation results made in StataSE19.

At the macro level, the estimated balance-sheet elasticities imply that the effectiveness of ECB rate moves depends critically on the equity-generation capacity and deposit dynamics of Sparkassen, a group that originates roughly two-fifths of German SME credit. When policy tightens, those savings banks that can replenish equity internally or attract fresh retail deposits continue to lend, muting the aggregate credit slowdown in their regions; conversely, highly capitalized or heavily provisioned Sparkassen curtail credit more sharply, amplifying contractionary impulses in areas that are already cyclically fragile. Because Sparkassen's lending is geographically bound by statute, such heterogeneous responses can translate into uneven regional transmission of monetary policy, with credit-rich districts facing shallower slowdowns than credit-poor ones. From a monetary-policy perspective, this heterogeneity

weakens the “one-size-fits-all” nature of the single policy rate and raises the risk that the ECB must move rates further than otherwise to achieve a given macro target.

The results also speak to the current normalization cycle. As rates rise and the stock of negative-rate reserves is wound down, Sparkassen with ample retained earnings and stable deposit franchises will deleverage less aggressively, supporting a smoother pass-through to the real economy. By contrast, institutions that entered the tightening phase with thin equity growth and elevated provisioning will experience a double squeeze: higher funding costs on the liability side and tighter capital constraints on the asset side. This asymmetry argues for supervisory guidance that makes capital buffers genuinely usable in downturns and for tiered reserve remuneration that limits the burden on deposit-rich banks. Finally, because Sparkassen fulfil a statutory development mandate, their credit decisions feed directly into local investment and labour-market conditions; hence a policy-induced pull-back by weaker savings banks could widen regional growth differentials, complicating Germany’s fiscal equalisation mechanism and, by extension, the euro area’s aggregate demand management. In sum, the micro evidence suggests that maintaining robust equity generation and predictable buffer policies at Sparkassen is not merely a prudential concern but a prerequisite for smooth and regionally balanced monetary transmission in Europe’s largest economy.

To gauge whether the aggregate lending-channel estimates mask economically meaningful interactions between capital strength and size, we partition the panel at the sample medians of capital ratios and total assets. This yields four mutually exclusive subsamples: small-low-CAP banks, large-low-CAP banks, small-high-CAP banks, and large-high-CAP banks. Each subsample is re-estimated with the full fixed-effects specification. Table 3 below reports the coefficient on the lagged annual change in the ECB interest rate, which captures the semi-elasticity of real loan growth with respect to monetary policy change.

Table 3.

The ECB interest-rate changes (ΔIR_{t-1}) on loans growth rate ($\Delta Loans_t$) – estimated coefficient for the groups of banks located below and above the median of the distribution of Size and CAP

	Size 0-50%	Size 50-100%
CAP 0-50%	-0.740***	-0.260
CAP 50-100%	-0.755***	-0.682***

Note. Full estimation results in the Appendix in Table 9. Definitions of CAP and Size are presented below Table 1. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels respectively.

Source: Author’s estimation results made in StataSE19.

Pass-through is very strong and quite similar for small high-CAP banks (-0.755***) and small low-CAP banks (-0.740***). A one-percentage-point increase in the policy rate reduces real loan growth by 0.74 p.p. for small, thinly capitalized Sparkassen and by 0.26 p.p. for their large, thinly capitalized peers. The result echoes the balance-sheet channel documented by

Kishan & Opiela (2000) and Jiménez et al. (2012): when regulatory buffers are thin, even municipally owned savings banks deleverage in response to higher funding costs to preserve minimum capital ratios.

Once buffers are ample, however, size no longer insulates lending: both small and large high-CAP banks exhibit sizable and significant semi-elasticities (-0.755 *** and -0.682 ***, respectively). This pattern implies that securities-portfolio repricing or opportunity-cost considerations eclipse scale advantages when surplus capital is abundant. This is reminiscent of findings that very high capital ratios can coincide with conservative (low-risk) balance-sheet management.

The median-split (presented in an abbreviated form in Table 3, and the full results in Table 9 in Appendix) shows that capital adequacy is the decisive margin of heterogeneity: small low-CAP banks contract sharply, while large low-CAP peers respond more weakly; once buffers are ample, size effects fade. We interpret this asymmetry as the interaction of regulatory constraints (when buffers are thin) with liability-cost management (larger franchises can re-price or diversify their funding base). This reading does not rely on any additional estimation; it simply organizes the already-reported pattern into a mechanism consistent with the literature on balance-sheet channels and liability-side pass-through.

To uncover the full interaction between capital adequacy and scale, we estimate the benchmark fixed-effects specification separately for every intersection of the four size quartiles and the four capital quartiles. Table 4 below reports the semi-elasticity of real loan growth with respect to a one-percentage-point change in the ECB deposit-facility rate (full results in Tables 10a and 10b in Appendix).

Table 4.

The ECB interest-rate changes (ΔIR_{t-1}) on loans growth rate ($\Delta Loans_t$) – estimated coefficient for the groups of banks located the subsequent quarters of the distribution of Size and CAP

	Size 0-25%	Size 25-50%	Size 50-75%	Size 75-100%
CAP 0-25%	-0.909**	-0.405	-0.332	0.293
CAP 25-50%	-0.834	-1.060***	-0.418	-0.613*
CAP 50-75%	-0.760	-0.441	-0.259	-0.721*
CAP 75-100%	-0.972**	-0.758*	-1.136**	-0.708*

Note. Full estimation results in the Appendix in Tables 10a and 10b. Definitions of CAP and Size are presented below Table 1. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels respectively.

Source: Author's estimation results made in StataSE19.

Generally, milder policy pass-through coefficients are observed for several bank categories in the middle of the capital distribution (CAP 25-75%), particularly within the CAP 50-75% quartile where elasticities range from -0.259 to -0.760 and are often insignificant. However, the CAP 25-50% quartile also contains a segment (Size 25-50%) with a notably strong and

significant pass-through (-1.060***). Under-capitalized Sparkassen (CAP 0-25%) reduce lending by -0.91 p.p. in the smallest size quartile, reflecting regulatory pressure to rebuild buffers. Over-capitalized Sparkassen (CAP 75-100%) also contract sharply (-0.97 to -1.14 p.p.), consistent with the argument that, when safe yields rise, holding liquid securities can dominate new lending (see Behn, Haselmann, Wachtel, 2016). This U-shape mirrors the buffer-usability narrative: credit is most elastic when buffers are either scarce or so ample that banks prefer to preserve them.

Size moderates transmission only when capital is scarce. In the lowest-capital quartile, small Sparkassen (Size 0-25%) show the steepest contraction (-0.909**), while the largest banks in the same capital bracket actually display a positive but insignificant coefficient (0.293). This pattern is consistent with liability-cost asymmetries: larger institutions can re-price corporate deposits and access wholesale liquidity more readily (Heider, Saidi, Schepens 2019). For the buffer-rich quartile, however, size no longer insulates lending: semi-elasticities remain sizable and significant across three of the four size groups, with the largest absolute response (-1.136**) occurring in the upper-middle size bracket (Size 50-75%).

Across the 16 cells of the quartile analysis, the policy coefficient ranges from +0.293 to -1.136, a significant spread that the estimate (-0.612) and even the median split results (which range from -0.260 to -0.755) conceal. The dispersion underscores that capital and scale interact non-linearly – the same policy move can be twice as contractionary for a small, under-capitalized savings bank as for a large, mid-capital peer, and almost identical for a medium-sized, over-capitalized institution.

Because Sparkassen are geographically confined, the size-capital mosaic maps directly into spatial credit outcomes. Rural districts dominated by small, weakly capitalized banks will face the sharpest loan contraction when the ECB tightens, whereas regions served by mid-tier buffers experience milder effects; paradoxically, affluent areas with buffer-rich Sparkassen may also see pronounced slowdowns as those banks hoard surplus capital or probably rotate into securities. At the system level, such heterogeneity implies that aggregate monetary transmission is the population-weighted average of highly divergent local elasticities, complicating policy calibration.

The 4×4 grid (Table 4) uncovers a U-shaped relation: pass-through is weakest in the middle of the capital distribution and strongest at both tails. We refrain from attaching additional quantitative claims and instead emphasize the design implication: where buffers are either scarce (regulatory defense) or abundant (opportunity cost of expanding loans when safe yields rise), lending reacts the most. This suggests that policy instruments which shape the effective usability of buffers (e.g., supervisory guidance on draw-downs) or the relative pricing of reserves (e.g., tiering) can materially influence the dispersion of credit responses across otherwise similar institutions.

Because Sparkassen are geographically circumscribed, the size-capital mosaic maps directly into spatial credit conditions: districts dominated by small, weakly capitalised institutions face sharper slowdowns when policy tightens, while regions with mid-tier buffers see milder effects; buffer-rich areas may also slow as banks prefer securities over new lending. This mapping follows mechanically from institutional statutes and the heterogeneity already documented; it does not require additional econometrics.

Together with the baseline and median-split results, the quartile grid completes a three-layer narrative: capital adequacy is the primary filter through which monetary shocks pass, size modulates that effect when buffers are thin, and extreme capital positions – whether scarce or abundant – amplify the contractionary impulse.

The three- layer analysis draws a clear picture of how ECB policy shocks propagate through Germany's savings-bank pillar. The pooled fixed-effects benchmark shows that a 1 p.p. rate hike trims Sparkassen loan growth by roughly 0.6 p.p. on average (model 5, Table 2), with equity and deposit inflows cushioning the shock and both thin capital buffers and higher provisions amplifying it. Splitting the sample at the medians of size and Tier-1 capital (Table 3) reveals that capital adequacy is the decisive margin of heterogeneity, i.e. low-CAP small banks contract by about -0.74 p.p., while high-CAP small banks contract by -0.76 p.p.; the only muted reaction (-0.26 p.p.) occurs for large low-CAP banks. Pushing disaggregation to the 4×4 size-capital grid (Table 4) uncovers a U-shaped pattern: pass-through is mild in the middle of the capital distribution but steep at both tails, reaching -0.91 p.p. for small, under-capitalized banks and -1.14 p.p. for buffer-rich institutions, while size moderates the effect solely in the low-CAP tier. Together the results show that capital strength dominates scale, that extreme buffer positions – whether deficits or surpluses – magnify monetary transmission, and that these balance-sheet asymmetries will translate into regionally uneven credit cycles unless buffer-usability rules and tiered-reserve design are aligned with the policy cycle.

Building on the observed heterogeneity in policy pass-through, we provide a model-based assessment to quantify the potential of macroprudential tools. Our fixed-effects estimates (Table 4) show that the semi-elasticity of loan growth to a 1 p.p. rate hike ranges from -0.26 to -1.14 p.p. across bank types, compared with -0.61 in the overall FE model (Table 2, model 5).

Using the quartile specification, one can ask how a change in countercyclical capital buffers (CCyB) that shifts behavior would operate across bank groups. The mechanism of a CCyB release lowers effective regulatory capital requirements, thereby freeing balance-sheet capacity for lending. In the most vulnerable banks (small, low-CAP), a 1 p.p. rate increase generates, on average, a 0.91 p.p. decline in loan growth, while loosening the capital ratio by 1 p.p. implies an increase in loan growth of 0.36 p.p. (model 1, Table 10a). However, this group comprises banks that generate only about 1% of aggregate credit, so the real-economy impact of CCyB decisions in this segment is minimal. Changing CCyB for all low-CAP banks (regardless of size) would affect about 25% of aggregate credit volume; nevertheless, given the documented U-shape and the lack of statistical significance of the CAP variable in the CAP 0-25% & Size

50-75% and 75-100% groups – i.e., models (9) and (13) in Table 10b – the aggregate result cannot be determined unambiguously.

On the other hand, for large banks with high CAP (CAP 75-100%, Size 75-100%), it should be noted that although a rate increase is accompanied by a 0.71 p.p. decline in loan growth, CCyB-type changes are unlikely to be the binding margin for these banks, which typically operate with capital ratios well above supervisory minima; accordingly, we expect limited lending impact from CAP adjustments in this cell. One should also remember that these banks generate about 20% of aggregate loan volume.

Second, a tiered reserve system alleviates funding-cost pressure. Assuming it boosts deposit growth by 1 p.p. during tightening, our estimated coefficient on $\Delta\text{CustDep}$ (0.22 p.p., Table 2, model 5) implies a direct offset of over 35% of the baseline monetary-policy effect (-0.61 p.p.). The coefficient on $\Delta\text{CustDep}$ is heterogeneous in our quartile distribution (all values available in Table 10a and Table 10b): for small, low-CAP banks it equals 0.13 (15% of the baseline policy effect). A similar effect can be observed among large banks with relatively high CAP, e.g., CAP 50-75%, Size 75-100%, where the $\Delta\text{CustDep}$ coefficient is 0.12 (17% of the baseline effect). However, in the group Size 25-50% and CAP 0-25%, a 0.43 coefficient on $\Delta\text{CustDep}$ implies 100% of the baseline effect (though here the coefficient is not statistically significant). This again illustrates the non-linearity of the relationship. This demonstrates that tiering can significantly mute lending-channel contraction by supporting stable deposit funding, but that we are dealing with U-shaped reactions.

In conclusion, coordinating monetary policy with these tools is critical. It dampens excessive credit contraction in reactive parts of the system, promotes regionally balanced transmission, and reduces the need for the ECB to enact disproportionately large rate moves to achieve its macro objectives.

5. Conclusion

This study set out to measure how European Central Bank policy shocks travel through Germany's public savings-bank sector and to determine the extent to which balance-sheet heterogeneity shapes that transmission. Using a twenty-year, bank-level panel of 491 Sparkassen, the benchmark fixed-effects regression revealed a statistically powerful lending channel: a one-percentage-point increase in the deposit-facility rate lowers real loan growth by roughly 0.6 percentage points. Equity accumulation and retail-deposit inflows counteract that contraction, whereas a higher Tier-1 ratio and larger loan-loss provisions reinforce it. Taken on its own, however, this pooled result masks wide variation – an intuition confirmed by progressively disaggregating the sample.

When the panel is split at the medians of assets and capital, capital adequacy clearly dominates scale. For instance, drawing from the median split analysis, small low-capital Sparkassen reduce lending by about 0.74 percentage points after a standard rate hike. The reaction of their well-capitalized (high-CAP) counterparts is strong as well, with small high-CAP banks showing a similar contraction (-0.755***) and large high-CAP banks also contracting significantly (-0.682***). In contrast, large low-capital Sparkassen display a notably muted and statistically insignificant response (-0.260) to a similar policy shock. Size moderates the shock only when buffers are thin: large, under-capitalized savings banks contract less than small, equally weak peers, presumably because broader funding bases allow them to absorb a rise in funding costs. Once buffers are ample, scale ceases to matter. Pushing the disaggregation further to a sixteen-cell size-by-capital grid exposes a pronounced non-linearity: pass-through tends to be milder for banks in the upper-middle of the capital distribution (CAP 50-75%) yet intensifies at both the low-capital and high-capital tails. It reaches almost one percentage point for the smallest, weakly capitalized banks (-0.909**) and exceeds one percentage point for certain buffer-rich institutions (-1.136**). The pattern suggests two distinct mechanisms: capital scarcity forces deleveraging to defend regulatory ratios, whereas surplus capital raises the opportunity cost of loan expansion when safe yields rise. Because Sparkassen lend strictly within their municipalities, this size-capital mosaic translates into geographically uneven credit cycles as the policy stance tightens.

For bank management, the results validate a focus on organic equity generation and on safeguarding stable retail funding: both reduce the contractionary impact of tightening without compromising risk discipline. For supervisors, credible, stigma-free buffer usability and calibrated reserve tiering can dampen excessive contraction where liability costs bind. Coordination between monetary and macro-prudential authorities can reduce the likelihood that a single policy rate yields uneven regional outcomes in a decentralized banking pillar. These are design-level takeaways implied by the observed ordering of coefficients rather than by any unreported estimates.

These findings carry several policy implications. First, the effectiveness of counter-cyclical capital buffers hinges on credible guidance that makes draw-downs stigma-free; without such clarity, the safest Sparkassen may reduce lending most in a downturn. Second, the tiered-reserve system should be calibrated with an eye to liability-cost asymmetries, as deposit-rich, low-capital banks bear the sharpest margin squeeze and thus the steepest contraction. Third, closer coordination between monetary and macro-prudential authorities is warranted: synchronized buffer release, targeted risk-weight adjustments, and liquidity facilities can offset the uneven real-sector impact that a single policy rate imposes on a structurally diverse banking landscape. Neglecting these asymmetries risks forcing the ECB to move rates further than otherwise to achieve a given macroeconomic objective.

Our annual panel is well suited to tracing medium-run balance-sheet adjustment but may understate intra-year rebalancing or credit-line management. The sample ends in 2019; we therefore refrain from generalizing quantitatively to the recent tightening cycle and treat our findings as a historically grounded benchmark. Finally, while the institutional homogeneity of Sparkassen is an asset for identification, it also means that external validity to shareholder-owned, wholesale-funded banks should be inferred cautiously. These limitations qualify interpretation without detracting from the internal consistency of the results presented.

Even with these caveats, the evidence underscores a broader lesson: public ownership and developmental mandates do not immunize Sparkassen from pro-cyclical behavior when buffers bind or when excess capital becomes costly. As the ECB pursues policy normalization, understanding how such balance-sheet asymmetries amplify or attenuate credit supply is essential for maintaining regionally balanced transmission throughout Europe's largest economy.

References

1. Altavilla, C., Canova, F., Ciccarelli, M. (2016). Mending the broken link: heterogeneous bank lending and monetary policy pass-through. *ECB Working Paper, No. 1978*. Retrieved from: <https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1978.en.pdf>, 27.09.2025.
2. Behn, M., Haselmann, R., Wachtel, P. (2016). Pro-Cyclical Capital Regulation and Lending. *Journal of Finance*, 71(2), pp. 919-955.
3. Bottero, M., Minoiu, C., Peydró, J.-L., Polo, A., Presbitero, A.F., Sette, E. (2022). Expansionary yet different: Credit supply and real effects of negative interest rate policy. *Journal of Financial Economics*, 146(2), pp. 754-778. <https://doi.org/10.1016/j.jfineco.2021.11.004>
4. Brunnermeier, M.K., Koby, Y. (2018). The reversal interest rate. *NBER Working Paper, No. 25406*. <https://doi.org/10.3386/w25406>
5. De Santis, R.A., Surico, P. (2013) Bank lending and monetary transmission in the euro area. *Economic Policy*, 28(75), pp. 423-457.
6. Dell'Ariccia, G., Laeven, L., Suárez, G.A. (2017). Bank leverage and monetary policy's risk-taking channel: Evidence from the United States. *Journal of Finance*, 72(2), pp. 613-654. <https://doi.org/10.1111/jofi.12467>
7. Demiralp, S., Eisenschmidt, J., Vlassopoulos, T. (2021). Negative interest rates, excess liquidity and retail deposits: Banks' reaction to unconventional monetary policy in the euro area. *European Economic Review*, 136, 103745. <https://doi.org/10.1016/j.eurocorev.2021.103745>

8. Gropp, R., Heider, F. (2010) The determinants of bank capital structure. *Review of Finance* 14(4), pp. 587-622. <https://doi.org/10.1093/rof/rfp030>
9. Hardie, I., Howarth, D. (2009). Die Krise but not La Crise? The financial crisis and the transformation of German and French banking systems. *Journal of Common Market Studies* 47(5), pp. 1017-1039. <https://doi.org/10.1111/j.1468-5965.2009.02033.x>
10. Heider, F., Saidi, F., Schepens, G. (2019). Life below zero: Bank lending under negative policy rates. *Review of Financial Studies*, 32(10), pp. 3728-3761. <https://doi.org/10.1093/rfs/hhz016>
11. Jiménez, G., Ongena, S., Peydró, J.-L., Saurina, J. (2012) Credit supply and monetary policy: Identifying the bank balance-sheet channel with loan applications. *American Economic Review*, 102(5), pp. 2301-2326. <https://doi.org/10.1257/aer.102.5.2301>
12. Kishan, R.P., Opiela, T.P. (2000) Bank size, bank capital and the bank-lending channel. *Journal of Money, Credit and Banking*, 32(1), pp. 121-141. <https://doi.org/10.2307/2601095>
13. Köhler, M. (2018). An analysis of non-traditional activities at German savings banks – *Deutsche Bundesbank Discussion Paper, No. 1*. Retrieved from: <https://www.bundesbank.de/resource/blob/704148/433ab5522d0c7b6111459ed046f13d07/mL/2018-02-05-dkp-01-data.pdf>, 27.09.2025.
14. Markgraf, J., Véron, N. (2018). *Germany's savings banks are uniquely intertwined with local politics*. Peterson Institute for International Economics. Retrieved from: <https://www.piie.com/blogs/realtime-economic-issues-watch/germanys-savings-banks-are-uniquely-intertwined-local-politics>, 27.09.2025.
15. Michaelis, H. (2023). Negative interest rate policy led to negative interest rates on corporate deposits and higher fees. *Deutsche Bundesbank Research Brief, No. 56*. Retrieved from: <https://www.bundesbank.de/en/publications/research/research-brief/2023-56-negative-interest-rate-policy-665708>, 29.05.2025.
16. Moody's Investors Service (2025). *Sparkassen-Finanzgruppe: Update to credit analysis*. Retrieved from: https://www.dsgv.de/content/dam/dsgv-de/sparkassen-finanzgruppe/downloads/rating/20250306_Moodys_Credit.pdf, 29.05.2025.
17. Puri, M., Rocholl, J., Steffen, S. (2011). Global retail lending in the aftermath of the US financial crisis: Distinguishing between supply and demand effects. *Journal of Financial Economics*, 100(3), pp. 556-578. <https://doi.org/10.1016/j.jfineco.2010.12.001>

Appendix

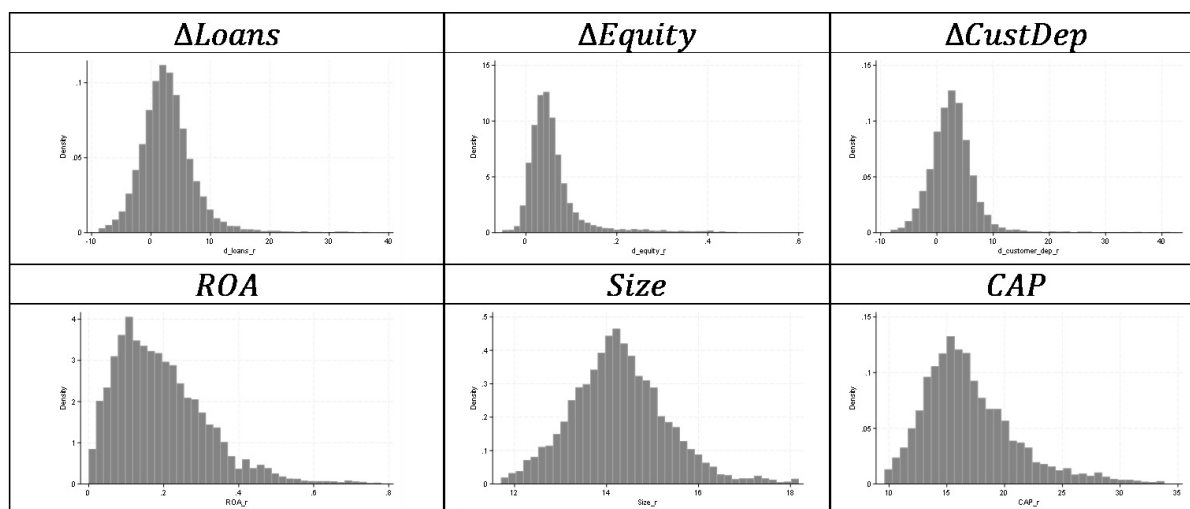


Figure 2. Growth rate distribution of loans, equity and customer deposits and bank-characteristics distribution of ROA, Size and CAP.

Source: Author's calculations made in StataSE19.

Table 5.
Correlation matrix

	Δ Loans	Δ Equity	Δ CustDep	ROA	Size	CAP	LLP	GDPG	Unempl	Δ IR
Δ Loans	1									
Δ Equity	0.333***	1								
Δ CustDep	0.376***	0.202***	1							
ROA	0.067***	0.168***	0.023**	1						
Size	0.090***	0.042***	0.119***	0.039***	1					
CAP	0.055***	0.004	-0.044***	0.13***	-0.071***	1				
LLP	-0.197***	-0.506***	-0.07***	-0.014	-0.117***	-0.009	1			
GDPG	0.051***	0.114***	-0.045***	0.035***	0.005	0.042***	-0.165***	1		
Unempl	-0.228***	-0.103***	-0.135***	0.18***	-0.134***	-0.217***	0.503***	0.053***	1	
Δ IR	-0.031***	-0.061***	0.052***	0.004	-0.007	0.041***	-0.05***	0.294***	-0.05***	1

Source: Author's estimation results made in StataSE19.

Table 8.
Descriptive statistics of real loan changes per Year

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
No of obs.	435	437	429	437	433	436	449	443	449	451	453	455	468	468	504	390	394	392	392	353
Δ Loans (average)	4.0	2.7	2.1	2.1	-0.1	0.4	1.3	0.5	0.2	2.2	3.1	4.2	2.7	2.4	2.2	4.0	4.2	3.7	3.6	4.3

Source: Author's estimation results made in StataSE19.

Table 9.

Fixed effect estimation results for the group of banks located below and above the median of the distribution of Size and CAP

VARIABLES	(1) fe SizeH1 CAPH1	(2) fe SizeH1 CAPH2	(3) fe SizeH2 CAPH1	(4) fe SizeH2 CAPH2
$\Delta \text{Loans}_{t-1}$	0.167*** (0.032)	0.125*** (0.029)	0.103*** (0.026)	0.099*** (0.028)
$\Delta \text{Equity}_{t-1}$	11.650*** (2.714)	11.628*** (3.706)	9.124*** (2.072)	13.048*** (2.990)
$\Delta \text{CustDep}_{t-1}$	0.233*** (0.031)	0.142*** (0.036)	0.281*** (0.024)	0.099*** (0.035)
ROA_t	-2.420 (2.175)	-1.721 (1.822)	-0.581 (1.492)	2.825* (1.619)
Size_t	1.229 (1.529)	2.702 (1.930)	-0.334 (1.298)	0.205 (1.176)
CAP_t	-0.224** (0.096)	-0.211*** (0.056)	-0.060 (0.069)	-0.132*** (0.050)
LLP_t	0.132 (0.270)	-0.197 (0.253)	-0.294 (0.210)	-0.083 (0.220)
GDPG_t	0.062 (0.047)	0.124** (0.053)	-0.040 (0.040)	-0.093** (0.045)
Unempl_t	-0.420*** (0.141)	-0.634*** (0.148)	-0.223** (0.109)	-0.755*** (0.121)
ΔIR_{t-1}	-0.740*** (0.207)	-0.755*** (0.216)	-0.260 (0.168)	-0.682*** (0.216)
Constant	-10.592 (21.654)	-28.082 (27.141)	8.294 (20.257)	4.299 (18.389)
Observations	980	1,094	1,110	919
No of Banks	115	131	131	114
R-squared	0.189	0.192	0.217	0.180

Source: Author's estimation results made in StataSE19.

Table 10a.

Fixed effect estimation results for the group of banks located the subsequent quarters of the distribution of Size and CAP

VARIABLES	(1) fe SizeQ1 CAPQ1	(2) fe SizeQ1 CAPQ2	(3) fe SizeQ1 CAPQ3	(4) fe SizeQ1 CAPQ4	(5) fe SizeQ2 CAPQ1	(6) fe SizeQ2 CAPQ2	(7) fe SizeQ2 CAPQ3	(8) fe SizeQ2 CAPQ4
$\Delta \text{Loans}_{t-1}$	0.132** (0.058)	0.128 (0.083)	0.143* (0.075)	0.072 (0.064)	0.045 (0.056)	0.365*** (0.060)	0.071 (0.053)	0.205*** (0.050)
$\Delta \text{Equity}_{t-1}$	0.706 (5.216)	0.096 (9.641)	7.310 (8.984)	17.052* (8.823)	17.266*** (3.776)	5.206 (6.618)	18.107** (7.523)	3.333 (6.542)
$\Delta \text{CustDep}_{t-1}$	0.133** (0.059)	0.037 (0.095)	-0.072 (0.077)	0.114 (0.085)	0.427*** (0.054)	0.133** (0.055)	0.320*** (0.059)	0.067 (0.072)
ROA_t	1.672 (4.491)	3.486 (6.267)	0.900 (3.227)	-2.311 (5.507)	-2.918 (3.446)	-7.979* (4.101)	-9.643** (3.827)	-0.047 (3.030)
Size_t	3.288 (3.399)	5.280 (3.603)	1.260 (5.967)	5.953 (5.845)	2.086 (3.174)	-1.126 (2.582)	-1.939 (2.600)	4.400 (3.561)
CAP_t	-0.357** (0.178)	0.497** (0.241)	-0.153 (0.160)	-0.033 (0.128)	-0.693*** (0.224)	-0.368** (0.157)	-0.215* (0.119)	-0.312*** (0.085)
LLP_t	-0.770 (0.499)	-0.983 (0.907)	-0.178 (0.695)	-0.027 (0.525)	0.869* (0.454)	-0.264 (0.563)	-0.339 (0.573)	-0.426 (0.388)
GDPG_t	0.053 (0.080)	0.159 (0.129)	0.232** (0.117)	0.199* (0.116)	0.112 (0.088)	-0.026 (0.080)	-0.080 (0.095)	0.151 (0.095)

Cont. table 10a.

Unempl _t	-0.251 (0.272)	0.527 (0.478)	-0.472 (0.449)	-0.515 (0.365)	-0.587** (0.250)	-0.638*** (0.231)	-0.620** (0.251)	-0.675** (0.276)
ΔIR_{t-1}	-0.909** (0.354)	-0.834 (0.680)	-0.760 (0.521)	-0.972** (0.493)	-0.405 (0.379)	-1.060*** (0.357)	-0.441 (0.364)	-0.758* (0.398)
Constant	-35.711 (45.446)	-79.076 (50.778)	-9.575 (80.281)	-73.597 (78.310)	-16.960 (45.313)	26.839 (38.073)	36.473 (37.780)	-49.832 (51.759)
Observations	278	180	201	260	261	261	294	339
No of Banks	35	24	28	33	27	29	32	38
R-squared	0.160	0.134	0.140	0.149	0.384	0.340	0.301	0.308

Note. $\Delta Loans$ – real loan growth rate, calculated as the log difference of bank loans (percentage points); $\Delta Equity$ – real equity growth rate (percentage points); $\Delta CustDep$ – real growth rate of customer deposits (percentage points); ROA – return on assets, defined as net income divided by total assets (percentage points); Size – logarithm of total assets; CAP – Tier 1 capital ratio, measuring core equity relative to risk-weighted assets (percentage points); LLP – loan-loss provisions ratio, calculated as loan-loss provisions divided by total assets (percentage points); GDPG – annual GDP growth rate in Germany (percentage points); Unempl – unemployment rate in Germany (percentage points); ΔIR – ECB interest rate change (percentage points). Real values deflated by author from nominal based on country inflation.

Source: Author's estimation results made in StataSE19.

Table 10b.

Fixed effect estimation results for the group of banks located the subsequent quarters of the distribution of Size and CAP

VARIABLES	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	fe SizeQ3 CAPQ1	fe SizeQ3 CAPQ2	fe SizeQ3 CAPQ3	fe SizeQ3 CAPQ4	fe SizeQ4 CAPQ1	fe SizeQ4 CAPQ2	fe SizeQ4 CAPQ3	fe SizeQ4 CAPQ4
$\Delta Loans_{t-1}$	0.157*** (0.051)	0.031 (0.049)	-0.001 (0.053)	0.086 (0.061)	0.053 (0.054)	0.269*** (0.053)	0.027 (0.050)	0.236*** (0.065)
$\Delta Equity_{t-1}$	15.980*** (4.660)	25.973*** (5.031)	22.322*** (4.711)	-7.992 (9.203)	0.707 (3.519)	-0.503 (4.444)	15.183*** (4.790)	12.279 (7.929)
$\Delta CustDep_{t-1}$	0.231*** (0.049)	0.293*** (0.051)	0.198*** (0.056)	0.052 (0.092)	0.307*** (0.046)	0.181*** (0.046)	0.123* (0.066)	-0.095 (0.079)
ROA _t	-6.553* (3.774)	-2.866 (3.439)	1.140 (2.449)	4.484 (5.189)	3.705 (3.206)	0.296 (2.110)	0.728 (3.958)	4.157 (2.720)
Size _t	-1.291 (2.288)	-1.784 (2.946)	-2.101 (1.491)	6.204 (3.978)	-0.000 (2.827)	1.500 (2.374)	1.076 (3.317)	-2.012 (3.232)
CAP _t	-0.035 (0.188)	-0.045 (0.145)	-0.351*** (0.113)	0.033 (0.117)	0.109 (0.120)	-0.378*** (0.135)	-0.287*** (0.095)	-0.088 (0.082)
LLP _t	0.389 (0.483)	1.241*** (0.476)	0.495 (0.352)	-1.316** (0.563)	-0.872** (0.429)	-1.230*** (0.390)	0.258 (0.416)	0.175 (0.536)
GDPG _t	-0.035 (0.076)	-0.079 (0.075)	-0.101 (0.074)	0.036 (0.115)	-0.128 (0.095)	0.101 (0.076)	-0.158* (0.088)	-0.145* (0.084)
Unempl _t	-0.273 (0.239)	-0.690*** (0.245)	-1.228*** (0.221)	-0.257 (0.324)	-0.105 (0.206)	-0.143 (0.209)	-0.844*** (0.198)	-0.632** (0.284)
ΔIR_{t-1}	-0.332 (0.355)	-0.418 (0.334)	-0.259 (0.347)	-1.136** (0.553)	0.293 (0.336)	-0.613* (0.319)	-0.721* (0.431)	-0.708* (0.418)
Constant	21.944 (34.283)	30.959 (44.612)	44.433* (23.352)	-88.880 (60.459)	0.313 (46.232)	-15.327 (37.908)	-6.443 (52.712)	37.579 (51.591)
Observations	248	325	287	226	266	271	217	189
No of Banks	26	40	34	28	33	32	28	24
R-squared	0.245	0.287	0.311	0.162	0.214	0.355	0.231	0.233

Note. $\Delta Loans$ – real loan growth rate, calculated as the log difference of bank loans (percentage points); $\Delta Equity$ – real equity growth rate (percentage points); $\Delta CustDep$ – real growth rate of customer deposits (percentage points); ROA – return on assets, defined as net income divided by total assets (percentage points); Size – logarithm

of total assets; CAP – Tier 1 capital ratio, measuring core equity relative to risk-weighted assets (percentage points); LLP – loan-loss provisions ratio, calculated as loan-loss provisions divided by total assets (percentage points); GDPG – annual GDP growth rate in Germany (percentage points); Unempl – unemployment rate in Germany (percentage points); Δ IR – ECB interest rate change (percentage points). Real values deflated by author from nominal based on country inflation.

Source: Author's estimation results made in StataSE19.

MARKET VALUE OF WATER SUPPLY AND SEWAGE NETWORKS – DETERMINANTS, ATTRIBUTES AND VALUATION METHODS

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Purpose: The uniqueness of water supply and sewage networks as assets, combined with the specific characteristics of their market, generates a number of challenges in their valuation. The purpose of the conducted research is to identify and assess the attributes of water supply and sewage networks that affect their market value.

Design/methodology/approach: The primary research method applied in this study was the case study and comparative analysis. Data were collected through document analysis and conducted interviews with representatives of selected enterprises and local government units from the Pomeranian Voivodeship in Poland.

Findings: As a result of the conducted research, a set of market attributes influencing the market value of water supply and sewage networks was identified, and their percentage impact on value was determined.

Research limitations/implications: Both Polish and international literature lack studies on the valuation of water supply and sewage networks. In particular, there is a noticeable gap in the methodology for calculating their market value.

Practical implications: The identified market attributes affecting the market value of water supply and sewage networks, along with the determined percentage impact of these attributes on value, can be used by property appraisers and valuation experts to determine the value of this specific type of asset.

Social implications: The acquisition of water supply and sewage networks from private investors, particularly households constructing such networks for their own needs, is a complex and socially challenging process. The research findings presented in this article may be applied to determine fair compensation based on the market value of water supply and sewage networks.

Originality/value: The research results address a topic that has been undertaken extremely rarely, and the specific outcomes in the form of market attributes and their calculated weights based on national market data have, to the authors' knowledge, been published in a scientific journal for the first time.

Keywords: water supply networks, sewage networks, valuation, market value, market attributes.

Category of the paper: Research paper; case study.

1. Introduction

A number of tasks in the field of water management in many countries, including Poland, are carried out by local government units. The responsibilities related to the management of water supply and sewage networks as well as water distribution are performed either directly by municipalities or delegated to municipal companies. Different solutions may apply with regard to the division of responsibilities. Most often, a company is entrusted with both the assets (including networks) and the distribution (sale) of water as well as sewage collection. However, in some cases these responsibilities are separated, whereby one company is assigned the assets (the enterprise managing the network), while another entity is responsible for water distribution and sewage collection (for example, the city of Gdańsk between 1992 and 2023) (Czaplak, 2024).

A company performing a public utility function faces a dual nature. On the one hand, it has an unusual owner in the form of a municipality (a local government unit which, by nature, should operate on a non-profit basis), while on the other hand it remains a business entity that must function in the market, with its management required to make economically rational decisions aimed at generating profit.

Regardless of whether water supply and sewage networks are managed directly by a municipality or indirectly through a designated company, decisions concerning assets sometimes involve the acquisition or disposal of networks. This raises the problem of determining the value (and subsequently the price) of such a specific asset as water supply and sewage networks. Information about the value and in particular the market value, of such assets may be required, for example, for the purchase of a water supply or sewage network from a private investor¹, the contribution of assets in kind to a company, or the resolution of court disputes.

Both Polish and international literature lack studies on the valuation of water supply and sewage networks. In particular, there is a methodological gap in the calculation of their market value.

The purpose of the research was to identify and assess the attributes of water supply and sewage networks that influence their market value.

The first part of the article presents the specific characteristics of water supply and sewage networks as valuation objects and discusses the theoretical essence of market value. The following section provides a review of the scientific literature concerning valuation methods for water supply and sewage networks.

¹ Private investors sometimes construct water supply and sewage networks as so-called accompanying investments, necessary for the proper functioning of, for example, a residential housing estate. Such private investors are often households building residential houses to meet their own needs.

The research section of the article presents findings that provide a basis for applying comparative methods² to determine the market value of water supply and sewage networks. The main part of the study was conducted in 2025 and covered selected municipalities in the Pomeranian Voivodeship in Poland. The primary research methods applied in this study were the case study and comparative analysis. Data were collected through document analysis and interviews conducted with representatives of selected enterprises and local government units.

2. The Specific Characteristics of Water Supply and Sewage Networks as Objects of Valuation

The article analyzes the issue of transactions involving assets in the form of water supply and sewage networks. The discussion focuses in particular on networks constructed by private investors, with the understanding that such projects are usually undertaken as an accompanying element of other investment ventures. Developers build these networks to provide water supply and sewage disposal for new residential estates or commercial facilities, while private individuals do so in connection with the construction or modernization of a single-family house. Consequently, the construction of networks forms part of a broader investment project.

The profitability of such ventures is evaluated by investors in the context of the entire construction project, rather than solely from the perspective of the network construction costs. It should be noted that private investors may accept a selling price lower than the expenditures incurred, since they obtain additional benefits from connecting their property to the municipal system, including an increase in its value. In the case of infrastructure developed by municipalities, various fees may be charged to distribute the construction costs of the network among the property owners who benefit from it (in Poland these are referred to as infrastructure improvement fees). However, when a private investor independently finances the construction and transfers the network to a utility company, such fees do not apply.

From the perspective of the entity acquiring the network, the key factor is an analysis of the transaction's profitability. The purchase price should correlate with the revenue-generating potential of the given infrastructure. For example, a 5-kilometer network serving a single residential building will have a lower value than a network of the same length and capacity serving ten buildings. Another factor influencing value is the potential for future connections to the existing network, although this aspect is difficult to estimate both in terms of the number of connections and the timing of their implementation.

Water supply and sewage networks relatively rarely become the subject of market transactions. The literature points to two primary cases (Trojanowski, Kisiel, 2012):

² Comparative methods are applied in real estate valuation.

- the disposal of networks (most often internal ones) together with an organized property complex including land, buildings, and structures, which occurs, for example, in the sale of enterprises. In such transactions, the price of the network itself is rarely extracted, as the total value of the entire complex is usually reported;
- the transfer of ownership of the network to a municipality or a company managing the infrastructure.

In the first case, transactions usually concern internal networks used for distributing utilities within the area of a given property or enterprise. The present discussion, however, refers to so-called municipal networks, which are characterized by different functional and economic attributes. The most significant problem remains the incidental nature of such transactions, which makes it impossible to apply the comparative approach based on market prices.

The second of the described variants occurs when, in a given area, the only purchaser of the network is the utility company operating the infrastructure. In such cases, the financial terms depend on the company's policy and the outcome of negotiations between the parties. The absence of competition among buyers in a given area results in a monopolistic market. Competition, however, may be considered in terms of general policies supporting investment within a municipality and in building a competitive advantage over neighboring, rival municipalities.

3. The Concept of Market Value

One of the most important concepts in economic sciences is the category of "value". Although the term "value" occupies a central place in economic theory, it remains ambiguous, imprecise, and far from definitive resolution. In contemporary economics, it is commonly understood that not all goods possess value, but only those characterized by utility, scarcity, and accessibility (Kucharska-Stasiak, 2016). Moreover, it appears that modern economists are less interested in debating the definition of value itself, and more focused on formalized tools and methods of determining the prices of goods. This implies that the issue at hand is primarily one of valuation and the appraisal of goods rather than a theoretical discussion about the value of a commodity (Trojanowski, 2019).

Valuation is therefore a procedure through which value is determined. The value of a property, as the outcome of a valuation, may differ from the actual price of the property resulting from a concluded transaction. E. Kucharska-Stasiak considers value as a hypothesis of price (Kucharska-Stasiak, 2011). As D. Trojanowski notes, if value is a hypothesis, then the valuation process may be equated with research aimed at formulating such a hypothesis (Trojanowski, 2019).

Publications concerning real estate valuation indicate the existence of subjective and objective categories of value, assigning specific types of value to particular groups (Mączyńska, Prystupa, Rygiel, 2008). Subjective value is understood as the value determined with regard to the individual preferences of a party to a sales transaction. Objective value, on the other hand, is the value verified by the market through comparison with the prices of similar objects achieved on the market. The basis of valuation in this context is not the individual preferences of the buyer or the seller, but rather the opinion of the wider market expressed, for example, through the prices of comparable objects. The distinction between subjective and objective categories of value in fact suggests a particular procedure aimed at determining value. It therefore seems that subjectivity or objectivity should be applied rather to the process of valuation than to value itself (Trojanowski, 2019).

It is therefore essential to consider what is meant by objective valuation or the objectification of real estate valuation. This issue may be approached in two ways. First, the objectification of valuation may be understood as an attempt to detach from one's own judgments and beliefs and to adopt what is indicated by the market (understood as the majority view). Second, the appraiser may strive to confirm (or refute) their own hypotheses through evidence derived from the market, which would be consistent with perceiving value as a hypothesis of price. In both cases, the study should be based on independent and verifiable market evidence.

In valuation practice, value is generally not defined as a separate category, but rather differentiated into many types (Appraisal Institute, 2020). The most frequently applied type of value is market value. However, this concept does not have a uniform definition. Definitions of this category differ across national laws and professional standards despite ongoing attempts to standardize real estate valuation. In Poland, market value is most often defined in the context of real estate valuation. This article, however, concerns water supply and sewage networks, which are linked to real estate. For this reason, an analysis of the concept of market value specifically in relation to real estate appears to be justified.

In Poland, the most significant definition of market value is the one provided by the Real Estate Management Act (the statutory definition)³. According to legal regulations, the market value of a property is the estimated amount for which the property should exchange on the date of valuation, in a transaction concluded under market conditions between a buyer and a seller who are each willing to enter into the contract, act knowledgeably, prudently, and without compulsion.

The statutory definition of market value should always be applied unless a specific regulation introduces exceptions. The category of market value is also invoked in tax regulations and applies not only to real estate but also to other assets or services. This raises the

³ The Act of 21 August 1997 on Real Estate Management (Ustawa o gospodarce nieruchomościami, Journal of Laws 1997, No. 115, item 741, as amended).

issue of applying the appropriate definition, or more precisely, adopting the correct guidelines in a given valuation case. According to M. Prystupa, “the definition of market value contained in the Real Estate Management Act may be regarded as a general (universal) standard, while definitions included in other acts and regulations are special (particular) standards” (Prystupa, 2013). Such an approach to the issue appears to be rational.

In addition to statutory definitions, a number of definitions of market value are also included in professional standards such as the International Valuation Standards (IVS) (International Valuation Standards Council, 2024) and the European Valuation Standards (EVS) (TEGoVA, 2020). These definitions reveal both similarities and differences regarding the conditions under which an estimated amount may be considered a market value.

A common feature of the definitions is the indication that value represents the estimated amount that can be obtained for a property on the date of valuation. Market value is therefore determined as of a specific date, ensuring that the estimated value is appropriate for that particular point in time. As emphasized in the IVS, “because of the potential for changes in the market or market conditions, the reported value may be incorrect or inappropriate at another point in time”. Importantly, the IVS also “...assumes the simultaneous conclusion and execution of the contract without consideration of any price changes that could occur in the absence of such simultaneity”. The EVS, on the other hand, stresses that “the hypothetical sale takes place under a private (individually negotiated) contract and is therefore subject to negotiations”. This means that as of the valuation date, the terms of the contract must be negotiated and finalized, and the time necessary for this process must be taken into account in order for the estimated value to be recognized as market value.

As noted earlier, the concept of market value assumes a hypothetical buyer and seller, with market value identified as a hypothesis of the price that objectifies the market by reflecting the most typical behavior of its participants. The literature highlights the need to account for typical (most common) behavior characteristic of a “market investor”. K. Jajuga and P. Cegielski explain the notion of a market (average) investor. According to the authors, “a market investor should be understood as an average (typical) investor actively operating in the market for a given type of real estate, representing a kind of average outcome based on the investment decisions made by participants in that market” (Jajuga, Cegielski, 2003). As they further note, valuation should reflect the behavior of a “hypothetical” market investor who would represent those operating in the studied market. K. Jajuga and P. Cegielski also emphasize that when determining “the market value of a property, in reality we attempt to answer the question: what is the equilibrium price that both parties to the hypothetical transaction - the seller and the buyer - agree upon?” According to the authors, this means that investors include not only buyers but also sellers. The seller, in deciding to conclude a transaction, also considers a range of factors influencing value and usually possesses significantly greater knowledge about them than the buyer (Jajuga, Cegielski, 2003).

Despite the multiplicity of definitions of market value contained in legal regulations and professional standards, the fundamental interpretations and assumptions describing this category, which is so crucial to valuation, remain largely consistent.

4. Valuation Methods of Water Supply and Sewage Networks – A Literature Review

The process of price determination is commonly understood as the procedure through which the value of a given good or service is expressed in monetary units (usually). It is essential that pricing policy remains consistent with the objectives of a company's operations. Regardless of the method adopted, determining a price requires an analysis of data to support this process. Such data include information on:

- demand for a given good or service,
- competition,
- the costs incurred by the company,
- the price levels acceptable to buyers.

In setting prices, particular attention must be paid to the type of asset being transacted and to data on market prices. The literature provides guidance on methods of determining the prices and values of goods and services (Turčínková, 2021). Assets, as a specific category of goods, may be valued using the following approaches:

- pricing methods and techniques based on construction costs,
- pricing methods based on income that will be generated in the future,
- pricing methods based on the prices set by competitors.

Naturally, there is a difference between price and market value. Nevertheless, in management theory, when referring to pricing methods, in practice the issue at stake is value. The final price is the outcome of a transaction, while determining value represents an attempt to forecast it. Consequently, it is important to consider both the methods of price determination applied by companies and the methods of value determination used by valuation experts in relation to such specific assets as water supply and sewage networks.

The relationship between the prices achieved by goods and their production costs may vary, particularly with respect to complementary goods (water supply and sewage networks are complementary to buildings). In Poland, cost-based methods are applied in special cases to real estate valuation; however, their application results in determining the replacement value (reconstruction cost less depreciation) rather than market value. Furthermore, methods based solely on construction costs do not take into account the relationship between the cost of constructing a network and its income-generating potential (Mika, 2015).

The price or value of an asset based on its income-generating potential can be determined using available investment profitability methods. These methods may be divided into traditional (static) and discounting (dynamic) approaches. In general, traditional measures reduce the analysis to simple indicators that ignore the time factor. Discounting methods, in contrast, provide a clear and coherent framework for assessing the efficiency of investment projects, presenting them in terms of total costs and benefits, and highlighting the relationship or difference between these categories, which allows for an evaluation of the project's effectiveness. Costs and benefits spread over time are adjusted through discounting, which ensures analytical consistency by accounting for both time and risk (Wiśniewski, 2008).

Dynamic investment appraisal methods incorporate irregular cash inflows and outflows incurred by an investor in connection with an investment project. Discounting serves to translate expenditures and outcomes occurring at different points in time into a common point of analysis. The use of discounting methods enables the inclusion of the entire operating horizon of a project in profitability calculations, covering both the implementation and the exploitation phases. Among the discounting measures most commonly used to assess the effectiveness of real investments are net present value (NPV), the profitability index (PI), and the internal rate of return (IRR). Of these, NPV is of greatest importance. The literature describes the application of these methods to the evaluation of typical investment projects (Sierpińska, Jachna, 1998; Damodaran, 2012).

The NPV method is also applied to determining the value of assets, such as real estate. In real estate valuation, professional standards for property appraisers indicate that, depending on the stability of income, the following techniques are distinguished:

- direct capitalization, in which the value of the property is determined as the product of a stable annual income stream obtainable from the valued property and the capitalization rate, or as the ratio of the stable annual income stream to the capitalization rate,
- income stream discounting, in which the value of the property is determined as the sum of discounted income streams obtainable from the valued property in successive years of the adopted forecast period, increased by the discounted residual value of the property.

These techniques are widely described in the literature (Sierpińska, Jachna, 1998; Damodaran, 2012). The research conducted for the purposes of this article shows that local government units or enterprises responsible for managing networks increasingly apply various pricing methods for the acquisition of networks (Table 1). Among the identified methods, NPV and rent capitalization stand out. The application of the NPV method in valuing water supply and sewage networks has been described, for example, in the paper *Price Calculation of Water Supply and Sewage Networks for the Purpose of Purchase by Supply Companies – Net Present Value Method* (Trojanowski, Kisiel, 2012a). The valuation of water supply networks using methods such as NPV, however, encounters a fundamental problem highlighted, among others, by Grafton — namely, that in many countries, water supply charges

cover only a portion of production costs, which results in negative cash flows (Grafton, Manero, Chu, Wyrwoll, 2023).

Rent capitalization, in turn, is presented in *Price Calculation of Water Supply and Sewage Networks to be Purchased by Supply Companies – Rent Capitalisation Method* (Trojanowski, Kisiel, 2012b) and *The Method of Determining the Surrender Value of Water Supply and Sewage Systems* (Mika, 2015).

In both management practice and valuation theory, various comparative methods based on competitor prices are frequently applied. Generally speaking, these methods involve comparing the asset under valuation with other similar assets that have already been sold. Therefore, the application of comparative methods requires access to information on the prices of goods traded on the market and applied by competitors. Using comparative methods, the value of goods is determined on the basis of so-called market attributes, meaning those attributes that significantly affect the value of the asset (Appraisal Institute, 2020). For example, in the case of residential real estate, market attributes include location, neighborhood, house size, technical condition, and standard of the dwelling. In the literature, no studies have been identified concerning the valuation of water supply and sewage networks using comparative methods.

In summary, management theory provides insights into various methods of price determination applied by companies, while valuation theory focuses on methods of determining the value of assets, including market value. Among these methods, NPV and direct capitalization are of particular importance. Cost-based methods, as a rule, are not applied to determining market value. Comparative methods, on the other hand, require knowledge of the prices of comparable assets and the identification of market attributes (those attributes that affect asset value). Given the aim of the present research, this section indicates the ways in which market attributes can be identified, and in particular how their weights can be determined. Weight should be understood as the percentage impact of a given attribute on the asset's value. It appears that the greatest number of both practical and scientific publications in this field concerns the market attributes of real estate and their weights used in valuation. Publications emphasize that the identification of real estate market attributes should be based on market analysis. In practice, this involves analyzing real estate transaction prices as well as property sale listings, in which sellers highlight the attributes that are significant for value. In terms of determining the weights of market attributes, experts consider the condition of the analyzed market and most often rely on (Polish Federation of Property Appraisers' Associations, 2008):

- results of analyses of data on prices and market attributes of comparable properties traded on the real estate market defined for valuation purposes,
- analogy to similar local markets in terms of type and area,
- surveys and/or observations of potential buyers' preferences.

In the analysis of price data, various statistical methods are applied, as well as the paired-sales analysis method. The paired-sales analysis method, described by M. Prystupa (Prystupa, 2023), involves identifying pairs of properties in a dataset of transaction prices that differ only

in one market attribute. The principle of *ceteris paribus* (all other factors held constant) is applied in this method. The price difference between such identified properties is then related to the so-called price delta, i.e. the difference between the maximum and minimum prices observed on the market. The entire analysis must be conducted within the market of goods of the same type, taking into account the impact of time on price changes.

In this article, the paired-sales analysis method was applied to calculate the weights of market attributes influencing the value of water supply and sewage networks.

5. Market Attributes Influencing the Value of Water Supply and Sewage Networks – Case Studies

This section of the article presents the results of research on the identification of market attributes influencing the value of water supply and sewage networks. The study covered selected local government units (LGUs) and enterprises providing water supply and sewage services in the Pomeranian Voivodeship in Poland. The research area was chosen due to access to data. The main part of the research was carried out in 2025, while documentation and data from interviews were collected between 2015 and 2025.

According to M. Komorowski, in the Pomeranian Voivodeship there are seven organizational forms under which water supply and sewage management is carried out (Komorowski, 2024). More than half of the entities responsible for these tasks operate as companies. Twenty-six municipalities perform these tasks through their departments or municipal offices. In total, 23 cases involve municipal utilities and budgetary units. Eight municipalities have delegated these responsibilities to inter-municipal associations, while in two cases public–private partnerships have been applied. The organizational forms vary depending on the size of the municipality and its population. Regardless of the legal form, entities managing water supply and sewage networks face challenges in acquiring so-called private networks. The research conducted by the authors of this article indicates that in at least seven local government units in the Pomeranian Voivodeship, similar models are used to determine the purchase price of such networks. These models are based on the rent capitalization method described above. First, the rental rate is determined, which for the studied entities analyzed ranged from 4 to 6 percent of the replacement cost (estimated construction cost) of the network. This rent is then adjusted using a set of market attributes and the ratings assigned to them. The adjusted rent is capitalized with the discount rate applied by the enterprise or LGU, and the percentage of network acquisition—relative to its replacement cost—is determined. The studied entities applied different sets of attributes and weights, depending on their specific circumstances and preferences.

To draw general conclusions, the authors analyzed the selected cases to identify market attributes and attempted to determine the weights of these attributes using the paired-sales analysis method. In order to obtain consistent data, each case evaluated a water supply network of the same length (excluding additional elements such as hydrants) as of 24 September 2025. The studied entities applied different principles and indicators for estimating replacement cost (preparing construction cost estimates) of the network. Therefore, it was decided to determine the impact of individual attributes on the percentage of network acquisition (the ratio of acquisition price to replacement cost of the network).

The research identified five key market attributes influencing the value of water supply networks: location, average flow in the network (network diameter), service life of the network, depreciation, and type of network (related to the potential for future connections). Each entity assigned different sets of ratings to these attributes when determining the acquisition price of a network.

Table 1 presents the market attributes influencing the value of water supply networks identified in seven case studies. Analogous attributes appeared in the valuation model for sewage networks, although the number of ratings assigned to individual attributes sometimes differed.

Table 1.

Market attributes affecting the value of water supply networks

Assessed Entity	Municipality ~17k inhabitants	City ~47k inhabitants	Municipality ~30k inhabitants	Municipality ~16k inhabitants	Municipality ~31k inhabitants	City over 200k inhabitants	Municipality ~7.5k inhabitants
Object number	1	2	3	4	5	6	7
Attribute	Ratings assigned to individual attributes						
Location	area I–IV, best-rated are zones within the spatial development plan and in urbanized areas	area I–III, best-rated are cadastral districts preferred in terms of future development, including land value	areas I–IV, additional criterion: location of the network in a municipal road/plot, private road, or private plot	area I–II, development preferences of the municipality	area I–II, development preferences of the municipality	division into districts, best location depends on population density	location assessed multi-criterially depending on land use, number of landowners, number of active connections
Average flow in the network	PVC Ø90–160PE Ø40–160	cast iron Ø80–300PE Ø63–315	PVC Ø90–300PE Ø90–300PE RC Ø90–300	cast iron Ø80–300PE Ø63–315	cast iron Ø80–250PE Ø75–250	cast iron Ø80–600PE Ø63–315	PVC Ø40–160PE Ø40–160
Service life of the network	does not differentiated	cast iron, PE	does not differentiated	cast iron, PE	cast iron, PE	cast iron, PE	does not differentiated
Depreciation	0–100%	0–100%	0–100%	0–100%	0–100%	0–100%	0–100%
Type of network	ring network, terminal network	ring network, terminal network	development network, terminal network	ring network, terminal network	transit network, terminal network	ring network, terminal network	development network, terminal network

Note. Due to the protection of sensitive data and confidentiality obligations, the article does not disclose the names of the enterprises and municipalities included in the analysis; the identifying data remain in the source materials available to the authors.

Source: Authors' own elaboration based on document analysis and conducted interviews.

As shown by the comparative analysis presented in Table 1, the attributes recur across all studied cases, with the exception of the attribute “service life of the network”, which was not distinguished in cases 1, 3, and 7, due to the lack of differentiation of this network in terms of this attribute. The attribute of location, although present in all cases, was assessed differently depending on the specific characteristics of each municipality. In most cases, location ratings were linked to zones (e.g. cadastral districts), ranging from two to four zones. The division into zones often reflected municipal authorities’ preferences regarding development directions. Higher prices were associated with zones where local government supported residential construction, and lower prices were applied in zones where agricultural land use was preferred. In one case, the division was based on city districts, where the district with the highest population density (and therefore highest water consumption) was considered the most valuable. There were also cases where location was evaluated using multi-criteria analysis, taking into account, among others, land function (with roads preferred), land ownership type (municipality or State Treasury preferred), and the number of landowners of the plot crossed by the evaluated network.

The attribute average flow in the network is closely related to the pipe diameter and the volume of so-called trade water. As a rule, the larger the pipe diameter, the higher the network’s value. Service life appeared as a market attribute in municipalities where cast iron networks had been constructed. This type of network is also considered the most valuable. Depreciation depends on the year of construction: newer networks received the highest ratings. In each studied case, the type of network—reflecting its potential for future connections—was also considered. One type was the terminal network, which has a limited number of connections and cannot be extended. By contrast, networks with higher potential (and higher value) were described, depending on the municipality, as ring, developmental, or transit networks.

The above findings indicate that municipalities applied similar criteria when assessing the value of networks, though terminology as well as the type and number of ratings assigned to individual attributes varied. It can therefore be stated that in the Pomeranian Voivodeship a market has formed in which sellers consider similar attributes when determining the acquisition price of networks.

Taking the attributes listed in Table 1 as the market attributes of water supply and sewage networks, an attempt was made to calculate the percentage weights reflecting the impact of each attribute on network value using the paired-sales analysis method. The weights were analyzed separately for each attribute by determining the difference between the maximum price established for a water supply network with all the most favorable ratings and the price of a network reflecting the least favorable rating of the examined attribute (e.g., location). The remaining attributes were assigned the most favorable ratings in order to account for the *ceteris paribus* principle.

Table 2 presents the results of the conducted research for each case study and the calculated average values.

Table 2.
Weights of Market Attributes of Water Supply Networks

Assessed entity	Municipality ~17k inhabitants	City ~47k inhabitants	Municipality ~30k inhabitants	Municipality ~16k inhabitants	Municipality ~31k inhabitants	City over 200k inhabitants	Municipality ~7.5k inhabitants	Min	Max	Average
Attribute	Attribute Weights									
Location	57.92%	39.52%	40.32%	39.52%	29.17%	42.49%	60.91%	29.17%	60.91%	44.27%
Average flow in the network	14.28%	39.52%	40.32%	39.52%	34.66%	41.78%	14.12%	14.12%	41.78%	32.03%
Service life of the network	-	1.97%	-	1.97%	2.91%	3.65%	-	1.97%	3.65%	2.63%
Depreciation	10.44%	7.11%	7.26%	7.11%	15.75%	4.54%	6.70%	4.54%	15.75%	8.42%
Type of network	17.40%	11.86%	12.11%	11.86%	17.51%	7.55%	18.27%	7.55%	18.27%	13.79%
Total:	100%	100%	100%	100%	100%	100%	100%	-	-	101%

Source: Authors' own elaboration based on conducted research.

As shown above, the most important market attribute of water supply networks is location, with an average weight of 44.27%, indicating its impact on value. In contrast, the attribute with the smallest influence among those identified is “service life of the network” (2.63%).

6. Discussion

The research results concern the valuation of water supply and sewage networks, a topic that is rarely addressed, while the specific outcomes in the form of market attributes and their weights, calculated on the basis of domestic market data, have, to the authors' knowledge, been published in a scientific journal for the first time. A certain set of attributes was identified by P. Mika, who, based on his analysis, distinguished three key attributes: the possibility of further network expansion, the age of the network, and its diameter (cross-section) (Mika, 2015). It should be noted that the set of attributes identified by the authors of this article includes analogous attributes.

Both in Polish and international literature, there is a lack of studies on the valuation of water supply and sewage networks. In particular, there is a noticeable gap in the methodology for calculating market value. The authors hope that this article will provide a foundation for the application of comparative methods in the practice of valuing water supply and sewage networks.

At this point, certain limitations of the conducted research should be acknowledged. First and foremost, the study was based on seven cases, which cannot serve as a basis for broad generalizations. The research concerned enterprises from the Pomeranian Voivodeship in Poland, which, on the one hand, is advantageous since it can be assumed that the same economic factors related to the local market apply. On the other hand, in other regions of the country, different attributes may be considered relevant to the prices and values of water supply and sewage networks. It should also be emphasized that the study reflected the preferences of the buyer (the investor), who holds a certain monopoly in the local market. Sellers of water supply and sewage networks cannot choose buyers, as these are always municipalities or municipal enterprises. Nevertheless, the conditions offered by a given municipality regarding water supply and sewage infrastructure, including network buyouts, influence its attractiveness to potential land buyers and homebuilders. Thus, it can be argued that competition arises between municipalities, which compete to attract developers and new residents.

7. Summary

The unusual nature of water supply and sewage networks as goods, combined with the specificity of their market, generates numerous challenges in their valuation. The objective of this study was to identify and assess the attributes of water supply and sewage networks that affect their market value. The primary research method applied for the purposes of this article was the case study and comparative analysis. Data were collected through document analysis and interviews conducted with representatives of selected enterprises and local government units in the Pomeranian Voivodeship of Poland. Seven cases were examined, in which the studied entities applied similar models for determining the buyout prices of private networks. The theoretical part of the study included a review of the relevant literature.

The research identified five key market attributes influencing the value of water supply networks: location, average flow in the network (pipe diameter), service life of the network, depreciation, and type of network (related to the potential for future connections). Using the paired-sales analysis method, weights were calculated for these attributes, indicating the percentage impact of each attribute on the value of a water supply network. The most important market attribute of water supply networks is location, with an average weight of 44.27%. In contrast, the attribute with the smallest impact among those identified is “service life of the network” (2.63%). To maintain consistency, the study was conducted with reference to water supply networks; however, in the authors’ view, the results concerning the set of market attributes and their weights would be similar in the case of sewage networks. Nevertheless, detailed research directly addressing sewage networks should certainly be continued.

The process of acquiring water supply and sewage networks from private investors, particularly households constructing such networks for their own needs, is complex and socially challenging. Household expectations often conflict with the principles of managing public funds. The findings presented in this article can be used to establish fair compensation based on the market value of water supply and sewage networks. The results also provide a basis for applying comparative methods—commonly used in real estate valuation—to the valuation of water supply and sewage networks.

References

1. Appraisal Institute (2020). *The Appraisal of Real Estate. 15th ed.* Chicago: Appraisal Institute, pp. 22-32.
2. Czaplak, J. (2024). The Main Premises of the Re-municipalisation of Water Supply and Sewage Management on the Example of Gdańsk (Główne przesłanki rekomunalizacji gospodarki wodociągowo-kanalizacyjnej na przykładzie Gdańska). *Optimum. Economic Studies*, No. 2(116), pp. 179-193, doi: 10.15290/oes.2024.02.116.09
3. Damodaran, A. (2012). *Investment Valuation: Tools and Techniques for Determining the Value of Any Asset.* 3rd ed. Hoboken, NJ: John Wiley & Sons.
4. Grafton, R.Q., Manero, A., Chu, L., Wyrwoll, P. (2023). *The price and value of water: An economic review. Cambridge Prisms: Water*, 1, e3, 1-17 <https://doi.org/10.1017/wat.2023.2>.
5. International Valuation Standards Council (2024). *International Valuation Standards 2024.* London: IVSC.
6. Jajuga, K., Cegielski, P. (2003). Discount Rate in Real Estate Valuation – Methodological Foundations (Stopa dyskontowa w wycenie nieruchomości – stopa dyskontowa – podstawy metodologiczne). *Nieruchomości*, No. 10, C.H. Beck, p. 40.
7. Komorowski, M. (2024). *Structuring the Financing of Municipal Infrastructure Projects (Strukturyzacja finansowania projektów infrastrukturalnych gmin).* Doctoral dissertation. Gdańsk: Wydział Zarządzania, Uniwersytet Gdański.
8. Kucharska-Stasiak, E. (2011). Measurement of Value in Economics – Repercussions for Property Valuation (Pomiar wartości na gruncie ekonomii – reperkusje dla wyceny nieruchomości). *Studia i Materiały Towarzystwa Naukowego Nieruchomości*, Vol. 19, No. 1, p. 11.
9. Kucharska-Stasiak, E. (2016). *The Economic Dimension of Real Estate (Ekonomiczny wymiar nieruchomości).* Warsaw: PWN, pp. 1-459.
10. Mączyńska, E., Prystupa, M., Rygiel, K. (2008). *How Much is Real Estate Worth (Ile jest warta nieruchomość).* Warsaw: Poltext, pp. 1-232.

11. Mika, P. (2015). *The Method of Determining the Surrender Value of Water Supply and Sewage Systems*. *Świat Nieruchomości - World of Real Estate Journal*, 94, pp. 17-22.
12. Polish Federation of Property Appraisers' Associations (2008). *Interpretative Note: The Application of the Income Approach in Real Estate Valuation (Nota interpretacyjna: Zastosowanie podejścia dochodowego w wycenie nieruchomości)*. Resolution of the National Council of 9 December 2008. PFSRM.
13. Prystupa, M. (2013). Hierarchy of Legal and Methodological Conditions in the Real Estate Valuation Process (Hierarchia uwarunkowań prawnych i metodologicznych w procesie wyceny nieruchomości). *Rzeczoznawca Majątkowy*, No. 1(77), p. 9.
14. Prystupa, M. (2023). *Real Estate Valuation Using the Comparative Approach. A Discussion of the Standard with Examples (Wycena nieruchomości przy zastosowaniu podejścia porównawczego. Omówienie standardu wraz z przykładami zadań)*. Warsaw: PFSRM, pp. 34-35.
15. Sierpińska, M., Jachna, T. (1998). *Enterprise Evaluation According to Global Standards (Ocena przedsiębiorstwa według standardów światowych)*. Warsaw: PWN.
16. TEGoVA (2020). *European Valuation Standards 2020. 9th ed.* Brussels: TEGoVA.
17. Trojanowski, D. (2019). *The Dilemmas of Commercial Real Estate Valuation in Poland (Dylematy wyceny nieruchomości komercyjnych w Polsce)*. Gdańsk: Wydawnictwo Uniwersytetu Gdańskiego, pp. 1-371.
18. Trojanowski, D., Kisiel, P. (2012a). Price Calculation of Water Supply and Sewage Networks for the Purpose of Purchase by Supply Companies – Net Present Value Method. *Świat Nieruchomości - World of Real Estate Journal*, No. 1(79), pp. 34-39.
19. Trojanowski, D., Kisiel, P. (2012b). Price Calculation of Water Supply and Sewage Networks to be Purchased by Supply Companies – Rent Capitalisation Method. *Świat Nieruchomości - World of Real Estate Journal*, Vol. 2(80), pp. 24-32.
20. Turčínková, J. (2021). The Value-Based Pricing Determination Matrix for Pricing Method Selection. *Journal of Business Economics*, No. 92(3), pp. 1-15.
21. Wiśniewski, T. (2008). *Evaluation of the Effectiveness of Real Investments with Particular Consideration of Risk (Ocena efektywności inwestycji rzeczowych ze szczególnym uwzględnieniem ryzyka)*. Szczecin: Wyd. Naukowe Uniwersytetu Szczecińskiego, p. 58.

IDENTIFYING LEADERSHIP STYLES THAT SUPPORT THE ORGANIZATION'S MATURITY UNDER INDUSTRY 4.0 CONDITIONS

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Purpose: The aim of the article was to examine the effectiveness of different leadership styles in the context of Industry 4.0 and to determine which ones best support organizational maturity in the conditions of digital transformation. This article sought to compare the perceptions of leadership style effectiveness among academics and industry practitioners.

Design/methodology/approach: The study was conducted using the Delphi method, involving 33 experts, of whom 26 respondents were ultimately selected based on a competence coefficient (Kk). The participants were divided into two groups – representatives of science and industry. The experts assessed the effectiveness of selected leadership styles in the context of Industry 4.0 using a five-point Likert scale, which enabled a detailed analysis of their opinions.

Findings: The results of the study showed that both academics and practitioners considered participatory and transformational styles to be the most effective in Industry 4.0 conditions. On the other hand, autocratic and transactional styles, although useful in certain situations, were considered less appropriate in an environment requiring flexibility and rapid adaptation to technological changes.

Research limitations/implications: The study is limited by the relatively small number of experts and its focus on selected leadership styles. However, the results indicate a need for further analysis of the role of leadership in the digital transformation of organizations and the development of their maturity in the context of Industry 4.0.

Originality/value: The article provides cognitive value by identifying leadership styles that best support organizations in the Industry 4.0 era. It also makes a valuable contribution to understanding the differences between how leadership is perceived by theorists and practitioners, emphasizing the importance of leadership based on cooperation, flexibility, and innovation.

Keywords: Leadership, Leadership 4.0, Industry 4.0, Management, Organization maturity.

Category of the paper: Research paper.

Introduction

Industry 4.0, the result of dynamic technological change, involves the transformation of traditional manufacturing and management processes with the help of modern technologies such as artificial intelligence, the Internet of Things, Big Data, and autonomous robots. This transformation is not only revolutionizing the way organizations produce and deliver their products, but is also affecting the structure and management of organizations. Industry 4.0 requires new skills and approaches from leaders that are able to meet the challenges of digitization, automation, and the growing complexity of processes (Erboz, 2017; Tay et al., 2018; Dubey et al., 2022).

In this context, leadership plays a key role in shaping and adapting organizations to changing conditions. Traditional leadership styles, such as autocratic or transactional, are gradually giving way to more flexible and collaborative approaches that promote innovation and adaptation in the face of increasing automation (Oberer, Erkollar, 2018). The literature is paying increasing attention to participative and transformational leadership styles that promote collaboration, employee engagement and decentralization of decisions - traits that are key to the successful operation of organizations in Industry 4.0 (Gupta, Gupta, 2020; Canbay, Akman, 2023).

The gap of this research lies in the fact that there has been limited understanding of what kind of leadership style best fosters organizational maturity in the context of Industry 4.0. While literature provides various approaches on styles, on the other hand, large-scale empirical data is missing with respect to how these styles can enable organizational adaptation to the rapid technological changes brought about by Industry 4.0, in particular, automation, AI, and Big Data. The study further points to the under-researched gap concerning differences in preferred leadership styles by practitioners and academics in light of digital transformation. This gap constitutes a dire need for further research on the various ways of leading an organization to best performance in times characterised by constant technological disruption. The paper also points out that the previous literature has not sufficiently debated how leadership styles have to be adapted in order to meet the specific challenges caused by decentralized decision-making and innovation in highly automated environments.

The purpose of this article is to explore which leadership styles are most effective in supporting organizational maturity in an Industry 4.0 environment. To this end, a survey was conducted with industry experts and academics, allowing them to compare their preferences for different leadership styles. The analysis aims to provide practical guidance for leaders who need to adapt their approach to the requirements of digital transformation.

The article poses the following research questions:

- Q1 - What leadership styles support organizational maturity in an Industry 4.0 environment?
- Q2 - Are there differences in perceptions of the effectiveness of different leadership styles between academics and industry representatives?
- Q3 - Which characteristics of leadership styles are most desirable in a rapidly changing technological environment?
- Q4 - Which leadership styles group into key managements that support organizational maturity in Industry 4.0, and what lessons emerge from these groupings for industry leaders?

By answering the above questions, this article aims to fill a research gap concerning the relationship between leadership styles and organizational maturity in the context of the Fourth Industrial Revolution. The results of the study can make a significant contribution to both the development of leadership theory and management practice, providing an understanding of which leadership styles best support the flexibility, innovation, and adaptability of organizations, which is becoming a key success factor in an environment characterized by continuous technological progress. Consequently, this study is an attempt to combine scientific and practical perspectives in order to identify leadership styles that enable organizations to function effectively in the dynamically changing world of Industry 4.0.

Identification of leadership styles

Dynamic technological changes have led to the concept of Industry 4.0, which is seen as a comprehensive transformation of traditional production and management processes with the help of modern technologies, such as: Autonomous Robots, Augmented Reality, Simulations, Incremental Manufacturing, Integration of Information Systems, Cybersecurity, Internet of Things, Cloud Computing, Big Data, Artificial Intelligence (Erboz, 2017; Tay et al., 2018; Trzop, 2020; Dubey et al., 2022). This revolution not only includes the optimization of production processes, but also the changes taking place in the ways organizations are managed and their structures, which requires modern skills and approaches from leaders (Gupta, Gupta, 2020; Canbay, Akman, 2023).

Leaders in Industry 4.0 play a key role in leading organizations in the face of increasing automation and digitization (Oberer, Erkollar, 2018). In traditional industrial models, where processes were clearly defined, the role of the leader was mainly to make decisions, control teams, adapt his own policies, and influence the group to achieve common goals by motivating, inspiring, and mobilizing (Moore, 1927; Morris, 1959; Weber, 1972; Gleick, 1987; Abercrombie, 1988; Yukl, 1989; Bogdanor, 1993; Adair, 2009). In the context of Industry 4.0,

the situation becomes even more complex, as organizations must operate in a dynamically changing environment in which not only technology, people and data are highly integrated, but also market requirements and needs are constantly changing (Vaida, et al., 2018).

Modern technology is changing not only how organizations produce and deliver their products, but also how they are managed. This poses many challenges for leaders in terms of how they approach people management, using advanced analytical tools to make decisions and forecast future trends.

One of the main challenges for leaders in Industry 4.0 is to integrate advanced technologies with the work of human teams (Venkatesh, 2020; Puhovichova, Jankelova, 2021). This requires the ability to manage diverse teams, flexibility and the ability to collaborate in an environment that is constantly evolving (Behie et al., 2023, Haleem et al., 2024). Leaders must not only understand how technologies affect operational processes, but also support their teams in adapting to new tools and work methods. In this context, leadership based on cooperation, trust, motivating and supporting employee innovation becomes particularly important (Juhro et al., 2019; Mubarak, Petraite, 2020).

Traditional approaches to leadership are the foundation on which modern management concepts in Industry 4.0 are based. The literature distinguishes several basic leadership styles that are still applicable, although their role is constantly evolving.

Autocratic Leadership

Autocratic leadership is characterized by the leader making decisions on his own, without consulting his team (Hoel et al., 2010; Erdem, 2021). It expects strict adherence to issued instructions and procedures. Employees have little freedom to express their opinions, and their role is mainly reduced to following orders (Jony et al., 2019). This style can be effective in crisis situations when quick decisions are needed (Makhdoom et al., 2021; Saadi et al., 2023). In the long run, it can lead to a decrease in motivation and commitment in the team (Abdullahi et al., 2020).

Participatory Leadership

Participative leadership involves actively involving the team in the decision-making process (Kezar, 2001, Damanik et al., 2021). The leader promotes cooperation and joint problem-solving, allowing employees to participate in decision-making (Ahn, Bessiere, 2022). This style fosters a sense of community and responsibility within the team, which can increase employee motivation and creativity (Prasetyo et al., 2021; Huang et al., 2022). Participative leadership is particularly effective in organizations where innovation and collaboration are key (Lythreitis et al., 2022; Mata et al., 2023).

Democratic Leadership

Democratic leadership is based on including team members in the decision-making process (Fakhri et al., 2021). Decisions are made based on employees' opinions and input, which fosters participation and cooperation (Adobor, 2020; Setiawan et al., 2021). A democratic leader not only listens to his employees, but actively encourages them to offer ideas and suggestions (Haryanto et al., 2022). This leadership style builds commitment and supports team development (Hilton et al., 2021). The time-consuming nature of this style may make it unsuitable for organizations that require quick action (Fakhri et al., 2021).

Transformational Leadership

Transformational leadership is a style in which a leader inspires and motivates a team to achieve higher goals, often beyond current needs and expectations (Bojovic, Jovanovic, 2020, Tongkachok et al., 2022). Transformational leaders strive to make changes that have a long-term impact on the organization, as well as develop the potential of individual team members (Usman, 2020). With their vision and commitment, transformational leaders often build strong relationships with their team, leading to higher motivation and innovation (Afsar, Umrani, 2020; Shafi et al., 2020).

Transactional Leadership

Transactional leadership focuses on the exchange of rewards and consequences for performance (Mahdinezhad et al., 2013). The leader clearly defines the goals to be achieved by the team and then rewards employees for achieving them or applies consequences for failure (Brahim et al., 2015). This style is particularly effective in situations where work is clearly defined and results must be measurable (Laohavichien et al., 2009; Aga, 2016). Transactional leadership can limit employee creativity and autonomy (Wei, Yuan, 2010; Ma, Jiang, 2018).

Laissez-faire Leadership

Laissez-faire leadership, also known as the “free hand” style, is characterized by minimal intervention by the leader in the team's activities (Salas, 2020). Employees have a great deal of freedom in making decisions and carrying out tasks (Lawrence, 2000, Ali, Ullah, 2023). The leader intervenes only when absolutely necessary. This style can be effective in teams composed of highly skilled professionals who do not need supervision (Chaudhry, Javed, 2022). However, the lack of an active leadership role can lead to chaos or a decrease in efficiency in situations that require more coordination (Skogstad et al., 2007; Eğriboyun, 2023).

Charismatic Leadership

Charismatic leadership is based on the strong personality of a leader who can inspire and mobilize a team through his charisma (Wisniewska, 2021). Such a leader often builds a strong emotional bond with employees, which can lead to high levels of loyalty and commitment (Babcock-Roberson, Strickland, 2010, Xenikou, 2014). The team is willing to follow the leader due to his vision and ability to inspire enthusiasm (Conger, 2011). Nevertheless, there is a risk that the effectiveness of charismatic leadership may depend mainly on the person of the leader, rather than on stable organizational structures.

Servant Leadership

Servant leadership focuses on meeting the needs of the team and supporting its members in reaching their full potential (Jackson, 2008; Hanse et al., 2016). A servant leader puts the well-being of the team above his or her own interests, nurturing the development of employees and helping them overcome difficulties (Jit et al., 2017). This leadership style is conducive to building strong, committed teams based on trust (Wdowiak, 2022). Servant leadership is particularly effective in organizations where interpersonal relationships play a key role (Rai, Prakash, 2012; Gotsis, Grimaldi, 2016).

Situational Leadership

Situational leadership implies that the leader adapts his management style to the specific circumstances and individual needs of team members (Kaitonen, 2016). Depending on the level of competence and commitment of employees, a leader may use a more authoritarian or more democratic management style (Bhargavi, Yaseen, 2016; Smith et al., 2018). Situational leadership requires a high degree of flexibility and the ability to assess current conditions in order to match the management style to the situation (Rajbhandari et al., 2014). In this way, the leader can maximize the effectiveness of the team by responding to changing circumstances.

Methods

In the Delphi survey, 33 people participated in the first round. On the basis of a self-assessment questionnaire from this round, based on the competence coefficient (K_k), which is the arithmetic average of the familiarity coefficient (K_z) and the argumentation coefficient (K_a), 26 experts were selected - 13 from industry (working in organizations) and 13 representatives of science - who scored $K_z \geq 0.5$ (Męczyńska, 2006). The participants in the survey were selected using the recommendation method, and the final selection was based on certain coefficients.

The purpose of the study is to assess the correlation between preferences for different leadership styles under Industry 4.0 conditions in groups of respondents from industry and science. The analysis aims to compare the extent to which preferences for one leadership style in one group are correlated with evaluations of other styles in the same group, and then contrast these patterns with the results of the other group, in order to identify similarities and differences between groups in leadership style preferences.

In the survey, respondents were asked to rate the extent to which each leadership style fit the requirements and context of Industry 4.0. Ratings were made on a five-point Likert scale, with 1 representing the least fit and 5 the greatest. The scale provided detailed insight into both the industrial and scientific group's preferences for different leadership styles, allowing them to compare their opinions in the context of the modern requirements of organizations operating in an Industry 4.0 environment.

Results

Table 1 shows the results in detail on how different leadership styles are perceived to provide support for organizational maturity in Industry 4.0. For each leadership style, the average score, standard deviation, and median are considered in order to find out the degree to which various forms of leadership are perceived to mean greater growth and adaptation in an ever-evolving industrial context.

Table 1.

The assessment of leadership styles level of supporting organizational maturity in the context of Industry 4.0

Management styles	Average	Standard Deviation	Median
Autocratic	2.42	1.21	2
Participative	4.31	0.55	4
Democratic	3.88	1.14	4
Transformational	4.15	0.83	4
Transactional	3.23	1.27	3
Laissez-faire	2.77	1.18	3
Charismatic	3.50	0.99	4
Servant	2.85	1.01	3
Situational	3.73	1.04	4

Source: Own elaboration.

The autocratic leadership style received a low average score of 2.42 with a high standard deviation of 1.21. In general, the median of 2 indicates that most of the respondents perceive autocratic leadership as less effective for supporting organizational maturity, as often required by the context of Industry 4.0: flexibility, innovation, and collaboration. The high SD in response represents high variability, which basically suggests that perceptions of autocratic

leadership are highly variable across respondents, with some finding the style less appropriate and others seeing value in certain situations.

Participative leadership is one of the best evaluated styles; the mean score provided by the sample is 4.31. The very low standard deviation of 0.55 reflects a very strong agreement among the participants. Additionally, the median, which is 4, expresses great and deep consensus on the effectiveness of participative leadership in supporting organizational maturity. This style of leadership is therefore oriented toward involvement and collaboration that will fit well into the principles of Industry 4.0 with the requirements of decentralizing decisions and employee empowerment that will help in innovativeness and agility.

Concerning the average score for democratic leadership at 3.88 and the standard deviation at 1.14, a medium of 4 recorded that this style, where equal participation and full input from team members is encouraged, was supportive of organizational maturity, although there is a bit more dispersion in the responses than for participative leadership. This could imply divergent visions on the balance between decision-making efficiency and the need for inclusiveness in Industry 4.0.

Similarly, transformational leadership is regarded as very supportive of organizational maturity, with an average of 4.15 and a standard deviation of 0.83. The median score, with a value of 4, strengthens the assertion that the leadership style of transformational leaders-who inspire, influence, and motivate through vision and change-can handle organizations through the complexities of Industry 4.0. It can, therefore, be said that this leadership type especially provides value during this industrial context by assuring innovation and adaptation to changes.

From this, the transactional leadership style with an average of 3.23 and a standard deviation of 1.27 is one of the more moderate standings. The median score of 3 suggests that this style, focused on clear structures and rewards, is somewhat supportive but perhaps not as highly valued in the context of Industry 4.0 as more flexible and collaborative styles. The higher standard deviation here reflects difference of opinion, perhaps because the transactional approaches may be more or less applicable depending on the specific organizational needs.

Meanwhile, laissez-faire leadership is treated as not very supportive of organizational maturity, too, with an average of 2.77 and a standard deviation of 1.18. The median score of 3 indicates that some may find the hands-off approach of laissez-faire leadership somewhat helpful; however, as a general trend, it does not support the dynamism and the innovation-oriented context of Industry 4.0, where often quite active and engaging leadership is needed.

The charismatic leadership, therefore, only reaches an average of 3.50 with a standard deviation of 0.99, showing a moderate support for organizational maturity whose median score is 4. It can, therefore, be perceived that charismatic leaders are moderately effective in inspiring and influencing through personal charm and vision; however, this can have an impact which might be less consistently recognized as opposed to structural styles such as transformational or democratic.

The last one refers to servant leadership, putting great attention on the issues of serving and developing employees. Its average score is 2.85, with a standard deviation of 1.01. The median at a score of 3 indicates that some respondents believe that some value of servant leadership does exist; servants in general, however, are seen as less effective leaders as compared to the rest of the styles within the Industry 4.0 framework. This perhaps is because of increased demands on high-velocity innovation and critical strategic decisions which may or often conflict with the Servant leadership philosophy.

Situational leadership, which also would finally adapt to whatever the situation or the team requires, has an average of 3.73 and a standard deviation of 1.04. A median score of 4 shows that this adaptive style of leadership is found helpful to support organizational maturity on the transforming dimensions of Industry 4.0. Probably, the ability to adapt various leadership approaches according to the prevailing conditions is seen as one of the most valued assets in treading through the labyrinth of modern industrial environments.

Table 2 presents the result of an assessment that captures the opinion of two different groups, scientists and representatives of industry, with regard to the level of various leadership styles in efficiently supporting organizational maturity in the context of Industry 4.0. Such comparative analysis enables one to draw conclusions about the perception of two groups in regard to different managerial approaches and their contribution to organizational growth and adaptation.

Table 2.

The assessment of leadership styles level of supporting organizational maturity in the context of Industry 4.0 – division between scientists and industry representatives

Management styles	Scientists	Industry representatives
Autocratic	2.38	2.46
Participative	4.31	4.31
Democratic	3.54	4.23
Transformational	4.31	4.00
Transactional	2.85	3.62
Laissez-faire	2.85	2.69
Charismatic	3.77	3.23
Servant	3.00	2.69
Situational	3.77	3.69

Source: Own elaboration.

Both groups have a similar mean score regarding participative leadership, which is 4.31; this suggests that there is strong agreement in the belief of this type of leadership being particularly serving the interest of organizational maturity. Convergence of views from scientists and industrial representatives would suggest that by all concerned, collaboration and employee involvement in decision-making is seen as critical drivers in treading the challenges thrown up by Industry 4.0. This high agreement rate attests to participative leadership as a facilitator of innovation and adaptability within organizations.

Democratic leadership is viewed differently by the two groups. The average for scientists in scoring democratic leadership was 3.54, while for industry representatives, this average was higher at 4.23. From this divergence, it can be said that representatives from industry consider democratic leadership much more valuable for organizational maturity than scientists do. The orientation to teams for input and consensus building may be more relevant to the industrial representatives, who are bound to feel in actual operation the effects of these leadership styles.

Transformational leadership is similarly rated by the two groups: 4.31 average for scientists and 4.00 for the industry representatives. Even though both groups agree on the superiority of transformational leadership for motivating and encouraging employees, this small difference in ratings would indicate that scientists see the impact as being somewhat stronger. Based on this result, it is easier to interpret that scientists might appreciate the long-term perspective and drive for innovation typically associated with transformational leadership more than their industry counterparts.

Transactional leadership receives contrasting ratings from the two groups. Where scientists on average rated this style 2.85, indicating only a very low level of support, industry representatives rated this style at an average of 3.62, which is significantly higher. One may infer from this that the representatives value the structured and performance-oriented elements of transactional leadership, in keeping with practical realities of managing workforce productivity to achieve results. The scientists may view transactional leadership as less valid for developing organizational maturity and may, instead support an approach that emphasizes innovation and teamwork.

The rating of analysis of *laissez-faire* leadership is relatively low for both groups, where the average for scientists is 2.85 and that of industry representatives stands at 2.69. This would mean a general feeling by the respondents that the *laissez-faire* kind of leadership does not considerably help in achieving organizational maturity. It should be expected by both groups to realize that the hands-off approach probably would not provide sufficient guidance and support for teams to deliver their full potential in an industrially dynamic environment.

Another difference is charismatic leadership, which obtained an average rating of 3.77 among scientists, as opposed to the rating of industry representatives at 3.23. This may imply that while scientists could attach a higher value inspirationally and motivational-wise to charismatic leaders, the industry representatives place more importance on other styles of leadership as proving more effective in a real-life context.

Servant leadership received 3.00 by scientists and 2.69 by industry representatives, the lowest scores from both groups. This already tells us that, though serving and developing the team members is important, neither group perceives servant leadership as effective in building organizational maturity for Industry 4.0. These lower ratings probably signal a preference for more directive or transformational approaches better-suited to the fast pace and innovation demands placed on today's organizations.

Situational leadership is also viewed similarly between the two groups, as scientists graded it 3.77, while industry representatives graded it at 3.69. This serves to suggest that a shared understanding is in place: namely, that the ability to adapt the style of leadership depending on the particular context carries value. The small difference in scores will testify that both groups appreciate the flexibility carried within situational leadership and acknowledge its relevance in addressing the diverse challenges at hand brought about by Industry 4.0.

The Mann-Whitney U test was conducted for scientists and industry representatives in order to define whether there is any statistically significant difference between their judgments with regard to the various types of leadership styles in terms of effectiveness for organizational maturity in view of Industry 4.0. The Mann-Whitney U test is a non-parametric test that is used to compare differences between two independent groups where a dependent variable is either ordinal or continuous but not normally distributed.

The significant differences detected from this analysis are only for the democratic leadership style. The implication of the p-value, 0.0415, at the significance level of $\alpha = 0.05$ is that there is a difference in the perceptions of scientists and those of industry representatives on democratic leadership. In this case, democratic leadership was rated by scientists at an average of 3.54, while for industry representatives, it received an average score of 4.23. This discrepancy might suggest that representatives of industry consider democratic leadership to be more helpful for organizational maturity than representatives of science do.

Table 3: Correlation coefficients between the leadership styles as assessed by scientists and industry representatives. The table searches for relations between the assessment of different management styles by the two groups in supporting organizational maturity in the context of Industry 4.0. These correlation coefficients lie between -1 and 1. A value close to -1 indicates a perfect negative correlation; that is, there is a perfect negative linear relation between the variables. A value close to 1 indicates that there is a perfect positive correlation between the variables. A value near 0 suggests no or negligible relationship between the two variables.

Table 3.

The correlations of results between scientists and industry representatives

Management styles (scientifics)	Management styles (industry representatives)								
	Autocratic	Participative	Democratic	Transformational	Transactional	Laissez-faire	Charismatic	Servant	Situational
Autocratic	-0.458	-0.503	-0.202	0.453	-0.414	-0.029	0.557	-0.201	0.142
Participative	-0.116	-0.064	0.171	0.321	-0.358	0.192	0.011	-0.562	0.309
Democratic	-0.247	-0.722	-0.516	0.205	-0.205	-0.456	0.083	0.186	-0.109
Transformational	0.432	-0.064	-0.147	-0.321	-0.213	-0.120	0.151	0.453	0.032
Transactional	-0.107	-0.556	-0.568	0.361	-0.533	0.198	0.551	-0.199	-0.240
Laissez-faire	-0.312	-0.452	0.027	-0.241	0.176	0.140	0.288	0.029	0.020

Cont. table 3.

Charismatic	0.152	0.204	0.343	-0.258	0.215	0.511	0.078	-0.150	-0.103
Servant	0.057	-0.229	-0.264	-0.134	-0.060	0.000	0.292	0.169	-0.289
Situational	-0.365	-0.489	-0.303	0.093	-0.181	-0.354	-0.025	-0.108	-0.234

Source: Own elaboration.

Starting with autocratic leadership, the highest negative correlation was to participative leadership with a value of -0.503, while democratic leadership had -0.458 among scientists. It appears that as the assessment of autocratic leadership by scientists goes up, then their assessments for the participative and democratic leading styles go down. Therefore, it would seem from these findings that scientists perceive the more authoritarian methods to be in conflict with collaborative and democratic ways, which most often are considered indispensable on the path to innovation and adaptability toward Industry 4.0. In contrast, it is positively correlated with transformational leadership, 0.453, suggesting that those scientists who rate transformational leadership highly also view autocratic leadership in positive terms. It would follow that some scientists may view a combination of directive and visionary approaches as being effective under certain circumstances.

As for the participative style, the most salient relationship, democratic leadership presents a negative value of -0.722, that is a very strong negative correlation with this leadership style. This would mean that the scientists who hold a positive view of participative leadership are less likely to like democratic approaches, possibly as a result of a preference for direct involvement rather than consensus-building. The association with situational leadership is 0.309, indicating a moderate positive correlation and that the scientists partly view participative leadership in relation to the flexibility and adaptability of situational leadership.

Democratic leadership stands in relation to other correlations, most notably the negative association of -0.516 with transformational leadership and the positive of 0.343 with charismatic leadership. This relation to negative transformational leadership could hint that those oriented toward democratic processes might view the transformational style less favorably, perhaps too top-down or visionary compared to their preference for inclusive decision making. This positive correlation with charismatic leadership may suggest that scientists view something positive about inspirational and engaging leadership within the team but still maintaining democratic processes.

Transformational leadership correlates positively with autocratic leadership at 0.432 and negatively with transactional leadership at -0.568. Those rating transformational leadership highly would view autocratic leadership favorably, perhaps perceiving that a blend of inspiration and direction offers something useful. The strong negative correlation with transactional leadership may indicate that scientists valuing transformational approaches perceive transactional methods, focusing on structured reward and punishment systems as less effective to support organizational maturity.

In the case of transactional leadership, relations are much more complex. Strong negative relations exist with democratic leadership (-0.568) and participative leadership (-0.556); this means that people who believe in transactional leadership do not support collaborative or inclusive approaches. This may mean that the transactional approach is perceived as not fitting into the demands of flexibility and participation that organizations raise for Industry 4.0.

The laissez-faire leadership style only shows low correlations overall, which might propose that this style of leadership does not greatly influence other styles of leadership. It has a very slight positive correlation of 0.288 with charismatic leadership, which might be indicative that within the population sampled, there is a belief that a hands-off approach can balance out inspiring leadership in a particular context.

Charismatic leadership normally correlates positively with the other styles of leadership, in particular transformational leadership 0.511. This might suggest that the scientists who prefer charismatic leadership also like transformational styles because they are inspirational and vision-oriented. The negative correlation with situational leadership -0.150 would suggest that the scientists view this as somewhat of a disconnect between these two styles, possibly in the respect that charismatic leadership might not be as adaptable to specific contexts when compared to situational leadership.

In the servant leadership style, we generally notice a weak linkage with other styles, with a slight positive correlation of 0.292, which may indicate that scientists view servant leadership compatible with the inspirational qualities of charismatic leaders. On the other hand, the negative correlation with participative leadership is at -0.229, which means that those who support servant leadership do not pay attention to direct involvement and collaboration in their decisions, reflecting potential divergence in leadership priorities.

In particular, situational leadership is negatively related to autocratic, -0.365; participative, -0.489; and laissez-faire leadership, -0.354. That would suggest that scientists feel that situational leadership somewhat inhibits these respective styles because true leadership must be adapted to the situation and context.

From Table 3, it is clear that there is something really interesting in the evaluation of various leadership styles by scientists and representatives of industry; this proves how each group perceived which management approach is effective in reaching organizational maturity in the context of Industry 4.0.

The first important observation to be made is the clear orientation of the scientists toward participative and transformational styles of leadership, which shows a strong positive correlation between the different measures. This disposition reflects the assumption that collaboration and transformational leadership are required to generate innovation and adaptability. Industry representatives, by contrast, are more tolerant of transactional leadership on dimensions of structure and performance management, which can better meet practical needs than those of academic environments. This strong negative correlation might suggest that the scientists are somewhat skeptical of the democratic approach, believing that a choice has to be

made between direct involvement and consensus-building, whereas the industry representatives do not display such polarity in their ratings.

Another interesting divergence is the correlation between autocratic and transformational leadership. There is a positive correlation among these styles from the scientists' standpoint, which may indicate that they consider an integration of the authoritative direction and visionary inspiration as something worthwhile. Industry representatives do not demonstrate the same tendency, perhaps indicating a more pragmatic perspective that would keep the two styles apart based on their situational applicability. This deviation suggests that scientists might want to combine these styles more, while business associates keep them separate-but maybe a function of the particular contextual environment.

Transactional leadership scores different ratings between the two groups; again much lower ratings from scientists than business associates. The high negative correlations with both participative and democratic styles indicate that scientists are incredulous about transactional methods because these seem deleterious for creating an innovative atmosphere. Industry representatives, however seem to have taken pleasure in transactional leadership since their scores were more encouraging of practical orientation appreciating the need for performance-based management required in their work environments. That says a lot about greater acceptance of structured ways among industry representatives- their focus on measurable outcomes.

The second important difference is related to the correlation of laissez-faire leadership. Scientists are more skeptical of this style, as can be read from the generally low correlations across the different styles, suggesting it holds little if any value in promoting organizational maturity. By contrast, representatives of industry treat the laissez-faire leadership style with a bit more leniency, yet their ratings still remain low. This could be an indication that representatives of industry see value in a hands-off approach under specific circumstances, especially in environments that require creativity and innovation.

About charismatic leadership, correlations also show a difference in perception. Scientists have more favorable views over charismatic leadership with higher positive correlations into transformational leadership. This would mean that scientists are seeing the inspirational qualities of charismatic leaders and view them as compatible with the visionary dimension of transformational leadership. These are in contrast to the charismatic leadership of industry representatives, which has a weaker correlation and therefore might not be as cherished by them as it is by their scientific counterparts. This difference in pattern suggests that while scientists are drawn to leaders who can inspire and motivate, industry representatives may place more emphasis on leadership styles that yield tangible results.

The situational leadership analysis yields that scientists view this type of leadership as equally adaptable and relevant within various contexts; hence, it strongly negatively correlates with autocratic and participative leadership. As to the industry representatives, all the signs for correlations are weaker; therefore, they tend to be more balanced in representing the

applicability of situational leadership in diverse scenarios. This would mean that scientists could stress flexibility and context awareness more, while the representatives of industry could hold on to the more traditional view in which the variety of styles signals the variety of organization-specific needs.

Factor analysis for leadership styles examined was conducted. In factor analysis, variables are grouped into factors by the method. Normalized Varimax rotation was applied. The Kaiser-Meyer-Olkin test of the correlation matrix for adequacy gives a value of 0.77, hence justifying the factor analysis to be applied in the case under consideration. A KMO value higher than 0.7 is commonly regarded as acceptable, and so this result supports the validity of the analysis. The Kaiser criterion suggests retaining 4 factors whose eigenvalues are greater than 1. By the scree plot criterion of Cattell, it also retains 4 factors. Table 4 Factor analysis output After running factor analysis, the exact picture of how different dimensions of management styles group into four factors, or ways, which account for the total variation in data by 72%. Each factor represents another dimension of management styles, as can be seen from the factor loadings in Table 2. Normalized Varimax Rotation was used for identifying the factors because this rotation method maximizes the variance explained by each factor and keeps orthogonality or uncorrelated factors. In general, 72% of the variance is explained by the identified factors. This will mean that these factors are representative; they give a wide variety of the underlying structure of the management styles under study.

Table 4.
The loadings of factors

Management styles	Factor 1	Factor 2	Factor 3	Factor 4
Autocratic	0.183	0.141	-0.285	0.765
Participative	0.609	0.034	-0.360	0.294
Democratic	0.117	0.871	-0.253	0.114
Transformational	0.001	0.022	0.821	-0.075
Transactional	-0.029	0.468	0.642	0.128
Laissez-faire	0.722	0.236	-0.341	0.157
Charismatic	0.572	0.474	0.152	0.210
Servant	-0.107	0.006	0.067	0.838
Situational	0.046	0.752	0.452	0.103
Explained value	1.281	2.053	1.709	1.487

Source: Own elaboration.

Factor 1 - Collaborative and Empowerment Oriented Leadership. Factor 1 is characterized by high loadings on the Laissez-faire (0.722), Charismatic (0.572), and Participative (0.609) styles of leadership. It would, therefore, suggest that the kind of leadership represented by this factor is flexible, loosely structured, and empowering to team members. High-scores on this factor enact behaviors that facilitate independence among followers, the prevailing climate is one where there is more freedom for the individual and more democratization of decision-making. This style of leadership has been characterized as a collaborative form wherein leaders are commanding through charisma and ideas, not fiat. Thus, positive loadings of Participative and Charismatic leadership styles develop this idea that this factor reflects those kinds of leaders

who inspire their teams and motivate them by allowing a certain degree of personal initiative and shared responsibility.

The second factor is Structured and Democratic Leadership. The factor structure indicates that Factor 2 is particularly related to the Democratic style of leadership with a loading of 0.871, and secondarily, the Situational, 0.752, and Transactional, 0.468 styles of leadership. This structure of the factor suggests that leaders classified under this factor make decisions in a structured manner and at the same time ensure participation and adaptability. The high loading on Democratic leadership, which is 0.871, indicates that the leader derives input from the members of the group and arrives at consensus. A high association with Situational leadership, 0.752, signifies that leaders change their style to suit the demands of the situation and capabilities of the team. Besides, Transactional leadership, with a loading of 0.468, indicates the leader's preference for clarity in structure, reward, and performance management. Overall, Factor 2 stands for a leadership style that is democratic in its processes and flexible enough to change with evolving contexts.

Factor 3-Performance-oriented and Transformational Leadership. This factor is primarily defined by high loadings from Transformational (0.821) and Transactional (0.642) leadership styles. This factor has been characterized by leaders who accomplish high performance through motivation, vision, and a clear system of rewards. The Transformational leaders, with a loading of 0.821, inspire their teams by giving them a sense of direction and infusing innovation and change into the workplace. Meanwhile, the positive loading into Transactional leadership, 0.642, would suggest that while these leaders may inspire, there is also an emphasis on concrete goals and outcomes, rewarding success, holding individuals accountable for results. In this case, the combination of transformational and transactional styles here shows a strong focus on driving performance and organizational change by means of both visionary leadership and structured incentives.

Factor 4 - Authoritarian and Supportive Leadership. The leadership styles of Autocratic and Servant are significantly loaded into Factor 4, with 0.765 and 0.838, respectively. Curiously, though those two styles contrast in concept, the emergence here in this single factor does indicate a sort of leadership which is both authoritarian in making decisions and supportive in its practice. But these findings also indicate that high scorers on this factor may strongly control and make decisions unilaterally-as evidenced by the loading of 0.765 from the Autocratic style-yet still demonstrate servant leadership, focusing on their followers' needs and development, as indicated by a loading of 0.838 with Servant. Such leadership can be realized in contexts where the leaders hold authority but are deeply concerned with the well-being and personal growth of their subordinates.

Discussion

The results of the study indicate that participative and transformational leadership styles are key to fostering organizational maturity in Industry 4.0. The participative style received the highest score (mean 4.31), suggesting that employee involvement in decision-making is not only desirable, but necessary. Similar findings can be found in a study by Oberer and Erkollar (2018), who noted that leaders in the era of Industry 4.0 must promote collaboration and decentralization of decisions in order to effectively manage high-tech organizations. The research results described in this article are consistent with their findings, pointing to the important role of participatory approaches in adapting to changing technological conditions.

Transformational style, which received an average score of 4.31 in our survey, also plays an important role in managing in an Industry 4.0 environment. As Dubey, Gunasekaran and Childe (2022) note, transformational leadership is essential in organizations that must constantly evolve and adapt to new technologies such as Big Data and artificial intelligence. Transformational leaders motivate their teams to embrace innovation and adaptation, which is consistent with our findings.

In this study, the democratic style scored lower (mean of 3.54) than the participative style, which may suggest that while promoting equal participation in decision-making is important, there is a diversity of opinion about its effectiveness in a rapidly changing technological environment. A study by Behie, Alizadeh and Gillani (2023) showed a similar trend, indicating that democratic leadership, while promoting cooperation, may be less effective in situations that require quick decision-making. The results reflect these findings, showing that while democratic leadership is valued, its effectiveness may be limited in the context of rapid technological change.

Interestingly, the transactional style received an average score of 2.85, which is consistent with the findings of Dubey, et al. (2022), who emphasize that transactional leadership, which focuses on explicitly setting expectations and rewarding performance, is less effective in an Industry 4.0 environment where innovation and flexibility are key. Our results suggest that while this style can be effective in structures that require close supervision, it is seen as less appropriate in an environment that promotes innovation and agility.

The low autocratic style scores (mean of 2.38) in our study confirm previous research by Oberer and Erkollar (2018), who found that an authoritarian approach is not responsive to the needs of modern technology organizations. The high standard deviation (1.21) in our sample suggests that while some leaders may prefer an autocratic approach in specific situations, it is generally considered inappropriate in settings that require innovation and flexibility.

Conclusion

Research on leadership styles in the context of Industry 4.0 indicates that participative and transformational styles are key to fostering organizational maturity. The participative style, with its ability to promote employee involvement and decentralize decisions, is particularly effective in an environment that demands innovation and flexibility. Transformational leadership, which inspires teams to achieve long-term goals and adapt to rapidly changing technologies, also plays a key role in managing organizations operating in Industry 4.0.

On the other hand, styles such as autocratic and transactional are less effective in the context of Industry 4.0, where flexibility, innovation and collaboration are fundamental. While autocratic leadership can be useful in specific situations requiring quick decisions, its long-term effectiveness in technology organizations is limited. The transactional style, focused on clear expectations and rewards for performance, also shows limited usefulness in an environment requiring rapid adaptation to changing market conditions.

Participative leadership, according to the research, is the best, with the average of 4.31 showing the situation where employees are engaged in decision-making processes Q1. Through this form of leadership, it promotes decentralization and collaborativeness. These are essential ingredients for organizations in fast-changing technological environments. Innovation and flexibility thrive through participative leadership whereby employees are integrated into making major decisions. This decision is very crucial in treading the complexities occasioned by automation and digital transformation that characterize Industry 4.0.

Meanwhile, transformational leadership also has a very important contribution, with 4.15 in this research, and is noted for engaging in inspiring teams for long-term-oriented vision. In the Industry 4.0 era, when business models are being disrupted by emerging technologies like artificial intelligence, Big Data, and autonomous systems, transformational leadership would permit employees to be more open towards change and innovation. This leadership enables the continuous learning and adaptation necessary to ensure the organization remains competitive and responsive to emerging digital demands.

Finally, with regard to Q2, there are noted differences between the academia and industry representatives in the perceived effectiveness of various leadership styles in supporting organizational maturity in Industry 4.0. In particular, democratic leadership is highly divergent between the groups. The respective rating for democratic leadership is 4.23 for industry representatives on an average, while the scientists have provided an average score of 3.54. What this may further indicate is that in an industrial environment where things are fast-moving and practical, there is a greater belief in collaboration and incorporation of employee input through consensus. The latter may view it as less productive in their context of rapid technological changes, which will call for speedier and more centralized decisions. Another important difference deals with the perception of transactional leadership as viewed by the two

groups: industry representatives with 3.62 versus 2.85 for the scientists. This innately indicates that industry professionals will appreciate the transactional leadership structure for its clarity and performance-based rewards, possibly quite critical toward the meeting of immediate operational goals. Contrarily, scientists will view this style as less conducive to fostering innovation and flexibility required in Industry 4.0; hence, they would favor other leadership approaches that emphasize long-term development and adaptability. The observed differences bring to light the different needs and priorities of academia versus industry in terms of leadership in the context of digital transformation.

Among such styles, those that can give full significance to adaptability, collaboration, and innovation are the most wanted from the point of view of a fast-changing technological environment. In this respect, participative leadership works especially well, for which an average score of 4.31 was registered within the study. This kind of style allows employees to participate in decision-making, promoting a culture of shared responsibility and collaboration. These are attributes particularly in demand within an environment where technological progress happens point-blank, with a requirement for the ability of rapid adaptation to new toolsets and processes. Participative leadership instances, with their bottom-up approach to decision-making, allow organizations to be even more responsive to trends and emerging challenges in Industry 4.0.

Another highly valued leadership style in this environment is transformational leadership, which received an average score of 4.15. The leaders practicing transformational leadership let their teams be inspired and motivated to pursue innovation and change, something quite relevant to the industries where the introduction of AI, Big Data, and automation will continue to reshape business. Transformational leadership encourages a forward-thinking mindset that promotes creativity and continuous learning. It is ideal for leaders to take into action in leading the organizations through complexities and uncertainties at a digitized and automated world.

From the factor analysis in the study, the leadership styles-including participative, charismatic, and laissez-faire-which clustered into "Collaborative and Empowerment-Oriented Leadership" are P4. The participative leadership style focuses on employee involvement and making decisions, while charismatic leadership and laissez-faire leadership focus on employee empowerment and independence with factor loadings of 0.572 and 0.722, respectively. Put together, the styles mentioned imply that Industry 4.0 leadership should be about empowering workers, encouraging innovation, and giving them latitude of autonomy for self-alignment with a rapidly changing environment.

Another significant grouping from the factor analysis involves transformational and transactional leadership, which are combined into "Performance-Oriented Leadership". Transformational leadership has a strong loading of 0.821, since it inspires and motivates teams toward innovation and change, while transactional leadership comes in at 0.642, with a focus on clear goals and performance-based rewards. Having both approaches to the methodology combined into one style suggests that Industry 4.0 leaders need to somehow balance visionary,

imaginative leadership with a practical, results-oriented approach to management. This makes it possible for organizations to be innovative, while drawing on clear structures and accountability are an important ingredient in today's dynamic and fast-evolving technological landscape.

In general, modern industrial organizations, in order to succeed in Industry 4.0, should strive for leadership based on collaboration, engagement and inspiring teams.

The article adds significant value by providing new empirical data on preferred leadership styles in the context of Industry 4.0, which allows for a better understanding of the role of leaders in technology organizations. Of particular value is the demonstration of how participative and transformational styles foster innovation and adaptation in changing environments, which has direct application to management practice. These findings can be used by leaders of industrial organizations to adjust their leadership strategies, enabling more effective management of technology teams and projects.

Limitations of this study include a relatively small sample of respondents, which may affect the ability to generalize the results to a broader population. In addition, the research focused primarily on the context of Industry 4.0, which may limit its applicability to other sectors. In addition, using only quantitative research methods may not fully capture the complexity of leadership styles, so future research could also incorporate qualitative approaches to get a more complete view.

Despite these limitations, the article provides a solid foundation for further research on the role of leadership in the era of digital transformation, offering concrete conclusions that can be useful in both management theory and practice

References

1. Abdullahi, A.Z., Anarfo, E.B., Anyigba, H. (2020). The impact of leadership style on organizational citizenship behavior: does leaders' emotional intelligence play a moderating role? *Journal of management development*, 39(9/10), 963-987.
2. Abercrombie, N., Hill, S., Turner, B.S. (1988). *The Penguin dictionary of sociology*. Penguin Books.
3. Adair, J. (2009). *Effective Leadership: How to Be a Successful Leader*. Pan Macmillan.
4. Adobor, H. (2020). Open strategy: role of organizational democracy. *Journal of Strategy and Management*, 13(2), 310-331.
5. Afsar, B., Umrani, W.A. (2020). Transformational leadership and innovative work behavior: The role of motivation to learn, task complexity and innovation climate. *European Journal of Innovation Management*, 23(3), 402-428.

6. Aga, D.A. (2016). Transactional leadership and project success: the moderating role of goal clarity. *Procedia Computer Science*, 100, 517-525.
7. Ahn, Y.J., Bessiere, J. (2022). The role of participative leadership in empowerment and resident participation. *Sustainability*, 14(18), 11223.
8. Ali, M., Ullah, M.S. (2023). Role of laissez-faire leadership in talent management: Evidence from the pharmaceutical industry of Bangladesh. *Heliyon*, 9(6).
9. Babcock-Roberson, M.E., Strickland, O.J. (2010). The relationship between charismatic leadership, work engagement, and organizational citizenship behaviors. *The Journal of psychology*, 144(3), 313-326.
10. Behie, S.W., Pasman, H.J., Khan, F.I., Shell, K., Alarfaj, A., El-Kady, A.H., Hernandez, M. (2023). Leadership 4.0: The changing landscape of industry management in the smart digital era. *Process Safety And Environmental Protection*, 172, 317-328.
11. Bhargavi, S., Yaseen, A. (2016). Leadership styles and organizational performance. *Strategic Management Quarterly*, 4(1), 87-117.
12. Bogdanor, V. (ed.) (1993). *The Blackwell Encyclopedia of Political Science*. Oxford, Cambridge: Blackwell Publishers.
13. Bojovic, I., Jovanovic, S.S. (2020). Transformational leadership and psychological needs of employees. *Technium Soc. Sci. J.*, 7, 226.
14. Brahim, A.B., Ridic, O., Jukic, T. (2015). The effect of transactional leadership on employees performance-case study of 5 Algerian banking institutions. *Economic Review: Journal of Economics and Business*, 13(2), 7-20.
15. Canbay, K., Akman, G. (2023). Investigating changes of total quality management principles in the context of Industry 4.0: Viewpoint from an emerging economy. *Technological Forecasting and Social Change*, 189, 122358.
16. Chaudhry, A.Q., Javed, H. (2012). Impact of transactional and laissez faire leadership style on motivation. *International Journal of Business and social science*, 3(7).
17. Conger, J.A. (2011). *Charismatic leadership*. The SAGE handbook of leadership, 86-102.
18. Damanik, S., Situmorang, B., Dewi, R. (2021). The Influence of Participatory Leadership, Quality Culture, and Job Satisfaction on Lecturer Organizational Commitment (Case Study of Universities in Indonesia). *Budapest International Research and Critics Institute-Journal (BIRCI-Journal)*, 4(1), 654-663.
19. Dubey, G., Gupta, R.K., Kumar, S., Kumar, M. (2022) Study of industry 4.0 pillars and their uses in increasing productivity and reducing logistics defects. *Materialstoday: Proceedings*, Vol. 63, 85-91.
20. Dubey, R., Gunasekaran, A., Childe, S.J., Blome, C., Papadopoulos, T. (2019). Big data and predictive analytics and manufacturing performance: integrating institutional theory, resource-based view and big data culture. *British Journal of Management*, 30(2), 341-361.

21. Eğriboyun, D. (2023). Mediating Role of the Laissez-faire Leadership Practices between Transformational Leadership and Job Satisfaction. *Kastamonu Education Journal*, 31(4), 695-706.
22. Erboz, G. (2017). *How To Define Industry 4.0: Main Pillars Of Industry 4.0. Conference: Managerial trends in the development of enterprises in globalization era*. Slovak University of Agriculture in Nitra, 761-766.
23. Erdem, A.T. (2021). The mediating role of work alienation in the effect of democratic and autocratic leadership styles on counterproductive behaviors: A study in Ankara OSTİM industrial zone. *OPUS International Journal of Society Researches*, 17(34), 873-902.
24. Fakhri, M., Syarifuddin, S., Winarno, A., Nurnida, I., Hanum, S. (2021). Democratic leadership practice to construct clan organizational culture in family companies. *The Journal of Asian Finance, Economics and Business*, 8(1), 803-811.
25. Gleick, J. (1987). *Chaos: Making a New Science*. Viking Penguin Inc.
26. Gotsis, G., Grimani, K. (2016). The role of servant leadership in fostering inclusive organizations. *Journal of Management Development*, 35(8), 985-1010.
27. Gupta, K., Gupta, M.K. (Eds.) (2020). *Optimization of manufacturing processes*. Springer International Publishing.
28. Haleem, A., Javaid, M., Singh, R.P. (2024). Perspective of leadership 4.0 in the era of fourth industrial revolution: A comprehensive view. *Journal of Industrial Safety*, 100006.
29. Hanse, J.J., Harlin, U., Jarebrant, C., Ulin, K., Winkel, J. (2016). The impact of servant leadership dimensions on leader–member exchange among health care professionals. *Journal of Nursing Management*, 24(2), 228-234.
30. Haryanto, H., Suharman, H., Koeswayo, P.S., Umar, H. (2022). Enhancing Employee Engagement in Indonesian Logistics and Forwarders Industry: The Moderating Role of a Democratic Leadership Style. *Economies*, 10(11), 284.
31. Hilton, S.K., Arkorful, H., Martins, A. (2021). Democratic leadership and organizational performance: the moderating effect of contingent reward. *Management Research Review*, 44(7), 1042-1058.
32. Hoel, H., Glasø, L., Hetland, J., Cooper, C.L., Einarsen, S. (2010). Leadership styles as predictors of self-reported and observed workplace bullying. *British Journal of management*, 21(2), 453-468.
33. Huang, Z., Sindakis, S., Aggarwal, S., Thomas, L. (2022). The role of leadership in collective creativity and innovation: Examining academic research and development environments. *Frontiers in Psychology*, 13, 1060412.
34. Jackson, D. (2008). Servant leadership in nursing: a framework for developing sustainable research capacity in nursing. *Collegian*, 15(1), 27-33.
35. Jit, R., Sharma, C.S., Kawatra, M. (2017). Healing a broken spirit: Role of servant leadership. *Vikalpa*, 42(2), 80-94.

36. Jony, M.T.I., Alam, M.J., Amin, M.R., Jahangir, M. (2019). The impact of autocratic, democratic and laissez-faire leadership styles on the success of the organization: A study on the different popular restaurants of Mymensingh, Bangladesh. *Canadian Journal of Business and Information Studies*, 1(6), 28-38.
37. Juhro, S.M., Aulia, A.F., Aliandrina, D., Hadiwaluyo, D., Lavika, E. (2019). *The Role of Catalytic Collaboration in Leveraging Transformational Leadership Competencies to Generate Sustainable Innovation*.
38. Kaitonen, J. (2016). *Definition of situational leadership roles in a modern expert organization: the leadership style*.
39. Kezar, A. (2001). Investigating organizational fit in a participatory leadership environment. *Journal of Higher Education Policy and Management*, 23(1), 85-101.
40. Laohavichien, T., Fredendall, L.D., Cantrell, R.S. (2009). The effects of transformational and transactional leadership on quality improvement. *Quality Management Journal*, 16(2), 7-24.
41. Lawrence, E.T. (2000). *The relationship between, transformational, transactional, and laissez-faire leadership styles of the senior executives/department heads and their immediate subordinates' perceived satisfaction, extra effort, effectiveness, and organizational culture typology in the hospital setting*. Nova Southeastern University.
42. Lythreatis, S., El-Kassar, A.N., Smart, P., Ferraris, A. (2022). Participative leadership, ethical climate and responsible innovation perceptions: evidence from South Korea. *Asia Pacific Journal of Management*, 1-28.
43. Ma, X., Jiang, W. (2018). Transformational leadership, transactional leadership, and employee creativity in entrepreneurial firms. *The Journal of Applied Behavioral Science*, 54(3), 302-324.
44. Mahdinezhad, M., Bin Suandi, T., bin Silong, A.D., Omar, Z. B. (2013). Transformational, transactional leadership styles and job performance of academic leaders. *International Education Studies*, 6(11), 29-34.
45. Makhdoom, T.R., Shaikh, M.A., Baloch, M.N. (2021). Traditional Leadership Styles Influencing Employee Work Behaviors in Islamic Banks of Sindh, Pakistan. *Journal of Organizational Behavior Research*, 6(1), 46-58.
46. Mata, P.N., Mata, M.N., Martins, J. (2023). Does participative leadership promote employee innovative work behavior in IT organizations. *International Journal of Innovation and Technology Management*, 20(05), 2350027.
47. Męczyńska, A. (2006). *Wspomaganie procesów zarządzania w przedsiębiorstwie przemysłowym metodami heurystycznymi*. Zabrze.
48. Moore, B.V. (1927). The May conference on leadership. *Personnel Journal*.
49. Morris, R., Seeman, M. (1959). The Problem of Leadership: An Inter-Disciplinary Approach. *American Journal of Sociology*, no. 56.

50. Mubarak, M.F., Petraite, M. (2020). Industry 4.0 technologies, digital trust and technological orientation: What matters in open innovation? *Technological Forecasting and Social Change*, 161, 120332.
51. Oberer, B., Erkollar, A. (2018). Leadership 4.0: Digital leaders in the age of industry 4.0. *International Journal Of Organizational Leadership*.
52. Prasetyo, M.A.M., Bashori, B., Rahmi, A. (2021). The Adiwiyata Islamic Boarding School Management (A Study of Participatory Leadership Style). *AL-TA'LIM JOURNAL*, 8(2), 104-116.
53. Puhovichova, D., Jankelová, N. (2021). Leadership in Conditions of Industry 4.0. *SHS Web of Conferences*, Vol. 115. EDP Sciences, p. 03013.
54. Rai, R., Prakash, A. (2012). A relational perspective to knowledge creation: Role of servant leadership. *Journal of Leadership Studies*, 6(2), 61-85.
55. Rajbhandari, M.M. ., Looock, C., Du Plessis, P., Rajbhandari, S. (2014). *Leadership Readiness for Flexibility and Mobility: The 4th Dimensions on Situational Leadership Styles in Educational Settings*. Online Submission.
56. Saadi, I.A., Sawadi, Z. T., Al-Salami, Q.H. (2023). An Evaluation Study on Leadership Styles and its Impact on Academic Employees' Job Satisfaction (Private Iraqi Universities as an Example). *Journal Port Science Research*, 6(3), 240-250.
57. Salas, F. (2020). *Impact of Leadership Style on Employees Commitment among Selected Cooperatives in Panabo City* (Doctoral dissertation, UM Panabo-Learning Information Center).
58. Setiawan, R., Cavaliere, L.P.L., Navarro, E.R., Wisetsri, W., Jirayus, P., Chauhan, S., Rajan, R. (2021). *The impact of leadership styles on employees productivity in organizations: A comparative study among leadership styles* (Doctoral dissertation, Petra Christian University).
59. Shafi, M., Lei, Z., Song, X., Sarker, M.N.I. (2020). The effects of transformational leadership on employee creativity: Moderating role of intrinsic motivation. *Asia Pacific Management Review*, 25(3), 166-176.
60. Skogstad, A., Einarsen, S., Torsheim, T., Aasland, M.S., Hetland, H. (2007). The destructiveness of laissez-faire leadership behavior. *Journal of Occupational Health Psychology*, 12(1), 80.
61. Smith, G., Minor, M., Brashen, H. (2018). Spiritual Leadership: A Guide to a Leadership Style That Embraces Multiple Perspectives. *Journal of Instructional Research*, 7, 80-89.
62. Tay, S., Te, C.L., Aziati, A., Ahmad, A.N.A. (2018) An Overview of Industry 4.0: Definition, Components, and Government Initiatives. *Journal of Advanced Research in Dynamical and Control Systems*, 10, 14.
63. Tongkachok, K., Garg, S., Balakrishnan, S., Vijayalakshmi, N.S. (2022). Impact of transformational leadership on organizational performance through employee motivation. *ECS Transactions*, 107(1), 12873.

64. Trzop, A. (2020). Przegląd rozwiązań z zakresu Przemysłu 4.0 stosowanych w obszarze logistyki. *Zeszyty Naukowe Politechniki Śląskiej*, Nr 81, 233-246.
65. Usman, M. (2020). Transformational leadership and organizational change: In the context of today's leader. *International Business Education Journal*, 13(1), 95-107.
66. Vaidya, S., Ambad, P., Bhosle, S. (2018). Industry 4.0—a glimpse. *Procedia manufacturing*, 20, 233-238.
67. Venkatesh, D.A.N. (2020). Leadership 4.0: Leadership strategies for industry 4.0. *Solid State Technology*, 63(6).
68. Wdowiak, A. (2022). *Model wygrany-wygrany jako rodzaj relacji pracownik-organizacja w przedsiębiorstwach sektora informatycznego*.
69. Weber, M. (1972). *Wirtschaft und Gessellschaft. Grundriss der Verstehnden Soziologie*. Tübingen: J.C.B. Mohr (Paul Siebeck).
70. Wei, F., Yuan, X., Di, Y. (2010). Effects of transactional leadership, psychological empowerment and empowerment climate on creative performance of subordinates: A cross-level study. *Frontiers of Literary Studies in China*, 4(1), 29-46.
71. Wiśniewska, M. (2021). *Anatomia przywództwa charyzmatycznego*. Wydawnictwa Uniwersytetu Warszawskiego.
72. Xenikou, A. (2014). The cognitive and affective components of organisational identification: The role of perceived support values and charismatic leadership. *Applied Psychology*, 63(4), 567-588.
73. Yukl, G.A. (1989) *Leadership in Organization*. Englewood Cliffs, New York: Prentice-Hall.

MODELLING EMPLOYEE TURNOVER INTENTION IN THE IT INDUSTRY USING THE PLS-SEM METHOD

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Purpose: This study aimed to develop a PLS-SEM model of IT employees' turnover intention. In particular, the influence of selected factors, such as job characteristics, affective commitment and salary satisfaction, on the propensity to change employment was analysed.

Design/methodology/approach: The survey was conducted on 258 IT employees using partial least squares structural equation modelling (PLS-SEM). Data was collected via an online survey, and the SmartPLS 4 software was used for statistical analysis.

Findings: The study's results indicate that social support, feedback, and affective commitment significantly reduce turnover intention, while low salary satisfaction increases the propensity to change jobs. In turn, autonomy, ergonomics and job complexity had no statistically significant effect on intention to leave. The model explains 49.1% of the variance in the dependent variable, a significant result in organisational behaviour studies.

Research limitations/implications: The study has certain limitations related to its cross-sectional design and the focus on a single national context. The research was conducted in Poland, which may restrict the generalisability of the findings to other countries and cultural settings. Future research could employ a longitudinal approach to examine how changes in organisational practices and employee attitudes affect turnover intention over time. In addition, a multi-country comparative design would allow for cross-cultural validation of the model and provide insights into how national HR practices, labour markets, and cultural norms influence turnover intention in the IT sector. Further studies could also integrate moderating variables such as perceived organisational support or remote work intensity to capture the complexity of turnover mechanisms in hybrid work environments.

Practical implications: In practical terms, HR departments in IT companies can translate these findings into concrete retention strategies. First, implementing structured feedback systems that ensure regular, two-way communication between supervisors and employees can strengthen affective commitment and reduce ambiguity in performance evaluation. Second, developing mentoring and peer-support programmes may further enhance social support and foster a culture of collaboration. Third, salary benchmarking and transparent pay structures should be introduced to maintain competitive remuneration levels and prevent perceptions of inequity. Finally, periodic employee engagement surveys can serve as diagnostic tools for monitoring turnover risk and adjusting HR policies accordingly.

Social implications: The study provides conclusions relevant to employment policy and talent management in the IT sector. It can contribute to developing strategies to reduce the negative effects of high employee turnover, such as professional instability or increased workload for those remaining in the organisation.

Originality/value: The article contributes to the literature on intention to quit using the PLS-SEM method in the IT industry's HRM context. It identifies important determinants of the decision to change jobs and provides practical recommendations for managers and HR professionals.

Keywords: turnover intention, organisational commitment, salary satisfaction, IT employees, PLS-SEM.

Category of the paper: Research paper.

1. Introduction

Voluntary employee turnover is a significant challenge for today's organisations, especially in the rapidly growing IT industry. High turnover of specialist staff generates significant costs in recruitment, training of new employees and loss of organisational knowledge. As a result, research into the determinants of intention to leave is becoming increasingly important to identify the mechanisms underlying employees' decisions to change employment (Hom et al., 2012).

One of the approaches used in the analysis of turnover intentions is the application of structural equation modelling (SEM), which allows both direct and indirect relationships between variables to be considered. In particular, the partial least squares method (PLS-SEM) is gaining popularity in the context of organisational research due to its ability to model complex relationships under limited assumptions about the distribution of data (Hair et al., 2022; Rakowska, Mącik, 2016; Mącik, 2016).

PLS-SEM modelling in human resource management (HRM) allows for analysing the relationship between multiple factors influencing employee attitudes and behaviours (Rakowska, 2021). The technique allows for studying organisational commitment, job satisfaction, engagement, motivation, and turnover intention (Sarstedt et al., 2017). The literature emphasises that the PLS-SEM is particularly useful in HRM analyses because it allows for the inclusion of mediating and moderating variables, leading to a deeper understanding of employees' decision-making mechanisms (Ringle et al., 2020).

SEM modelling about turnover intention has been used in studies on:

- Model the effects of job satisfaction and organisational commitment on intention to leave - research has indicated that job satisfaction and organisational commitment are key predictors of turnover intention (Tett, Meyer, 1993). SEM allows for modelling indirect and direct effects, e.g., by mediating job stress.
- The impact of leadership style on turnover intention, in which an autocratic management style was shown to increase levels of burnout, leading to increased intention to leave (Sparrowe et al., 2001).

- A model of the impact of organisational justice and social support on turnover intention - organisational justice (distributive, procedural and interactional) can indirectly influence the intention to leave through job satisfaction (Colquitt et al., 2001).
- Job Demands-Resources (JD-R) model and turnover intention - The JD-R model allows us to consider the simultaneous effects of job resources (e.g. autonomy) and burdens (e.g. excessive demands) on job burnout and intention to quit (Demerouti et al., 2001).
- The impact of person-organisation fit on turnover intention - research shows that the greater the fit between employee and organisation values, the lower the intention to leave. SEM allows mediation to be tested through job satisfaction (Kristof-Brown et al., 2005).

This paper aims to develop a structural model to explain IT employees' intention to leave using the PLS-SEM method. The study considers key determinants such as organisational commitment, salary satisfaction, job characteristics, work centrality and self-esteem. The analysis conducted on a sample of IT employees allows the identification of significant predictors of the decision to leave, which can provide valuable guidance to managers and HR professionals on retention strategies.

The article's structure includes a literature review on turnover intention and its determinants, a description of the research methodology, a presentation of the analysis results and a discussion of theoretical and practical implications. Ultimately, the article provides recommendations for actions that can reduce turnover in the IT industry and increase employment stability and employee satisfaction.

Although numerous studies have analysed turnover intention in various sectors, relatively few have applied the PLS-SEM approach specifically to IT professionals in Poland. Previous research has primarily focused on traditional SEM techniques or examined single determinants, such as job satisfaction or organisational commitment (e.g., Lo, 2015; Tekleab et al., 2005). There remains a research gap concerning a comprehensive, multivariate model explaining turnover intention among IT employees, which integrates both organisational and individual factors. The present study addresses this gap by applying the PLS-SEM method to a Polish IT workforce sample, offering new insights into the determinants of turnover intention in this dynamic and knowledge-intensive industry.

2. The concept of turnover intention

The phenomenon of voluntary employee turnover was first described by March and Simon (1958), but a significant increase in interest in this topic occurred in the 1990s. In an era of dynamic organisational and market change, intention to leave remains an important research issue. It is considered a key indicator of the likelihood of changing employers, especially when

an employee perceives more attractive career alternatives (Mobley, 1982; Sager, Griffeth, Hom, 1998; Jacobs, Roodt, 2007; Bester, 2012; Zhou, Volkwein, 2004; Xu, 2008; Hassan, Hashim, 2011).

In the literature, the term turnover intention is defined relatively uniformly. Tett and Meyer (1993) describe it as a conscious and deliberate willingness to leave an organisation, which is also emphasised by Schyns, Torka and Gössling (2007). The key point is that this intention represents a subjective attitude of the employee and not a direct action (Sousa-Poza, Henneberger, 2004). Its level can be high - signifying a strong desire to change - or low when the employee is not considering leaving. Researchers indicate that this intention is due, among other things, to a lack of identification with the workplace (Bothma, Roodt, 2012).

High intention to leave often precedes actual turnover, as confirmed by numerous studies (Mobley, 1982; Sager, Griffeth, Hom, 1998; Jacobs, Roodt, 2007; Bester, 2012; Zhou, Volkwein, 2004; Xu, 2008; Hassan, Hashim, 2011). Therefore, its measurement is a useful diagnostic tool for organisations (Kaur, Mohindru, Pankaj, 2013; Perez, 2008).

The decision-making process associated with leaving involves several phases, from considering a job change to exploring alternatives to making a final decision (Martin, 2007). The model was described in detail by Mobley (1977), who distinguished ten phases, including evaluating the current job, analysing available options and comparing alternatives before leaving. Lee and Mitchell (1994, 2001) further developed this concept by introducing a model of employment fluidity that considers unexpected 'shocks' affecting employees' decisions. Research has confirmed that exit decision pathways are intensely situational (Osiwalska, 2023).

The literature points to nine key theories explaining turnover intention (Wojcik, 2024), including organisational balance theory, social exchange theory, job embeddedness theory or perceived organisational support theory (Ngo-Henha, 2017; Radhakrishnan, Inim, Kok, 2016). The aforementioned approaches provide a better understanding of the mechanisms influencing employees' decisions and help organisations to develop effective retention strategies.

3. Factors shaping turnover intention

Identifying the determinants of employees' decision to leave voluntarily is a key challenge in HRM. Although the topic has received much attention from researchers, there are differences in identifying the most important variables influencing turnover intention.

Analysis of the literature indicates that the most commonly studied determinants are job satisfaction, organisational commitment, work centrality and job characteristics. Factors such as perceived organisational support, job stress, job burnout, psychological contract, availability of alternative job opportunities, work-life balance, salary and its satisfactory level, employee well-being, transformational leadership, supervisor-subordinate relationships, employer

branding, corporate social responsibility, identification with the organisation, career satisfaction and job embeddedness are considered to a lesser extent (Wojcik, 2020).

Despite some divergence in the researchers' approach, the main factors influencing the decision to leave are the subjective assessment of working conditions, relationships within the organisation, and career development opportunities.

Job characteristics and turnover intention

Research indicates a significant relationship between job characteristics and employees' turnover intention, particularly in the IT industry (Lo, 2015). The Job Characteristics Model (Hackman, Oldham, 1980) identifies five key attributes: autonomy, feedback, work significance, skill variety and work identity, which increase satisfaction and commitment and thus reduce the propensity to leave. Hauk (2014), on the other hand, identifies eleven important job characteristics that influence job satisfaction.

Krzyszowska's (2015) research highlights that negative work experiences, such as a lack of development prospects, excessive workload or interpersonal conflicts, can increase the intention to leave. Similar findings were presented by Spector and Jex (1991), pointing to the importance of autonomy and feedback as factors in reducing turnover.

Additionally, Markey, Ravenswood and Webber (2012) showed that perceiving the work environment as stable and supportive decreases the intention to leave, while lack of feedback and job stress increases the risk of resignation. Shalley, Gilson and Blum (2000) highlight that creativity and task complexity influence decisions to stay in an organisation.

Work centrality and turnover intention

Work centrality refers to the extent to which an individual perceives work as a central part of their life (Diefendorff et al., 2022). Research indicates that high work centrality reduces the desire to retire but does not necessarily influence the decision to change employment (Schmidt, Lee, 2008). Work centrality was defined by Paullay, Alliger and Stone-Romero (1994) as the degree of importance that work plays in an individual's life.

Organisational commitment and turnover intention

Organisational commitment is one of the most studied factors influencing intention to leave. The concept of Meyer and Allen (1991) distinguishes three dimensions of commitment:

- affective commitment - an emotional connection to the organisation,
- continuance commitment - fear of the costs associated with leaving,
- normative commitment - a sense of moral obligation to remain in the organisation.

Research confirms that strong affective commitment reduces the intention to leave, while continuance and normative commitment play a lesser role in this process (Lewicka, 2016; Wnuk, 2017).

Self-esteem and intention to leave

Self-esteem plays a key role in the decision to leave an organisation. It can be global or specific to the work context - work-related self-esteem and organisational-based self-esteem (OBSE), i.e., relating to the individual's value in the organisation (Pierce, Gardner, 2004).

Individuals with high self-esteem show greater resilience to stress and cope better with work difficulties, which reduces their propensity to leave (Judge et al., 1998). In contrast, low self-esteem increases the risk of job burnout and job dissatisfaction, which can lead to higher turnover (Kammeyer-Mueller et al., 2009).

The conservation of resources theory (COR) suggests that people with high self-esteem have more significant resources to cope with stress, which lowers the intention to leave (Hobfoll, 1989). OBSE acts as a mediator here - employees who feel valued and valuable are less likely to consider changing jobs (Duffy et al., 2002).

Salary satisfaction and turnover intention

Salary satisfaction is a subjective evaluation of the adequacy and fairness of the pay received (Heneman, Schwab, 1985). Adams' (1963) fairness theory suggests that employees compare their pay to others and that an unfair perception of pay increases dissatisfaction and turnover intention. Similarly, Vroom's (1964) expectancy theory indicates that an employee may consider changing jobs when pay does not meet expectations.

Research confirms low salary satisfaction correlates with higher turnover intention (Tekleab et al., 2005; Trevor et al., 1997). However, the impact is more substantial for those who also experience other sources of dissatisfaction, such as a lack of development opportunities (Hom et al., 2012).

The Total Reward model (WorldatWork, 2010) indicates that salary is only one element of the benefits package - in addition to salary, benefits, bonuses, and promotion opportunities are also important. On the other hand, Meyer and Allen (1997) emphasise that high organisational commitment can weaken the negative impact of dissatisfaction with salary on turnover intention. Conversely, the availability of alternative offers reinforces this relationship - the more options on the market, the greater the propensity to change jobs (Mitchell et al., 2001).

4. Research method

The data used in the creation of the structural model of the turnover intention of IT employees was collected for the doctoral dissertation entitled "Determinants of employee turnover intention in the IT industry", defended at the Faculty of Economics of the Maria Curie-Skłodowska University in Lublin in 2024. The dissertation examined only the relationships between selected factors and turnover intention. In the conclusions of the dissertation, attention was drawn to the need for further research on turnover intention, also taking into account other factors causing the intention to stay or leave an organisation.

In order to investigate the intention of IT employees to leave their jobs further, it was decided to develop a structural model using the PLS-SEM method and SmartPLS 4 software.

The selection of respondents was purposive. The survey was conducted online. The survey was opened nearly 900 times, and 304 were completed. However, due to the incompleteness of some responses, 258 surveys were included for further analysis. Participants in the survey were IT professionals involved in software development, testing, implementation and maintenance in their organisations.

Forty-eight women (18.6%) and 210 men (81.4%) participated in the survey. The largest group comprised respondents aged 20-40, who comprised 84.6% of the sample. Most respondents had a master's degree (51.9%) or a bachelor's/engineering degree (31.4%). In terms of length of service, those with work experience of 1 to 5 years, 6 to 10 years (28.7% each) and 11 to 15 years (22.1%) predominated. Half the respondents performed their duties remotely (50.0%), while 40.7% worked in a hybrid model. The smallest group consisted of employees performing their duties exclusively stationary (9.3%). Regarding dominant job responsibilities, most respondents were involved in software development (58.1%). This was followed by software implementation (17.1%), servicing (15.5%) and testing (9.3%).

The study used adapted scales and one of its own (Table 1). A 7-point Likert scale was used to assess the variables (Tarka, 2016), except for the salary satisfaction variable, where a 5-point Likert scale was used. The Turnover Intention Scale (TIS-6) questionnaire by Bothma and Roodt (2013) was used to measure turnover intention. The scale consists of 6 statements and is an abbreviated version of an earlier 15-item tool developed by Roodt (2004). The Job Characteristics Questionnaire by Hauk (2014), for which the starting point was the Work Design Questionnaire (WDQ) developed by Morgeson and Humphrey (2006), was used to explore job characteristics. The tool consists of 11 job characteristics: job complexity, physical requirements and working conditions, job feedback, autonomy, ergonomics, feedback from others, used equipment, interrelations among employees, interactions outside the organisation, social support - friendships in the organization, and work significance. A scale by Paullay, Alliger and Stone-Romero (1994) was used to examine the phenomenon of work centrality. The affective commitment was examined using the Polish version of the scale of commitment to organisations according to Meyer and Allen (1991) developed by Bańka, Wołowska and Bazińska (2002). The Polish version of the Rosenberg Self-Esteem Scale (SES) by Łaguna, Lachowicz-Tabaczek and Dzwonkowska (2007) was used to examine the level of self-esteem. The survey of satisfaction with salary consisted of answering the question: *Are you satisfied with the amount of salary you receive?*, on a 5-point Likert scale.

Table 1.
Measurement scales used

Variable		Author	Name of scale	Number of items	Variable symbol
Turnover intention		Bothma, Roodt (2013)	Turnover Intention Scale (TIS-6)	6	TI
Job characteristics	Job complexity	Hauk (2014)	Job Characteristics Questionnaire	12	JC
	Physical requirements and working conditions			5	PR
	Job feedback			4	JF
	Autonomy			4	Aut
	Ergonomics			4	Erg
	Feedback from others			3	FO
	Used equipment			3	EU
	Interrelations among employees			5	IAE
	Interactions outside the organisation			2	IOO
	Social support - friendships in the organisation			2	Soc
	Work significance			2	WS
Work centrality		Paullay, Alliger, Stone-Romero (1994)	Work Centrality Scale	12	WC
Affective commitment		Meyera, Allen (1991), Bańska, Wołowska, Bazińska (2002)	Affective Commitment Scale, The Polish version of the Organizational Commitment Scales	6	AC
Self-esteem		Rosenberg (1965), Laguna, Lachowicz-Tabaczek, Dzwonkowska (2007)	Rosenberg Self-Esteem Scale (SES), The Rosenberg Self-Esteem Scale: Polish adaptation of the scale	10	SE
Salary satisfaction		own	-	1	SS

Source: own elaboration.

In summary, the results presented in this chapter confirm that interpersonal and affective factors, such as social support, feedback, and affective commitment, play a crucial role in shaping employees' turnover intentions. The statistical analyses using the PLS-SEM method demonstrated that these variables significantly reduce the propensity to leave, whereas low salary satisfaction increases it. These findings form the basis for the discussion and practical recommendations presented in the subsequent chapter.

5. Data analysis

At the beginning of the study, the initial model was assumed to consist of an explanatory variable in the form of turnover intention and explanatory variables including 11 job characteristics, work centrality, affective commitment, self-esteem and salary satisfaction.

As a first step, the reliability of the surveyed variables was verified using Cronbach's alpha coefficient and the Composite Reliability (CR) coefficient (Fornell, Larcker, 1981) (Table 2). The reference values for both indices are > 0.7 . As the value of Cronbach's alpha and CR were insufficient, it was decided not to include the following job characteristics in further analyses: physical requirements and working conditions, used equipment, interrelations among employees, interactions outside the organisation, and work significance. In other cases, assuming that the Cronbach's alpha value is taken as the lower limit of the actual reliability of the scale and the coefficient of composite reliability as the upper limit (Henseler et al., 2015), the reliability level obtained can be considered to meet expectations (Mącik, 2016).

Table 2.

Assessments of the reliability of the measurements used in the study of variables

Variable		Assessment of reliability	
		Cronbach's alpha	CR
Turnover intention		0.817	0.872
Job characteristics	Job complexity	0.899	0.915
	Physical requirements and working conditions	0.526	0.123
	Job feedback	0.808	0.875
	Autonomy	0.817	0.877
	Ergonomics	0.858	0.902
	Feedback from others	0.864	0.917
	Used equipment	0.616	0.790
	Interrelations among employees	0.494	0.060
	Interactions outside the organisation	0.751	0.510
	Social support - friendships in the organisation	0.803	0.909
	Work significance	0.452	0.776
Work centrality		0.843	0.873
Affective commitment		0.816	0.868
Self-esteem		0.763	0.823

Source: Own elaboration based on conducted research.

Convergent relevance was further checked using the average variance explained coefficient (AVE) (Fornell, Larcker, 1981) and differential relevance - meeting the Fornell-Larcker criterion (Fornell, Larcker, 1981) (Table 3).

Table 3.

Measurement relevance ratings of the variables used in the study

Variable	AVE	AC	SS	SE	TI	WC	Aut	Erg	FO	JF	Soc	JC
AC	0.525	0.725										
SS	-	0.221	1.000									
SE	0.416	0.052	0.218	0.645								
TI	0.546	-0.488	-0.497	-0.272	0.739							
WC	0.376	0.367	0.020	-0.076	-0.281	0.613						
Aut	0.641	0.242	0.248	0.274	-0.305	0.158	0.801					
Erg	0.701	0.300	0.256	0.168	-0.295	0.014	0.265	0.837				
FO	0.787	0.387	0.367	0.146	-0.531	0.249	0.272	0.319	0.887			
JF	0.637	0.321	0.405	0.248	-0.523	0.185	0.418	0.234	0.682	0.798		
Soc	0.833	0.367	0.239	0.205	-0.223	0.105	0.292	0.231	0.300	0.335	0.913	
JC	0.474	0.137	0.204	0.226	-0.205	0.146	0.417	0.194	0.219	0.397	0.162	0.688

Source: Own elaboration based on conducted research.

The reference value for AVE is > 0.5 . As the variable self-esteem and work centrality do not meet this criterion, they were omitted from further analyses. The matrix diagonal (bold values) represents the square root of the AVE for each construct, while the diagonal values correspond to the correlation coefficients between them. The criterion is considered to be met if the value on the diagonal exceeds all other values in its row and column (Mącik, 2016). The variable job complexity is slightly below the required AVE value but meets the Fornell-Larcker criterion, so it was decided to leave this variable for further research.

6. Findings

Based on the literature review, it was assumed at the initial stage of the study that the explanatory variable, which is the intention to quit, would be influenced by 15 explanatory variables. Verification of the Cronbach's alpha coefficient and the CR coefficient of the analysed variables resulted in 5 job characteristics not being accepted for further study: physical requirements and working conditions, used equipment, interrelations among employees, interactions outside the organisation, and work significance. In turn, self-esteem and work centrality did not meet the required AVE. Finally, eight explanatory variables were included in the model: 6 job characteristics (job complexity, job feedback, autonomy, ergonomics, feedback from others, social support - friendships at work), affective commitment and salary satisfaction.

A bootstrap subsample test of 5.000 verified the significance of the path coefficients. The variables job complexity ($p = 0.528$), autonomy ($p = 0.270$) and ergonomics ($p = 0.472$) are not statistically significantly related to the variable turnover intention. The remaining relationships are statistically significant and meet the accepted $p\text{-value} < 0.5$. The final model is shown in Figure 1.

The model estimated by the PLS-SEM method is a good fit as the SRMR value is 0.072 and ≤ 0.08 (Henseler et al., 2015). The value of the coefficient of determination $R^2 = 0.491$, which means that the independent variables in the PLS-SEM model explain 49.1% of the variance in the dependent variable. In the social sciences, the value obtained can be considered a good result, especially in empirical studies on complex human behaviour (Hair et al., 2019). According to Chin (1998), R^2 values in PLS-SEM models can be interpreted as follows: ≥ 0.67 - high explanatory power, 0.33 - 0.67 - moderate explanatory power, 0.19 - 0.33 - low explanatory power. The value of $R^2 = 0.491$ falls within the range of moderate explanatory power, which means that the model explains a significant part of the variation in the dependent variable. However, lower R^2 values are often accepted in the social sciences because the phenomena under study are usually multivariate and challenging to model mathematically (Falk, Miller, 1992).

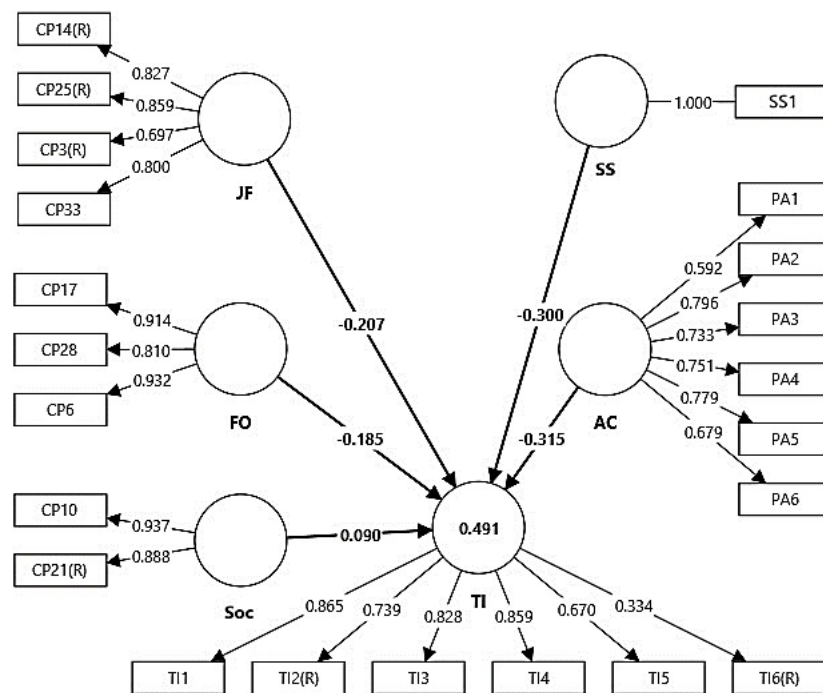


Figure 1. Structural model analysed.

Source: Own elaboration based on conducted research.

Finally, the Heterotrait-Monotrait Ratio of Correlations (HTMT) values of the discriminant validity measure in PLS-SEM models, which is used to check whether the variables in the model are sufficiently different from each other, were examined. HTMT compares the average correlation between different constructs (heterotrait) to the average correlation between indicators of the same construct (monotrait). Lower values indicate better discriminant validity; constructs measure different concepts rather than the same variables. HTMT is often recommended as a better alternative to the traditional Fornell-Larcker criterion, which often fails to detect differential accuracy problems (Henseler et al., 2015). An HTMT value < 0.85 is the most stringent criterion, but in the social sciences, an HTMT < 0.90 is acceptable (Gold et al., 2001). All correlations between variables in the model meet the HTMT criterion (Table 4).

Table 4.
Differential accuracy - heterotrait-monotrait ratio table

	AC	FO	JF	SS	Soc	TI
AC						
FO	0.452					
JF	0.395	0.820				
SS	0.243	0.396	0.449			
Soc	0.453	0.359	0.419	0.259		
TI	0.594	0.614	0.611	0.519	0.265	

Source: Own elaboration based on conducted research.

The model shows that interpersonal factors have a key impact on the intention to leave. Social support and feedback (JF, FO) significantly predict turnover intention. Good working relationships and constructive feedback can reduce the intention to leave. Affective

commitment reduces the intention to leave. Employees more emotionally attached to the organisation are less likely to think about changing jobs. Salary satisfaction is significant. Lower salary satisfaction increases the propensity to leave. This confirms Adams' (1963) fairness theory, according to which injustice in remuneration leads to dissatisfaction and a search for alternatives. No significant effect of autonomy, ergonomics and job complexity on the intention to leave was confirmed. This may suggest that IT workers value flexibility, but it is not a significant decision factor in the context of job change.

7. Conclusions

A study of IT employees' turnover intention using the PLS-SEM method provided important information on the key factors influencing the decision to change employment. The model explains 49.1% of the variance in the dependent variable, indicating its robustness in a social science context (Hair et al., 2019). The results show that the most significant factors from job characteristics reducing intention to leave are receiving job feedback and feedback from others, i.e. constructive feedback. Good working relationships and apparent organisational communication foster employee loyalty, suggesting that organisations should emphasise a culture of collaboration and open dialogue between teams (Demerouti et al., 2001; Colquitt et al., 2001).

Another important factor is affective commitment, which is key in reducing turnover. Employees who are strongly emotionally attached to the organisation show a lower propensity to leave the organisation, highlighting the importance of building organisational bonds through engagement strategies and loyalty programmes (Meyer, Allen, 1991). At the same time, the study's results confirmed that low salary satisfaction significantly increases the propensity to change jobs. Employees dissatisfied with their pay are more likely to consider leaving, which is supported by Adams' (1963) equity theory. This means organisations should regularly review and adjust their remuneration policies to ensure they are competitive with the labour market (Tekleab et al., 2005).

An interesting result of the study is that autonomy, ergonomics and job complexity do not significantly influence the intention to leave. This may suggest that IT employees, unlike representatives of other industries, value social and financial aspects more than the specificity of the job itself (Lo, 2015). That is, flexibility in their duties and the ability to manage tasks are not key determinants of their decision to stay in an organisation if other factors - such as pay and work atmosphere - do not meet their expectations (Hackman, Oldham, 1980).

The findings of the study have important practical implications. IT companies should invest more in developing a collaborative organisational culture and effective feedback systems that help build employee commitment and satisfaction (Shalley, Gilson, Blum, 2000). Additionally, attractive and fair remuneration remains one of the key elements influencing staff retention (WorldatWork, 2010). These measures can reduce turnover, contributing to more excellent job stability and better organisational performance.

References

1. Adams, J.S. (1963). Toward an understanding of inequity. *Journal of Abnormal and Social Psychology*, 67(5), 422-436. DOI: 10.1037/h0040968.
2. Bańka, A., Wołowska, A., Bazińska, B. (2002). Polska wersja skali przywiązania do organizacji według J.P. Meyera i N.J. Allen. *Psychologia Społeczna*, 2(4), 164-176.
3. Bester, C. (2012). Turnover intention and job satisfaction in the academic profession. *South African Journal of Industrial Psychology*, 38(1), 1-9.
4. Bothma, C.F.C., Roodt, G. (2012). Work-based identity and work engagement as predictors of turnover intention. *SA Journal of Industrial Psychology*, 38(1), 1-13.
5. Bothma, C.F.C., Roodt, G. (2013). The validation of the turnover intention scale. *SA Journal of Human Resource Management*, 11(1), 1-12. DOI: 10.4102/sajhrm.v11i1.507
6. Chin, W.W. (1998). The partial least squares approach to structural equation modeling. In: G.A. Marcoulides (Ed.), *Modern methods for business research* (pp. 295-336). Lawrence Erlbaum Associates.
7. Colquitt, J.A., Conlon, D.E., Wesson, M.J., Porter, C.O.L.H., Ng, K.Y. (2001). Justice at the Millennium: A meta-analytic review of 25 years of organizational justice research. *Journal of Applied Psychology*, 86(3), 425-445. DOI: 10.1037/0021-9010.86.3.425
8. Demerouti, E., Bakker, A.B., Nachreiner, F., Schaufeli, W.B. (2001). The Job Demands-Resources model of burnout. *Journal of Applied Psychology*, 86(3), 499-512. DOI: 10.1037/0021-9010.86.3.499
9. Diefendorff, J.M., Richard, E.M., Croyle, M.H. (2022). Work centrality and its effects on motivation and work outcomes. *Journal of Vocational Behavior*, 124, 103-115.
10. Duffy, R.D., Ganster, M.L., Pagon, M. (2002). The effects of organization-based self-esteem on workplace outcomes: Comparing Slovenia and the United States. *Applied Psychology: An International Review*, 51(3), 397-425. DOI: 10.1111/1464-0597.00098
11. Falk, R.F., Miller, N.B. (1992). *A primer for soft modeling*. University of Akron Press.
12. Fornell, C., Larcker, D.F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1), 39-50. DOI: 10.2307/3151312

13. Hackman, J.R., Oldham, G.R. (1980). *Work redesign*. Addison-Wesley.
14. Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E. (2022). *Multivariate data analysis* (8th ed.). Cengage Learning.
15. Hair, J.F., Hult, G.T.M., Ringle, C.M., Sarstedt, M. (2019). *A primer on partial least squares structural equation modeling (PLS-SEM)* (2nd ed.). SAGE Publications.
16. Hassan, A., Hashim, J. (2011). Role of organizational justice in determining work outcomes of national and expatriate employees. *European Journal of Social Sciences*, 19(1), 151-164.
17. Hauk, M. (2014). Kwestionariusz Cech Pracy – opracowanie polskiej wersji narzędzia do badania cech pracy i środowiska zawodowego: wstępne wyniki badań. *Acta Universitatis Lodzensis. Folia Psychologica*, 18, 129-153.
18. Heatherton, T.F., Polivy, J. (1991). Development and validation of a scale for measuring state self-esteem. *Journal of Personality and Social Psychology*, 60(6), 895-910. DOI: 10.1037/0022-3514.60.6.895
19. Heneman, H.G., Schwab, D.P. (1985). Pay satisfaction: Its multidimensional nature and measurement. *International Journal of Psychology*, 20(2), 129-141. DOI: 10.1080/00207598508247727.
20. Henseler, J., Ringle, C.M., Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, 43(1), 115-135.
21. Hobfoll, S.E. (1989). Conservation of resources: A new attempt at conceptualizing stress. *American Psychologist*, 44(3), 513-524. DOI: 10.1037/0003-066X.44.3.513
22. Hom, P.W., Mitchell, T.R., Lee, T.W., Griffeth, R.W. (2012). Reviewing employee turnover: Focusing on proximal withdrawal states and an expanded criterion. *Psychological Bulletin*, 138(5), 831-858. DOI: 10.1037/a0027983
23. Jacobs, E., Roodt, G. (2007). The development of a predictive turnover model for retention of critical skills. *SA Journal of Human Resource Management*, 5(2), 9-19.
24. Judge, T.A., Locke, E.A., Durham, C.C. (1998). The dispositional causes of job satisfaction: A core evaluations approach. *Research in Organizational Behavior*, 19, 151-188.
25. Kammeyer-Mueller, J.D., Judge, T.A., Scott, B.A. (2009). The role of core self-evaluations in the coping process. *Journal of Applied Psychology*, 94(1), 177-195. DOI: 10.1037/a0013214
26. Kaur, R., Mohindru, A., Pankaj, S. (2013). Antecedents of turnover intentions: A literature review. *Global Journal of Management and Business Studies*, 3(10), 1219-1230.
27. Kristof-Brown, A.L., Zimmerman, R.D., Johnson, E.C. (2005). Consequences of individuals' fit at work: A meta-analysis of person–job, person–organization, person–group, and person–supervisor fit. *Personnel Psychology*, 58(2), 281-342. DOI: 10.1111/j.1744-6570.2005.00672.x

28. Krzyszkowska, P. (2015). Zwolnienia pracowników jako nieuchronny proces zachodzący w działalności każdej organizacji. *Zeszyty Naukowe Politechniki Śląskiej, seria Organizacja i Zarządzanie*, 82(1940), 101-110.
29. Łaguna, M., Lachowicz-Tabaczek, K., Dzwonkowska, I. (2007). Skala samooceny SES Morrisa Rosenberga – polska adaptacja metody. *Psychologia Społeczna*, 2(4), 164-176.
30. Lee, T.W., Mitchell, T.R. (1994). An alternative approach: The unfolding model of voluntary employee turnover. *Academy of Management Review*, 19(1), 51-89.
31. Lee, T.W., Mitchell, T.R. (2001). 5. The unfolding model of voluntary turnover and job embeddedness: Foundations for a comprehensive theory of attachment. *Research in Organizational Behavior*, 23, 189-246. DOI: 10.1016/S0191-3085(01)23006-8
32. Lewicka, D. (2016). Jak zatrzymać wartościowych pracowników w organizacji? Wyzwania dla strategicznego ZKL (zarządzania kapitałem ludzkim). *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu. Zarządzanie strategiczne w teorii i praktyce*, no. 444, 274-284.
33. Lo, J. (2015). The impact of job characteristics on job satisfaction and turnover intention among IT employees. *International Journal of Business and Social Science*, 6(11), 55-65.
34. Mącik, R. (2016). Style podejmowania decyzji zakupowych a zachowania konsumentów w symulowanych zakupach w środowisku porównywarki cenowej. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 460, 153-166. DOI: 10.15611/pn.2016.460.14.
35. March, J.G., Simon, H.A. (1958). *Organizations*. John Wiley & Sons.
36. Markey, R., Ravenswood, K., Webber, D.J. (2012). The impact of the quality of the work environment on employees' intention to quit. *Economics Working Paper Series*, 1220, 1-33.
37. Martin, J. (2007). *Organizational behavior and management*. Cengage Learning.
38. Meyer, J.P., Allen, N.J. (1991). A three-component conceptualization of organizational commitment. *Human Resource Management Review*, 1(1), 61-89.
39. Meyer, J.P., Allen, N.J. (1997). *Commitment in the workplace: Theory, research, and application*. SAGE Publications.
40. Mitchell, T.R., Holtom, B.C., Lee, T.W., Sablinski, C.J., Erez, M. (2001). Why people stay: Using job embeddedness to predict voluntary turnover. *Academy of Management Journal*, 44(6), 1102-1121. DOI: 10.2307/3069391
41. Mobley, W.H. (1977). Intermediate linkages in the relationship between job satisfaction and employee turnover. *Journal of Applied Psychology*, 62(2), 237-240.
42. Mobley, W.H. (1982). *Employee turnover: Causes, consequences, and control*. Addison-Wesley.
43. Morgeson, F.P., Humphrey, S.E. (2006). The Work Design Questionnaire (WDQ): Developing and validating a comprehensive measure for assessing job design and the nature of work. *Journal of Applied Psychology*, 91(6), 1321-1339. DOI: 10.1037/0021-9010.91.6.1321

44. Ngo-Henha, P.E. (2017). A review of existing turnover intention theories. *International Journal of Economics and Management Engineering*, 11(11), 2750-2756.
45. Osiwalska, M.A. (2023). *Rozwijany model płynności zatrudnienia w grupie zawodowej pracowników centrum obsługi telefonicznej w Polsce*. Rozprawa doktorska. Sopot: Uniwersytet Gdański. Pobrane z: https://bip.ug.edu.pl/st-tyt_nauk/113829/monika_anna_osiwalska, 18.02.2025.
46. Paullay, I.M., Alliger, G.M., Stone-Romero, E.F. (1994). Construct validation of two instruments designed to measure job involvement and work centrality. *Journal of Applied Psychology*, 79(2), 224-228. DOI: 10.1037/0021-9010.79.2.224
47. Perez, M. (2008). Turnover intention. *Journal of Managerial Psychology*, 23(2), 100-118.
48. Pierce, J.L., Gardner, D.G. (2004). Self-esteem within the work and organizational context: A review of the organization-based self-esteem literature. *Journal of Management*, 30, 591-622. DOI: 10.1016/j.jm.2003.10.001
49. Radhakrishnan, T., Inim, I., Kok, T.K. (2016). Turnover intention and job satisfaction. *International Business Research*, 9(4), 38-48.
50. Rakowska, A. (2021). *Różnorodność zasobów ludzkich w organizacji: istota, dylematy, wyzwania*. Lublin: Wydawnictwo Uniwersytetu Marii Curis-Skłodowskiej.
51. Rakowska, A., Mącik, R. (2016). Zaangażowanie pracownika a satysfakcja z pracy — modelowanie zależności z wykorzystaniem PLS-SEM. *Przegląd Organizacji*, 5, 48-58. DOI: 10.33141/po.2016.05.07
52. Ringle, C.M., Wende, S., Becker, J.-M. (2020). *SmartPLS 3*. SmartPLS GmbH. Pobrane z: <https://www.smartpls.com>, 18.02.2025.
53. Roodt, G. (2004). *Turnover Intentions*. Unpublished manuscript. Johannesburg: University of Johannesburg.
54. Rosenberg, M. (1965). *Society and the adolescent self-image*. Princeton University Press.
55. Sager, J.K., Griffeth, R.W., Hom, P.W. (1998). A comparison of structural models representing turnover cognitions. *Journal of Vocational Behavior*, 53(2), 254-273.
56. Sarstedt, M., Ringle, C.M., Hair, J.F. (2017). Partial least squares structural equation modeling. In: C. Homburg, M. Klarmann, A. Vomberg (Eds.), *Handbook of market research* (pp. 1-40). Springer. DOI: 10.1007/978-3-319-05542-8_15-1
57. Schmidt, J.A., Lee, K. (2008). Voluntary Retirement and Organizational Turnover Intentions: The Differential Associations with Work and Non-Work Commitment Constructs. *Journal of Business and Psychology*, 22(4), 297-309. DOI: 10.1007/s10869-008-9068-y
58. Schyns, B., Torka, N., Gössling, T. (2007). Turnover intentions and leadership. *International Journal of Human Resource Management*, 18(11), 2025-2038.
59. Shalley, C.E., Gilson, L.L., Blum, T.C. (2000). Matching creativity requirements and the work environment: Effects on satisfaction and intentions to leave. *Academy of Management Journal*, 43(2), 215-223. DOI: 10.2307/1556378

60. Sousa-Poza, A., Henneberger, F. (2004). Analyzing Job Mobility with Job Turnover Intentions: An International Comparative Study. *Journal of Economic Issues*, 38(1), 113-137. DOI: 10.1080/00213624.2004.11506667
61. Sparrowe, R.T., Liden, R.C., Wayne, S.J., Kraimer, M.L. (2001). Social networks and the performance of individuals and groups. *Academy of Management Journal*, 44(2), 316-325. DOI: 10.2307/3069458
62. Spector, P.E., Jex, S.M. (1991). Relations of job characteristics from multiple data sources with employee affect, absence, turnover intentions, and health. *Journal of Applied Psychology*, 76(1), 46-53. DOI: 10.1037/0021-9010.76.1.46
63. Tarka, P. (2015). Własności 5- i 7- stopniowej skali Likerta w kontekście normalizacji zmiennych metodą Kaufmana i Rousseeuwa. *Prace naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 385, 286-295.
64. Tekleab, A.G., Bartol, K.M., Liu, W. (2005). Is it pay levels or pay raises that matter to fairness and turnover? *Journal of Organizational Behavior*, 26(8), 899-921. DOI: 10.1002/job.352
65. Tett, R.P., Meyer, J.P. (1993). Job satisfaction, organizational commitment, turnover intention, and turnover: Path analyses based on meta-analytic findings. *Personnel Psychology*, 46(2), 259-293. DOI: 10.1111/j.1744-6570.1993.tb00874.x
66. Trevor, C.O., Gerhart, B., Boudreau, J.W. (1997). Voluntary turnover and job performance. *Journal of Applied Psychology*, 82(1), 44-61.
67. Vroom, V.H. (1964). *Work and motivation*. John Wiley & Sons.
68. Wnuk, M. (2017). Właściwości psychometryczne polskiej wersji skali przywiązania do organizacji. *Organizacja i Kierowanie*, 3, pp. 109-125.
69. Wójcik, P. (2020). Determinants of employee turnover intention. *Scientific Papers of Silesian University of Technology, Organization and Management*, 149, 725-734.
70. Wójcik, P. (2024). *Determinanty intencji odejścia z pracy pracowników branży IT*. Lublin: Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej.
71. WorldatWork (2010). *The total rewards model: A framework for strategies to attract, motivate and retain employees*. WorldatWork Press.
72. Xu, Y.J. (2008). Gender disparity in STEM Disciplines: A study of faculty attrition and turnover intentions. *Research in Higher Education*, 49(7), 607-624. DOI: 10.1007/s11162-008-9097-4
73. Zhou, Y., Volkwein, J.F. (2004). Examining the Influences on Faculty Departure Intentions: A Comparison of Tenured Versus Nontenured Faculty at Research Universities Using NSOPF-99. *Research in Higher Education*, 45(2), 139-176. DOI: 10.1023/B:RIHE.0000015693.38603.4c

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