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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: project management; organizational culture; finances; logistics; ESG; Industry 4.0; sustainability; startup management; digital transformation; environmental management; innovation management; healthcare management; virtual reality; strategic management; marketing; e-services and human resources management.

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HYBRID PROJECT MANAGEMENT IN IT PROJECTS

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Purpose: To examine the possibility of integrating agile and traditional methodologies in IT project management. The paper focuses on assessing how the integration of these two approaches can affect the effectiveness of project implementation in the IT industry, as well as on formulating recommendations for companies and project managers who want to consciously use the advantages of both agile and traditional project management methodologies in their work.
Design/methodology/approach: The research used qualitative methods, i.e. covert participant observation and in-depth interviews with experienced project managers. The theoretical background of the research was based on methodological studies in the field of project management, represented by the PMBoK standard, the Prince2 methodology and the Scrum Guide framework.
Findings: The results of the study indicate that conscious and flexible combination of methodologies contributes to greater team effectiveness and better quality of delivered products. Furthermore, they point to the need to develop internal good practice guides, standardise communication and reporting, and implement cyclical evaluation mechanisms that will allow the management model to be flexibly adapted to changing project conditions.
Practical implications: Key to the effectiveness of the hybrid approach is the active involvement of management and the PMO, who should set standards of operation, support project teams, and ensure transparency of processes.
Originality/value: The article brings original value by attempting to standardize the approach to the use of hybrid methodologies in IT projects. The proposed approach reduces inconsistencies in project implementation and facilitates the decision-making process at the management level.
Keywords: project management, hybrid methodologies, methodology integration, traditional project management methodologies, agile project management.
Category of the paper: research paper.

1. Introduction

In an era of dynamic technological development and ongoing digital transformation, IT projects are gaining strategic importance in the functioning of organisations — both in terms of innovation and market competition. Contemporary IT projects are characterised by high uncertainty, rapidly changing stakeholder requirements and pressure to shorten time-to-market. Therefore, effective project management is becoming a determining factor in the success of projects — in terms of quality, cost and timeliness (Serrador, Pinto, 2021; Jovanović et al., 2022).

In response to these challenges, organisations are increasingly turning to a variety of project management methodologies. On the one hand, there are agile approaches, such as Scrum or Agile PM, which offer flexibility, iterativeness and rapid response to changing requirements. On the other hand, there are traditional methodologies, such as PRINCE2 or PMBoK, which provide a structured framework, precise planning and strict control over implementation. Each approach has its advantages and disadvantages, but there is a growing need to integrate them in order to fully respond to the specific nature of IT projects (Mirzaei et al., 2025; Conforto et al., 2016; Moeuf et al., 2023). This is also related to the fact that the choice of an effective project management methodology is critical for a project's success (Joslin, Muller, 2015).

There is growing interest in the literature in hybrid models that seek to combine the strengths of agile and traditional approaches. For example, Reiff and Schlegel (2022) identify various hybrid models in their systematic review and point to gaps in understanding the conditions for their effective implementation. Azenha, Reis & Fleury (2020), on the other hand, emphasise that although hybrid approaches are increasingly used in technology organisations, there is a lack of empirical research describing their practical application and impact on project effectiveness. Almeida et al. (2024) analyse various hybrid scaling models in the context of IT organisations, pointing, among other things, to the need to adapt to the specific nature of the organisation and to continuously improve integration mechanisms. Zasa, Patrucco & Pellizzoni (2020) also discuss how traditional approaches can coexist with agile in organisational structures, drawing attention to integration challenges and cultural changes.

Given the above, the need for this research stems from the lack of clear, unified approaches to the use of hybrid methodologies, which in practice leads to discrepancies in implementation, inconsistencies and decision-making barriers at the management level. This article aims to fill this gap by empirically analysing the possibilities of integrating agile and traditional methodologies in the context of IT projects and formulating practical recommendations for managers and PMO departments. In order to achieve the aim of the research, the following three research questions were asked, i.e.:

1) How to integrate agile and traditional approaches in order to achieve the best project results?
2) What are the key benefits of integrating agile and traditional methodologies?
3) In what types of IT projects is the integration of agile and traditional methodologies most effective?

The paper is organised as follows. Section 2 presents a literature review. In this section characterizes hybrid methodologies combining traditional and agile project management. Section 3 describes the empirical research methods. Results are reported in Section 4. Discussion and conclusion, including theoretical and practical implications as well as future research are presented in Section 5 and 6.

2. Literature review

2.1. Project management methodologies – a comparison of traditional and agile approaches

In the literature (e.g. Žužek et al., 2020; Gemino et al., 2021; Copola Azenha et al., 2021; Krug et al., 2019), hybrid methodologies are most often defined as a combination of traditional and agile project management methodologies. By combining an agile approach at the operational level with a traditional approach at the decision-making level, hybrid project management seeks to combine the advantages of both management systems (Binder et al., 2014; Reiff, Schlegel, 2022). Some authors (e.g. Cavalieri Barbosa, Saisse, 2019; Boehm, Turner, 2005; Cooper, Sommer, 2018) also describe hybrid project management as the result of integrating the agile approach with existing traditional project management methodologies.

Considering the differences between the two approaches, it should be noted that while traditional methodologies are based on detailed planning and formal procedures, agile approaches focus on flexibility and rapid adaptation to change (Strojny, Szmigiel 2015). It is also impossible not to mention the project constraints triangle, which differs depending on the methodology used. In traditional approaches, a rigidly defined scope is key, while in agile methodologies, the priority is to maintain fixed resources and time frames, with the scope of the project remaining flexible and adaptable to changing needs (Liebert, 2017).

Another important difference between traditional and agile methodologies is the way the project life cycle is managed. In traditional approaches, such as PRINCE2 or PMBoK, the cycle is linear – the project is implemented according to strictly defined stages. Key project processes are clearly defined and planning is based on a detailed schedule. In agile approaches, such as Scrum or Agile PM, the project life cycle is iterative – the product is developed gradually, in short, repetitive stages. The schedules created are short-term and flexible, and teams focus on delivering value in each subsequent iteration, which allows the project to be adapted on

an ongoing basis to changing conditions and stakeholder expectations (Strojny, Szmigiel, 2015).

The organisational aspect of the project is another key difference between traditional and agile methodologies. Traditional approaches are based on a strictly defined organisational structure, in which the division of labour is precisely specified and documentation is kept in a comprehensive manner. In agile methodologies, the organisation of work is much more flexible, which allows for quick adaptation to changing requirements. Documentation is kept to a minimum, and the management model can be modified during the course of the project (Strojny, Szmigiel, 2015).

The approach to risk management also differs between traditional and agile approaches. In traditional methodologies, risk management is a key process, involving detailed planning, identification of threats, their analysis (both qualitative and quantitative), preparation of a response strategy, and continuous monitoring and control of risks. In the agile approach, however, risk is treated in a more flexible manner – instead of formal procedures, agile methodologies assume that risk is an inherent part of every project and should be mitigated through the work itself. Daily team meetings, constant contact with the client and iterative delivery of parts of the product are activities that minimise potential threats (Trzeciak, Spałek, 2016).

With regard to change management in projects, in the traditional approach, any change in requirements is seen as a potential threat to the stability of the project and is subject to formal approval procedures. On the other hand, in agile methodologies, changes are treated as a natural and desirable part of the project management process. Changing requirements are seen as an opportunity to deliver greater value to the client and can be easily incorporated into subsequent iterations of the project (Łabuda, 2015).

Another difference worth noting is the personal aspect and the organisation of the project team. In the traditional approach, team members have specific roles and competences, and their tasks are strictly defined. In agile methodologies, the team functions in a more flexible and self-organising manner. Unlike the traditional approach, there is no emphasis on narrow specialisation – team members often perform different roles and their competences complement each other. The priority in these methodologies is cooperation, open communication and close integration of the team with the client (Strojny, Szmigiel, 2015).

When choosing a methodology, it is also worth considering various criteria that influence the selection. An important criterion is the size of the project, as traditional methodologies, thanks to their detailed processes, may work better in large projects. When using agile approaches, it may be more difficult to coordinate the activities of multiple teams and departments within the company. Communication with the client should also be taken into account when choosing a methodology. In an agile approach, contact is frequent and direct, which allows for ongoing verification of expectations and avoids misunderstandings. In traditional methodologies, on the other hand, the client is involved less frequently – mainly

at the beginning and end of the project. This can lead to a situation where the final product does not fully meet expectations, and corrections are costly and time-consuming. Another important factor in choosing a methodology is how the schedule is set. If the project requires strict adherence to set deadlines, classic methods based on detailed planning and clearly defined work stages may be a better choice. On the other hand, in a situation where deadlines are more flexible and may change depending on progress, agile methods, which allow for greater freedom in the organisation of tasks, will work better (Chmielarz, 2012).

In summary, when choosing a project management methodology, it is important to be aware that, despite the availability of many methodologies, there is no single methodology that is suitable for all projects. Methodologies are a set of specific patterns, rules and procedures that help to avoid mistakes, although they do not eliminate them entirely. Therefore, the final choice of methodology depends largely on the nature of the project, customer preferences and organisational context, so it is important to find the right balance between control and flexibility.

2.2. The use of methodologies in IT projects – results of literature research

The IT industry is one of the fastest growing sectors of the economy, characterised by dynamic changes and constant innovation. The IT industry is distinguished by the rapid introduction of new technologies, tools and changing trends. This dynamic nature of the industry means that in IT project management, it is crucial to adapt to changes and quickly adjust to constantly evolving requirements. Therefore, choosing the right IT project management methodology is fundamental to achieving project effectiveness and efficiency in this industry (Pietras, Szmit, 2003). Below are the results of research by various authors who have focused on traditional and agile project management methodologies and their integration in IT companies.

A study conducted by Krysiak and Głowania (2017) analysed project management methods in the IT industry. The authors based their conclusions on a survey of 200 people working in this industry. The results of the study indicate that classic methodologies, despite their formalisation, are still used in management, albeit by a small minority. Only 12% of respondents use classical approaches such as PMBoK or PRINCE2. The remaining 88% prefer agile approaches, with Scrum being the most popular, chosen by 62% of respondents. It is worth noting that 11% of survey participants declared that they do not use any project management methodology. The survey also showed that classic approaches are more commonly used in large companies with over 250 employees that operate on the basis of Polish capital. These results show that the IT industry is clearly dominated by an agile approach to project management, although classic approaches are still used in specific cases.

In turn, research conducted by Brzozowski (2020) focused on analysing the use of different approaches to project management in various types of organisations, including the IT sector. The author based his conclusions on empirical research conducted between 2016 and 2018

using a questionnaire survey. Analysing the results concerning the use of any project management methodologies in individual industries, Brzozowski points out that the IT sector uses them most often. Over 27% of the IT companies surveyed implement a comprehensive approach, consisting in the full application of one selected methodology. In turn, over 30% of organisations declare that they use a diversified approach, combining elements of different methodologies. The largest number, almost 41% of companies, indicated the integrated use of project management methodologies, which means that they implement selected practices but do not rely on the full framework of any of the methodologies. Only a small percentage of organisations – just over 1% – declared that they do not use any project management methodology. In his research, Brzozowski also noted that agile methodologies are dominant in the IT sector, which also achieved the highest score in the assessment of their usefulness.

Further research by Łapuńka, Marek-Kołodziej & Jagoda-Sobalak (2017) focused on the management of innovative projects, with particular emphasis on the development of new products, which is typical for IT projects. Based on their analyses, they concluded that a complete departure from the traditional waterfall model of project management in favour of an agile approach is not a good solution for organisations. This is due to the fact that classic models, based on a sequential approach to task execution, have been used for a long time and are well-established. At the same time, the authors emphasise the need to adapt practices to the specific nature of a given project. They propose a hybrid approach combining elements of both models – the so-called agile-waterfall – as a solution dedicated to new product development projects. They point out that the integration of selected practices from agile and traditional approaches can improve project management efficiency, especially in terms of flexibility and early problem detection. Among the agile practices that are worth implementing in traditional models, the authors mention, among others, regular and frequent team meetings, continuous integration of work enabling early detection of errors and increasing project flexibility, direct communication and systematic feedback, and prioritisation of tasks with the participation of customers. The authors' research clearly indicates a growing trend towards integrating elements of agile and traditional methodologies, which facilitates the management and implementation of project objectives.

As can be seen from the above analysis, the method of managing IT projects is a widely discussed topic in the literature on the subject. The authors emphasise that the choice of the appropriate methodology depends on many factors, but the agile approach is dominant. Nevertheless, not all IT companies are advocates of agile approaches, as they prefer traditional approaches such as PMBoK or PRINCE2, which have been used in organisations for years. Hybrid approaches that integrate traditional methodologies with agile methodologies are also becoming increasingly common, which is particularly useful in more complex projects that require both flexibility and strict control over the schedule.

Although the literature increasingly discusses hybrid approaches combining agile and traditional project management methodologies, there is still a lack of clear and unified procedures describing how such integration should be implemented in practice. Existing studies mainly focus on describing the use of methodologies rather than providing consistent frameworks for their integration in IT projects. Consequently, further empirical research is needed to better understand how hybrid methodologies are applied and under what conditions they contribute to project effectiveness.

3. Methods

The research was conducted in an international IT corporation that is a leader in its industry. The company operates in a highly competitive market characterised by strict regulatory requirements. In such conditions, project management requires a high degree of flexibility and the ability to adapt quickly to new challenges. To meet these requirements, the organisation uses a hybrid approach, combining elements of agile and traditional methodologies.

The research was conducted using a qualitative method, employing covert participant observation and in-depth interviews. In-depth interviews were conducted with four project managers in the IT industry who have at least five years of experience in IT project management. The full characteristics of the respondents are presented in Table 1.

Table 1.
Characteristics of the research sample

Person	Age	Education	Project management experience	Certificates	Gender
A	32	Master's degree in management	5 years	PRINCE2 Foundation, Scrum Master	K
B	37	Master's degree in production engineering	6 years	PRINCE2 Foundation, AgilePM	M
C	42	IT Systems Engineer	12 years	PRINCE2 Practitioner, AgilePM	M
D	50	Master's degree in management	10 years	PMP, AgilePM	K

Source: own elaboration.

The diversity of participants in terms of age, education, certifications and professional experience allowed for a better understanding of the phenomenon under study from different perspectives. This made it possible to learn about different project management methods and approaches used by managers depending on their experience and the projects they work on.

The selection of respondents was deliberate and based on the assumption that the interviewees had expert knowledge and practical experience of working in a hybrid project environment. This allowed us to obtain detailed information on the practices used, the challenges and the benefits of integrating agile and traditional methodologies.

The research procedure involved the preparation of a semi-structured interview scenario, which included questions about the approaches used in project management, the challenges encountered, the benefits of integrating methodologies, and the factors influencing the effectiveness of project teams. The scenario serves as a guide, but the interviews are flexible in nature, as the questions are explored in depth depending on the interviewees' answers, which allows for more detailed and valuable information to be obtained. The interviews were conducted individually, in the form of face-to-face meetings or online conversations, depending on the availability of the respondents. Each interview lasted between 30 and 60 minutes and was recorded with the consent of the participants. The analysis of the collected material consisted of identifying recurring themes and comparing the different perspectives of the interviewees, and then allowed for the formulation of practical conclusions and recommendations on the best ways to combine agile and traditional approaches in IT project management.

The research tool used in participant observation was an observation sheet, which allows for the systematic recording of observations and key information about the course of project processes. The observation was conducted in several project teams implementing IT projects of various types. It covered both projects carried out independently and an analysis of solutions used by other project managers. This made it possible not only to capture our own work experiences, but also to understand the good practices and challenges faced by other project leaders in the organisation. The observation focused primarily on medium-sized projects that concentrated on software development. These were mainly tactical projects that indirectly supported the implementation of the company's strategy.

The research observation period lasted two years, which allowed for the collection of a wide range of data on hybrid project management methods. Such a long observation period made it possible to collect material on various aspects of IT project implementation, both from a theoretical and practical perspective. During the research, an important element of the analysis was to identify challenges and problems arising at various stages of project implementation, as well as ways to solve them. During this time, numerous notes were made documenting key observations related to work methodology, decision-making and the integration of different management approaches.

4. Results

The responses of project managers regarding the possibility of integrating methodologies indicate that the organisation under study has general guidelines for integrating agile and traditional approaches, but these are not fully formalised. More experienced managers emphasised the freedom to adapt the way they work to the specifics of the project, while less

experienced managers pointed to the uncertainty resulting from the lack of clear procedures, especially at the beginning of the project. The organisation promotes the so-called hybrid model: iterative value delivery combined with classic planning, budget and quality management (modelled on PMBOK and PRINCE2). However, detailed solutions are left to the project team to decide.

In everyday practice The project managers surveyed indicated that in everyday practice they combine agile value delivery (e.g. sprints) with classic planning and control tools. One of the respondents emphasised that they use Scrum to carry out day-to-day tasks, but planning and project progress control are based on classic methodologies, which allows us to report in accordance with the requirements of the Steering Committee. In the projects observed, despite using the Scrum framework, some project managers regularly declare that they use planning elements characteristic of classic methodologies, such as creating detailed schedules, setting milestones, and formal risk management. Others, however, emphasised that for smaller or more dynamic projects, it is natural to use general product roadmaps rather than detailed schedules. Furthermore, according to the project managers surveyed, the initial project assumptions in the company are highly structured (in line with the classical approach), but changes that arise during implementation are introduced adaptively – updated in the backlog and discussed at ongoing meetings, which enables a quick response to business needs. In addition, it was also pointed out that risks are identified in accordance with classical methodologies, but their updating is agile, treating the register as a "living document".

In projects led by the managers surveyed, quality management is based mainly on a classic approach due to the specific nature of the industry. Quality-related processes are defined at the project planning stage and include detailed guidelines on coding standards, testing rules, and formal product verification and validation procedures. Comprehensive quality assurance plans are prepared for projects, specifying, among other things, unit, integration and system testing methods, as well as acceptance criteria for each functionality. At the same time, the respondents pointed out that agile elements, such as ongoing testing, support faster error detection and are a valuable addition to the classic approach, as well as contributing to improving the quality of the final product and shortening the time to deliver value to the customer.

In the area of stakeholder management, more experienced managers prefer agile, partnership-based relationships, while less experienced managers rely on formal documents and reports.

During the interviews, project managers also pointed to situations where traditional approaches complemented the limitations of agile methods and vice versa. Agile methodologies focus on flexible value delivery in short iterations, which often results in a lack of a comprehensive view of the project in the long term. On the other hand, in situations requiring a quick response to changing business needs, classic approaches showed limitations related to the high rigidity of processes and documentation. In such cases, the use of agile methodology

elements, such as product backlog, daily stand-up meetings and incremental delivery of solutions, allows managers to increase the flexibility of their activities and accelerate implementation.

The project managers interviewed identified several key challenges related to the integration of agile and traditional methodologies. More experienced managers pointed out that the most difficult aspect is maintaining a balance between a flexible approach to change and meeting formal requirements related to project reporting and control. An additional challenge identified by all interviewees was managing internal communication within the team, in particular the need to clearly define which elements of the process are carried out in an agile manner and which according to classic standards. According to managers, a lack of such transparency can lead to misunderstandings or divergent expectations within the project team.

The analysis showed that in the IT organisation surveyed, the integration of agile and traditional methodologies is deliberate, but not fully formalised. Interviews with project managers revealed that experienced managers appreciate the ability to adapt their working methods to the nature of the project, while less experienced managers perceive the lack of precise procedures as a barrier to effective task completion. It was also observed that elements of both approaches complement each other. As a result, combining both approaches allows for synergy and benefits both project teams and the entire organisation.

The benefits of integrating methodologies most frequently mentioned by project managers included: (1) increased flexibility, (2) a better fit between the approach and the type of project, and (3) the ability to respond more quickly to changes. Moreover, junior project managers were more likely to indicate that the structure of classic management gives them a sense of security and facilitates control over the project. Classic tools, such as schedules and risk registers, were their reference points for progress management and reporting. In turn, more experienced project leaders emphasised the advantages of the agile approach in day-to-day task execution, especially in terms of team engagement and speed of action. What is more, the managers surveyed indicated that in the areas of budget, schedule and scope, combining approaches allows for better control over key parameters. Classic tools such as Gantt charts, milestones and budgeting support precise planning, while agile practices – backlog and sprint management – allow for quick adjustments to the scope in line with current priorities and prevent team overload. Most managers also noted that a hybrid approach improves communication: Scrum meetings increase information flow and accountability, while formal communication channels facilitate collaboration with stakeholders and report preparation. As a result, the integration of approaches was perceived by respondents not as a compromise, but as a way to manage modern IT projects more effectively. Project managers unanimously emphasised that the hybrid approach has a positive impact on project implementation effectiveness. Iterative value delivery allows for quick detection of non-compliance, while classic control mechanisms ensure stability, quality and compliance with requirements. The integration of methodologies also improves work transparency and team engagement.

The research also found that the integration of agile and traditional methodologies is best applied in larger-scale projects with a high degree of uncertainty and a complex structure. Not only the nature of the project itself, but also organisational maturity, flexibility of work culture and clearly communicated rules of cooperation are key to the successful implementation of this approach. Table 2 summarises the characteristics that facilitate and hinder the integration of project management methodologies.

Table 1.
Features that facilitate and hinder the integration of project management methodologies in IT projects

Area	Features conducive to effective integration	Features hindering integration
Project type	Medium and large projects, high complexity, changing requirements, longer duration	Small projects with clear requirements and short duration
Nature of requirements	Frequent changes, need for an iterative approach	Stable and fully defined requirements
Organisational structure	Flexibility, no excessive bureaucracy, team autonomy	Rigid hierarchy, excessive control, lack of team autonomy
Organisational culture	Openness to change, trust in the project manager, supportive management style	Conservatism, strong central control, low acceptance of experimentation
Team experience	Knowledge of working in different methodologies, ability to adapt and make decisions	Lack of experience in working in a hybrid environment or low methodological competence
Communication and transparency	Clear definition of the project management style, communication of the principles and objectives of the hybrid approach	Uncertainty in the choice of methodology, lack of understanding of the practices used by the team
Project phase management	Ability to flexibly switch between agile and classic approaches depending on the project stage	Strict adherence to a single methodology throughout the project

Source: own study.

As shown in Table 2, well-functioning hybrid projects were characterised by transparency regarding the chosen working style, openness to adaptation, and a conscious separation of areas where agility or classic control mechanisms work best. On the other hand, a lack of clarity and failure to communicate methodological assumptions significantly reduces the effectiveness and commitment of the team. These conclusions confirm that the success of integration lies not only in the method itself, but in its thoughtful and flexible implementation in projects.

5. Discussion

The article posed three research questions. The first question referred to the way of integrating agile and traditional approaches in order to achieve the best project results. The second was related to the key benefits of integrating agile and traditional methodologies, and the third referred to the types of IT projects for which the integration of agile and traditional methodologies is most effective.

Answering the first question, it can be indicated that integrating agile and traditional methodologies is challenging, but at the same time offers a number of opportunities to improve IT project management. Management plays a key role in the effective implementation of a hybrid approach, as it sets the direction for organisational change, supports teams and establishes rules and standards of operation. What is more, effective integration of methodologies requires not only knowledge of both approaches, but above all, their conscious application based on a reliable diagnosis of project characteristics, such as its scale, complexity, risk level and team structure. According to research, the greatest effectiveness in IT project management can be achieved through a thoughtful combination of approaches tailored to the specifics of a given project. On the one hand, such integration allows for flexible response to changes and increases team efficiency, while on the other hand, it provides structure, control and predictability. This is also confirmed by the results of other researchers (e.g. Gemino et al., 2021; Reiff, Schlegel, 2022), which indicate that a hybrid approach to project management can deliver the same budgetary, time, scope and quality results as a traditional approach, while achieving the same level of stakeholder success as an agile approach.

Regarding the second research question, it should be noted that the analysis of interviews with project managers clearly indicates that the integration of agile and traditional methodologies in the IT environment brings a number of benefits to both project teams and the entire organisation. The hybrid approach allows combining the predictability and formalism of traditional methodologies with the flexibility and iterativeness of agile approaches. This combination promotes greater efficiency, improves the quality of delivered products and team engagement, and increases stakeholder satisfaction through better transparency and faster response to change. These results are consistent with reports from other researchers (e.g., Azenha, Reis, Fleury, 2020; Binder et al., 2014; Reiff, Schlegel, 2022).

Answering the third research question, it is important to point out that the integration of agile and traditional methodologies is an effective approach to IT project management, especially in environments characterised by high complexity, changing requirements, longer duration and the need for rapid adaptation. This is also revealed in Tanveer's (2015) research, which indicates that hybrid project management is particularly suitable for larger organisations and projects. Furthermore, effective integration of methodologies is possible primarily in organisations with a flexible structure, an open organisational culture that supports experimentation and rapid learning, and project teams with the relevant experience and ability to make decisions in conditions of uncertainty. Features conducive to integration also include the presence of a PMO supporting teams, the use of tools that promote transparency of activities, and the willingness to switch between agile and classic approaches depending on the stage of the project.

6. Conclusion

The article contributes to the literature on project management, focusing on the possibilities of integrating agile and traditional methodologies in the IT project environment. The results obtained indicate that the integration of agile and traditional approaches enables organisations to combine operational flexibility with structured governance, supporting adaptation to changing requirements while maintaining control over project objectives, budget and schedule. Furthermore, the article assesses the potential of the hybrid approach as a practical solution for reconciling dynamic business needs with the requirements of formal project supervision.

From a theoretical perspective, the study contributes to the discussion on hybrid project management by showing that hybrid methodologies should be treated as context-dependent configurations rather than fixed models, which reflects the ongoing debate concerning the lack of unified procedures for their implementation.

In practical terms, the article responds to the needs of companies running IT projects, showing how the integration of agile elements with traditional PMBOK or PRINCE2 standards allows long-term project goals to be harmonised with current operational requirements. The findings also served to define the following recommendations.

As for the organisation, the following recommendations are proposed: (1) developing internal standards or a guide to good practice in the use of a hybrid approach. An important element of such a guide should be the establishment of clear criteria for selecting the proportion of the agile and classic approaches, depending on the characteristics of a specific undertaking (type and scale of the project, its complexity, or regulatory conditions), (2) introducing mechanisms enabling cyclical assessment of the impact of scope changes on the budget and deadlines, e.g. through strategic reviews involving stakeholders, and the development of a transparent change management policy that clearly defines when decisions can be made by the team and when they require management approval, (3) standardisation of the communication model in hybrid projects. Such a model should include both agile elements (such as short, frequent team meetings and backlog updates) and classic elements (e.g. monthly progress reports, meetings with the Steering Committee). This standardisation can take the form of a so-called "project communication template" or a communication procedure within the PMO (Project Management Office), (4) development of a uniform project report template that takes into account key performance indicators (KPIs), scope implementation status, budget utilisation, schedule and problem identification, and (5) introduction of systematic methodological reviews and project audits, carried out on a regular basis. Such activities will not only allow for ongoing assessment of the compliance of project practices with the methodology assumptions, but above all for the identification of gaps, risks and areas for improvement. It is important that the evaluation is constructive, serves learning at the organisational level and leads to real process improvement, rather than merely meeting formal

requirements. The conclusions drawn from the audits should be translated into specific improvement measures, e.g. updating the methodology guide, modifying the tools supporting the work of project teams, or correcting reporting procedures.

Future research may focus on developing and validating unified frameworks for implementing hybrid project management methodologies in different organisational and project contexts, as well as on identifying factors that influence their long-term effectiveness in IT environments.

References

1. Almeida, F., Lopes, J., Calistru, C. (2024). Hybrid Agile Models for IT Project Management: A Scoping Review. *Information*, *Vol. 15, Iss. 10, No. 592,* pp. 1-20, 10.3390/info15100592.
2. Azenha, F., Reis, D., Fleury, A. (2020). Hybrid project management: A systematic literature review. *Journal of Modern Project Management*, *Vol. 8, Iss. 1,* pp. 1-19, 10.5585/jmpm.v8i1.1172
3. Binder, J., Aillaud, L., Schilli, L. (2014). The Project Management Cocktail Model: An Approach for Balancing Agile and ISO 21500. *Procedia Social and Behavioural Sciences 27th IPMA World Congress, vol. 119*, pp. 182-191, doi: 10.1016/j.sbspro.2014.03.022
4. Boehm, B., Turner, R. (2005). Management Challenges to Implementing Agile Processes in Traditional Development Organisations. *IEEE Software, vol. 22, no. 5,* pp. 30-39, doi: 10.1109/MS.2005.129
5. Brzozowski, M. (2020). *The use of project management methodologies in the light of empirical research. Selected aspects of process, project and risk management in enterprises*. Łódź: University of Łódź Press, pp. 140-142.
6. Cavalieri Barbosa, A.M., Saisse, M.C.P. (2019). Hybrid project management for sociotechnical digital transformation context. *Brazilian Journal of Operations & Production Management, vol. 16, no. 2*, pp. 316-332, doi: 10.14488/BJOPM
7. Chmielarz, W. (2012). Criteria for selecting IT project management methods. *Management Problems, 10(3),* pp. 25-40.
8. Conforto, E., Salum, F., Amaral, D.C., da Silva, S.L., de Almeida, L.F.M. (2016). Can Agile Project Management Be Adopted by Industries Other than Software Development? *Project Management Journal*, *Vol. 47, No. 3,* pp. 21-34, doi:10.1177/875697281604700303
9. Cooper, R.G., Sommer, A.F. (2018). Agile–Stage-Gate for Manufacturers. *Research-Technology Management, vol. 61, no. 2*, pp. 17-26, doi: 10.1080/08956308.2018.1421380

10. Copola Azenha, F., Aparecida Reis, D., Leme Fleury, A. (2021). The Role and Characteristics of Hybrid Approaches to Project Management in the Development of Technology-Based Products and Services. *Project Management Journal, vol. 52, no. 1,* pp. 90-110, doi: 10.1177/8756972820956884
11. Gemino, A., Horner Reich, B., Serrador, P.M. (2021). Agile, Traditional, and Hybrid Approaches to Project Success: Is Hybrid a Poor Second Choice? *Project Management Journal, vol. 52, no. 2*, pp. 161-175, doi: 10.1177/8756972820973082
12. Joslin, R.S., Müller, R. (2015). Relationships between a project management methodology and project success in different project governance contexts. *International Journal of Project Management, 33(6)*, 1377-1392.
13. Jovanović, P., Orač, D., Milinković, D. (2022). The relationship between traditional project management, agile project management (APM) and project success. *International Journal of Organisational Analysis*, *Vol. 30, No. 6,* pp. 1517-1537, doi:10.1108/IJOA-02-2022-3149
14. Krug, M., Ays, J., Sauermann, F., Prote, J.-P., Schuh, G. (2019). Synchronisation of Scrum and Stage-Gate in Hybrid Product Development Projects of Manufacturing Companies. In: J.P. Wulfsberg, W. Hintze, B.-A. Behrens (Eds.), *Production at the leading edge of technology* (pp. 421-430). Proceedings of the 9th Congress of the German Academic Association for Production Technology (WGP), 30 September - 2 October, Hamburg/Berlin/Heidelberg: Springer.
15. Krysiak, M., Głowania, S. (2017). IT project management methodologies and their risks: review and application. *Scientific Journals of the University of Economics in Katowice.* Katowice, p. 92.
16. Łabuda, W. (2015). Agile and traditional approaches to software development projects. *Scientific Journals of the Warsaw University of Information Technology*, pp. 59-60.
17. Liebert, F. (2017). Project management in IT companies – a literature review. *Scientific Journals, Organisation and Management*. Silesian University of Technology.
18. Mirzaei M. et al. (2025). Customising Hybrid Project Management Methodologies. *Production Planning & Control*, doi:10.1080/09537287.2024.2349231
19. Moeuf, A., Lamouri, S., Pellerin, R., Tamayo, S. (2023). Hybrid Project Management for Digital Transformation: A Scoping Review. *Journal of Cleaner Production*, *Vol. 413, No. 137419*, pp. 1-14, doi:10.1016/j.jclepro.2023.137419
20. Pietras, P., Szmit, M. (2003). *Project Management. Selected Methods and Techniques*. Łódź: Oficyna Księgarsko-Wydawnicza "Horyzont", pp. 7-10.
21. Reiff, M., Schlegel, M. (2022). Hybrid Project Management – A Systematic Literature Review. *International Journal of Information Systems and Project Management*, *Vol. 10, Iss. 2,* pp. 23-41, 10.12821/ijispm100203

22. Serrador, P., Pinto, J.K. (2021). Agile, Traditional, and Hybrid Approaches to Project Success: Is There a Relationship? *Project Management Journal*, *Vol. 52, No. 4,* pp. 389-404, doi:10.1177/8756972820973082
23. Strojny, J., Szmigiel, K. (2015). Comparative analysis of approaches to project management. *Modern Management Review*, pp. 252-253.
24. Tanveer, M. (2015). *Agile for large scale projects — A hybrid approach*. 2015 National Software Engineering Conference (NSEC), pp. 14-18.
25. Trzeciak, M., Spałek, S. (2016). Risk management in traditional and agile project management methodologies. *Scientific Journals, Organisation and Management*. Silesian University of Technology, pp. 485-488.
26. Zasa, F.P., Patrucco, A., Pellizzoni, E. (2020). Managing the Hybrid Organisation: How Can Agile and Traditional Project Management Coexist? *Research-Technology Management*, *Vol. 64, No. 1,* pp. 54-63, 10.1080/08956308.2021.1843331
27. Žužek, T., Kušar, J., Rihar, L., Berlec, T. (2020). Agile-Concurrent hybrid: A framework for concurrent product development using Scrum. *Concurrent Engineering, vol. 28, no. 4,* pp. 255-264, doi: 10.1177/1063293X20958541

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ORGANIZATIONAL CULTURE IN HEALTHCARE: PERSPECTIVES OF FOUR GENERATIONS OF MEDICAL STAFF

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Purpose: The purpose of this study is to examine how healthcare personnel in Poland perceive organizational culture and whether these perceptions differ across generations. The research aims to identify generational differences in the evaluation of workplace atmosphere, work-life balance, and the professional climate fostered by management, thereby contributing to a better understanding of workforce diversity in healthcare institutions.
Design/methodology/approach: A quantitative survey was conducted among 506 healthcare professionals in Poland, including physicians, nurses, midwives, and other clinical staff. The survey used a five-point Likert scale to assess perceptions of organizational culture. Data were analyzed using descriptive statistics, reliability analysis, Kruskal-Wallis tests, and post hoc pairwise comparisons to identify differences between generational groups.
Findings: The study found significant generational differences in perceptions of organizational culture. Older generations (Generation X and Baby Boomers) rated workplace atmosphere, work-life balance, and the professional climate fostered by management more positively than younger generations (Millennials and Generation Z). Generation Z reported the lowest evaluations across all three measured dimensions of organizational culture.
Research limitations/implications: The cross-sectional design limits causal inference, and contextual variables such as type of healthcare facility or employment conditions were not controlled. Future research should adopt longitudinal and mixed-method approaches to examine whether these generational differences are stable over time and how they impact organizational performance in Polish healthcare settings.
Practical implications: The findings indicate that perceptions of organizational culture differ across generational groups among healthcare personnel. Healthcare managers may benefit from considering how employees from different generational cohorts perceive workplace atmosphere, work-life balance, and the professional climate fostered by management.
Social implications: The study demonstrates that healthcare personnel from different generations perceive organizational culture differently. Recognizing these differences may support a more inclusive work environment and enhance staff well-being across all age groups.
Originality/value: This study provides empirical evidence of generational differences in healthcare personnel's perceptions of organizational culture in Poland. By comparing four generational cohorts using a consistent measurement framework, it addresses a notable gap in the literature on workforce diversity and organizational culture in healthcare settings.
Keywords: organizational culture; generational diversity; healthcare workforce.
Category of the paper: Research paper.

1. Introduction

Healthcare organizations operate in complex and dynamic environments, where the quality of care depends on clinical skills and resources, as well as the underlying organizational culture.

Organizational culture encompasses shared values, beliefs, norms, and practices that guide employees' behavior and influence decision-making, communication, and collaboration within institutions (Praveena, Fonceca, 2023; Schein, Schein, 2017). A positive culture can enhance staff satisfaction, engagement, and retention, while also improving patient outcomes and overall institutional performance. Conversely, cultural misalignment or neglect may contribute to stress, burnout, and reduced quality of care (Georgousopoulou et al., 2025; Kiptulon et al., 2024; Qin et al., 2023; Rafi'i et al., 2025).

In recent years, research has increasingly highlighted the role of generational diversity as a factor shaping perceptions and expectations within healthcare organizations. Different generational cohorts - Baby Boomers, Generation X, Millennials (Generation Y), and Generation Z - exhibit distinct work values, leadership preferences and attitudes towards technology. These differences can impact teamwork, communication, and the effectiveness of organizational policies and interventions. Understanding how generational composition interacts with organizational culture is therefore essential for designing strategies that foster collaboration, engagement, and high-quality patient care (Lee, Lee, 2023).

Polish healthcare institutions are undergoing demographic and structural changes, including shifts in the age distribution of physicians, nurses, and other clinical staff (GUS, 2025). These changes may further influence how organizational culture is perceived and enacted in daily practice. Organizational culture has been shown to play a critical role in the effectiveness and overall performance of healthcare organizations (Qin et al., 2023). Consequently, it is important to monitor and review the evolving literature on organizational culture in healthcare to identify emerging insights and strategies for improving healthcare delivery. Despite increasing interest in this area, empirical studies examining the relationship between organizational culture and generational diversity in Poland remain limited.

The aim of this study was to examine how healthcare personnel in Poland perceive organizational culture and whether these perceptions differ across generational cohorts. Prior research indicates that differences in work values and attitudes exist among employees of different generations (Caron, Bowers, 2000; Godino et al., 2025; Tan, Chin, 2023). Based on this literature, the following hypothesis was formulated:

H1: Perceptions of organizational culture in Polish healthcare institutions differ significantly according to employees' generational affiliation.

2. Organizational Culture in Healthcare Organizations

Organizational culture has been conceptualized in multiple ways across the literature. Deshpande and Parasuraman (1986) define it as a set of principles, often subconscious, that bridge the gap between unwritten rules and actual organizational behavior. Griffin (2017) emphasizes shared values that help members understand what the organization stands for, how it operates, and what it considers important. Hofstede (2000) describes culture as a set of values, norms, or organizational rules effectively instilled in a group, while Pettigrew (1979) frames it as a system of widely accepted meanings for a given group at a particular time. Schein (1998) conceptualizes organizational culture as a pattern of shared, basic assumptions developed by a group to solve the problems of external adaptation and internal integration. Likert and Likert (1976) describe it as the dominant pattern of values, myths, beliefs, assumptions, and norms, expressed through language, symbols, artifacts, technology, management practices, attitudes, and actions. Morgan (1997) interprets culture as a developmental pattern reflected in social knowledge systems, ideology, values, rules, and daily rituals, whereas Lewis (1997) emphasizes interpretative frameworks and core values that create unique meaning within an organization. Siehl and Martin (1984) highlight the cohesive function of culture, describing it as the "glue" that binds an organization together through shared patterns of meaning. Finally, Juchnowicz (2013) focuses on the behavioral aspect, defining organizational culture as an informal system of thinking and behavioral patterns within the organization. Collectively, these perspectives underline that organizational culture encompasses both formal and informal elements, shaping how members perceive, interpret, and act within their organizational environment.

In the context of healthcare, as emphasized by Sikorski (2002), organizational culture goes beyond standard definitions, encompassing specific aspects related to patient care, patient satisfaction, and the efficiency of medical staff. It can be understood as the sum of the shared values, attitudes, and beliefs across part of or the whole of an organization (e.g., across a medical division, an entire hospital, or a health service) (Braithwaite et al., 2018). In Poland, where the healthcare system is heavily dependent on public funding, organizational culture often reflects both the challenges associated with underfunding and the need to adapt to the evolving demands of patients and the broader environment (Sowińska-Domagała, Wolniak, 2025).

Organizational culture in healthcare settings has increasingly been recognized as a critical factor shaping staff attitudes and behaviors, patient outcomes, and institutional performance. It has been shown to influence a wide range of outcomes, including provider job satisfaction (Goodman et al., 2001; Joseph et al., 2023), patient satisfaction (Meterko et al., 2004; Tietschert et al., 2019), performance in acute hospital settings (Jacobs et al., 2013), patient safety (Singer et al., 2010), and the implementation of quality systems (Shortell et al., 1995).

In the Polish context, Pomaranik (2022) reported a positive correlation between organizational culture in hospitals and medical staff retention. Interest in organizational culture has been renewed recently, as challenges in healthcare quality and safety persist (Bates et al., 2023), and burnout among healthcare workers has become increasingly salient (Shanafelt et al., 2017), emphasizing its critical role in supporting effective and sustainable healthcare delivery (Mannion, Davies, 2018).

A recent systematic review by Rafi'i et al. (2025) demonstrates that organizational culture is significantly associated with provider work satisfaction, identifying six core cultural themes: continuous communication, organizational leadership, teamwork, employee involvement in decision-making, employee recognition, and autonomy. Earlier work confirms that organizational culture in hospitals also influences employee performance (Almutairi et al., 2022). The mechanisms by which culture exerts these effects are multifaceted. For example, Lu et al. (2022) found that a supportive culture correlates with staff well‑being and patient safety outcomes, while Kiptulon et al. (2024) report that positive organizational culture and climate are consistently associated with reduced work‑related stress among nurses, providing empirical evidence that culture can act as a protective factor in high‑demand clinical settings.

Leadership is a fundamental determinant of organizational culture in healthcare settings. Al-Shammary et al. (2023) highlight how leadership styles markedly influence both culture and performance, while Rovithis (2023) shows that interprofessional collaboration is intricately linked to organizational culture, indicating that culture can foster or inhibit cross‑disciplinary teamwork - a key element in modern care delivery. Beyond staff performance and leadership, research indicates that culture also impacts system‑level resilience and adaptability. Specific dimensions of organizational culture - including development, group, rational, and hierarchical cultures - are associated with healthcare supply chain resilience, highlighting culture's role in maintaining continuity of care during disruptions (Manda, 2017; Al-Ma'aitah, 2024). Moreover, technology orientation can strengthen the relationship between cultural dimensions and resilience outcomes, suggesting that culturally aligned technological capabilities may enhance organizational adaptability. The adaptation of measurement tools for culture in healthcare professional education has also been reported (Başer et al., 2025), indicating that cultural assessment is feasible and essential for strategic development.

Despite this growing body of research, several gaps remain. Many studies are cross‑sectional and limited to single organizations or professions, making it difficult to infer causality or generalize findings. Rafi'i et al. (2025) emphasize that although the link between culture and satisfaction is robust, more rigorous longitudinal and mixed‑method studies are needed. Furthermore, while teamwork, communication, and leadership dominate the literature, aspects such as culture's interaction with generational differences among staff remain under-explored - an important omission given workforce heterogeneity.

Research on generational dynamics in healthcare increasingly emphasizes that four generational groups - Baby Boomers (born approx. 1946-1964), Generation X (1965-1979), Millennials or Generation Y (1980-1994), and Generation Z (born from 1995 onwards) - differ in their work values, leadership expectations, and technology adoption (Tan, Chin, 2023). These generational differences are particularly relevant in the Polish context, where workforce demographics vary across professions. At the end of 2024, 166,515 physicians in Poland held the right to practice, of whom 141,193 were reported as working directly with patients. The largest age group among physicians was 30-39 years (20.4%), indicating a predominance of young- to mid-career professionals. Other core clinical professions working directly with patients included 36,965 dentists, 219,881 nurses, 28,828 midwives, and 62,087 physiotherapists (GUS, 2025). Midwives and some segments of the nursing workforce tend to be older on average, highlighting additional variability in workforce age structure. These demographic patterns provide an important context for organizational culture research, particularly when examining whether perceptions of organizational culture differ across generational groups.

3. Methods

A survey was conducted among healthcare professionals in Poland to collect research data. In total, 506 respondents took part in the study. Participation was voluntary, with full assurance of confidentiality and anonymity. To evaluate organizational culture, a five-point Likert scale was applied, ranging from 1 (strongly disagree) to 5 (strongly agree). The data obtained were processed using IBM SPSS Statistics 29. A reliability analysis was carried out to assess the properties of the measurement scale and its individual items. The overall organizational culture score did not follow a normal distribution, as indicated by the Shapiro-Wilk test. Subsequently, the data were analyzed using descriptive statistics and Kruskal-Wallis tests. In all analyzes, p-values below 0.05 were considered statistically significant.

4. Results

4.1. Characteristics of respondents

The study examined several socio-demographic variables to characterize the respondents and assess their suitability for participation. These included gender, age, healthcare profession, marital status, and years of work experience. The results are presented in Table 1.

Table 1.
Socio-demographic characteristics of the study participants (N = 506)

Construct		Frequency (N)	Percent (%)
Gender	Male	140	27.7
	Female	366	72.3
	Total	506	100.0
Age category and generations	Less than 31 years (Generation Z)	56	11.1
	Between 31-45 years (Millennials / Generation Y)	132	26.1
	Between 46-60 years (Generation X)	290	57.3
	Above 60 years (Baby Boomers)	28	5.5
	Total	506	100.0
Years of experience	Between 1-5 years	57	11.3
	Between 6-10 years	35	6.9
	Between 11-15 years	61	12.1
	Between 16-25 years	85	16.8
	Above 25 years	268	53.0
	Total	506	100.0
Marital status	Never married	57	11.3
	Married	377	74.5
	Widowed	18	3.6
	Divorced/separated	54	10.7
	Total	506	100.0
Healthcare profession	Physician	179	35.4
	Nurse	247	48.8
	Midwife	34	6.7
	Other	46	9.1
	Total	506	100.0

Source: Own elaboration.

The study results showed that the majority of respondents were female (72.3%), while male participants accounted for 27.7% of the total sample. This indicates a noticeable gender imbalance among the surveyed healthcare professionals, with women being significantly overrepresented.

In terms of age distribution, more than half of the respondents (57.3%) were aged 46-60 years, while 26.1% were between 31 and 45 years old. A smaller proportion (11.1%) were under 31 years, and 5.5% were over 60 years. The age structure therefore suggests that the majority of participants represented a mature, professionally active population rather than younger entrants or those approaching retirement in the healthcare workforce.

Regarding professional experience, more than half of the respondents (53.0%) reported over 25 years of work experience in healthcare institutions. Another 16.8% had between 16 and 25 years of experience, and 12.1% had worked for 11-15 years. A smaller proportion had shorter work experience: 11.3% had worked 1-5 years, and 6.9% reported 6-10 years of experience. This distribution indicates that the vast majority of participants possessed substantial professional experience, which likely enhanced the reliability of their responses in relation to the issues examined.

As for marital status, most respondents were married (74.5%), while 11.3% reported never having been married. Divorced or separated individuals accounted for 10.7%, and widowed participants for 3.6% of the total. These data suggest that the study group was largely composed of individuals with established family situations.

When analyzing healthcare professions, the largest group of respondents were nurses (48.8%), followed by physicians (35.4%) and midwives (6.7%). An additional 9.1% of participants belonged to other medical professions, including paramedics and laboratory diagnosticians. This distribution indicates that the sample reflected a diverse range of medical roles within the Polish healthcare system, with a predominance of nursing professionals.

4.2. Organizational culture in healthcare facilities - staff perspective

In order to examine the properties of the measurement scale and the items assessing organizational culture in the survey questionnaire for healthcare personnel, a reliability analysis was conducted. The detailed results of this analysis are presented in Table 2 and Figure 1.

Table 2.
Reliability analysis of the organizational culture items in the survey questionnaire for healthcare personnel and descriptive statistics of the variables (N = 506)

Construct	Variable	Mean	Standard Deviation
Organizational culture $\alpha = 0.790$	OC1. There is a friendly and supportive atmosphere in the healthcare facility	4.03	1.125
	OC2. Working conditions in the facility enable employees to maintain a work-life balance	3.77	1.336
	OC3. The management of the healthcare facility creates a professional climate in which medical staff are treated with respect	3.79	1.386

Source: Own elaboration.

Values of Cronbach's alpha exceeding 0.70 indicate that the scale demonstrates satisfactory internal consistency (Azhar et al., 2022). The significance levels for the individual variables were very low ($p < 0.001$), indicating that the null hypothesis of the Shapiro-Wilk test, which assumes normal distribution of the variables, is rejected. Consequently, the distributions of the analyzed variables deviate from normality.

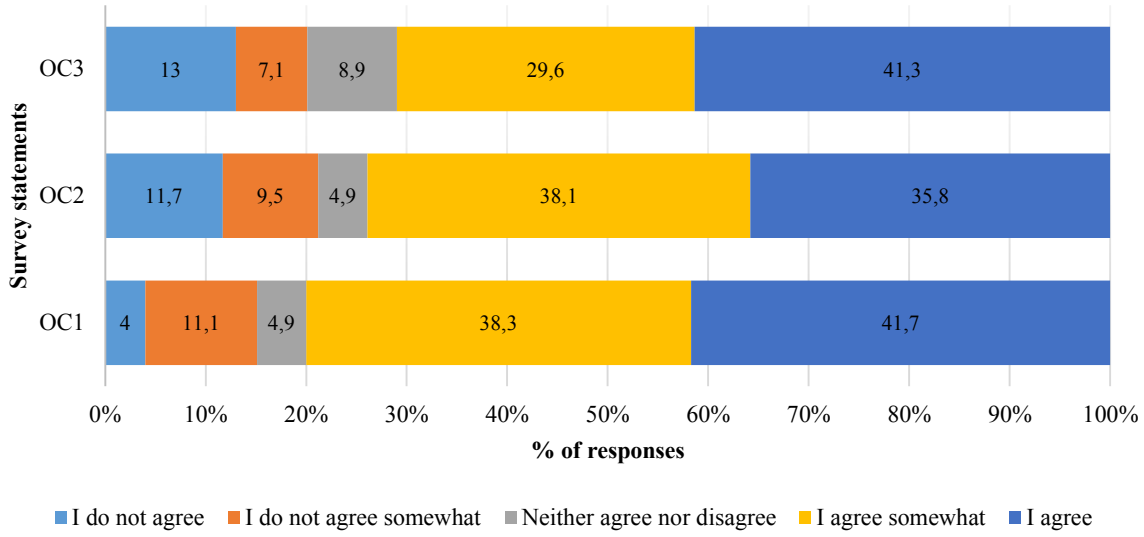


Figure 1. Distribution of survey responses.

Source: Own elaboration.

The results indicate that healthcare personnel rated aspects of organizational culture in their facilities at a moderately high level. The presence of a friendly and supportive atmosphere was assessed the highest (OC1: M = 4.03; SD = 1.125). Slightly lower ratings were given to the management's creation of a professional climate in which medical staff are treated with respect (OC3: M = 3.79; SD = 1.386), followed by the perception that working conditions allow employees to maintain a work-life balance (OC2: M = 3.77; SD = 1.336). These results suggest that staff generally view the organizational culture positively, though there remain areas that could be improved.

4.3. Differences in perceived organizational culture across staff generations

The next stage of the study examined whether ratings of individual aspects of organizational culture differed depending on the respondents' generational affiliation. Differences between generations were analyzed using the Kruskal-Wallis test, which is appropriate for nonparametric data (Wądołowska, 2013; Mondal et al., 2022).

Table 3.

Comparison of perceptions of organizational culture dimensions according to generation

Variable	Respondent's Generation	Mean rank	*Me*	*H(3)*	*p*	η^2
OC1. There is a friendly and supportive atmosphere in the healthcare facility.	Generation Z (*n* = 56)	192.25	4.00	16.894	**<0.001**	0.05
	Millennials (*n* = 132)	245.52	4.00			
	Generation X (*n* = 290)	270.73	4.00			
	Baby Boomers (*n* = 28)	235.13	4.00			
OC2. Working conditions in the facility enable employees to maintain a work-life balance.	Generation Z (*n* = 56)	189.17	3.00	28.278	**<0.001**	0.07
	Millennials (*n* = 132)	222.87	4.00			
	Generation X (*n* = 290)	278.38	4.00			
	Baby Boomers (*n* = 28)	268.84	4.00			

Cont. table 3.

OC3. The management of the healthcare facility creates a professional climate in which medical staff are treated with respect.	Generation Z (*n* = 56)	163.12	2.00	45.336	**<0.001**	0.10
	Millennials (*n* = 132)	221.15	4.00			
	Generation X (*n* = 290)	281.89	4.00			
	Baby Boomers (*n* = 28)	292.71	5.00			

Note. Me - median, H - Kruskal-Wallis H test; η2 - eta square, a measure of the strength of the association; p - an estimate of the probability that the observed difference between groups is random. The result of the analysis is statistically significant if the *p-value* is less than the assumed alpha threshold, which is 0.05.

Source: Own elaboration.

The aspects of organizational culture that significantly differed according to generation ($p < 0.05$) included all three analyzed dimensions: the presence of a friendly and supportive atmosphere in the healthcare facility, working conditions enabling work-life balance, and the creation of a professional climate by management in which medical staff are treated with respect.

The strongest generational differences were observed in the perception of respectful and professional management climate (OC3; $H = 45.336$, $p < 0.001$, $\eta^2 = 0.10$), indicating a moderate effect size. Slightly smaller but still statistically significant effects were found for work-life balance conditions (OC2; $H = 28.278$, $p < 0.001$, $\eta^2 = 0.07$) and friendly workplace atmosphere (OC1; $H = 16.894$, $p < 0.001$, $\eta^2 = 0.05$), both reflecting weak to moderate effects.

The analyzes indicate that the respondents' generation differentiates the perception of organizational culture dimensions. To identify the specific differences between generational groups, post hoc tests with Bonferroni correction were conducted. The results of these analyzes are presented in Table 4.

Table 4.

Significance value of pairwise comparisons with Bonferroni correction for organizational culture dimensions according to generation

Variable	Respondent's Generation	1	2	3
OC1. There is a friendly and supportive atmosphere in the healthcare facility.	1. Generation Z (*n* = 56)	-		
	2. Millennials (*n* = 132)	0.086	-	
	3. Generation X (*n* = 290)	**0.001**	0.469	-
	4. Baby Boomers (*n* = 28)	1.000	1.000	1.000
OC2. Working conditions in the facility enable employees to maintain a work-life balance.	1. Generation Z (*n* = 56)	-		
	2. Millennials (*n* = 132)	0.761	-	
	3. Generation X (*n* = 290)	**0.001**	**0.001**	-
	4. Baby Boomers (*n* = 28)	0.077	0.663	1.000
OC3. The management of the healthcare facility creates a professional climate in which medical staff are treated with respect.	1. Generation Z (*n* = 56)	-		
	2. Millennials (*n* = 132)	0.052	-	
	3. Generation X (*n* = 290)	**0.001**	**0.001**	-
	4. Baby Boomers (*n* = 28)	**0.001**	0.079	1.000

Source: Own elaboration.

It has been shown that:

- The organizational culture dimension related to a friendly and supportive atmosphere in the healthcare facility (OC1) was assessed significantly higher by Generation X representatives compared to Generation Z ($p = 0.001$). Other generational differences in this dimension were not statistically significant.
- The organizational culture dimension related to working conditions that enable employees to maintain a work-life balance (OC2) was also rated significantly higher by Generation X respondents than by Generation Z ($p = 0.001$) and Millennials ($p = 0.001$). No statistically significant differences were found between the other generational groups.
- The organizational culture dimension related to management creating a professional and respectful climate (OC3) was evaluated at a significantly higher level by Generation X and Baby Boomers compared to Generation Z ($p = 0.001$ for both comparisons). The difference between Generation X and Millennials was also statistically significant ($p = 0.001$), indicating that older generations perceived this aspect of organizational culture more positively.

Overall, the results suggest that older generations (Generation X and Baby Boomers) tend to rate the organizational culture of healthcare facilities more favorably, particularly in terms of professional climate and respect from management, while Generation Z consistently reported the lowest evaluations across all analyzed dimensions.

5. Discussion

The present study examined healthcare personnel's perceptions of selected dimensions of organizational culture and the extent to which these perceptions differ across generational cohorts. Overall, the findings indicate that all three analyzed dimensions of organizational culture - a friendly and supportive atmosphere (OC1), working conditions supporting work-life balance (OC2), and a professional climate characterized by respect from management (OC3) - were evaluated at moderately high levels. Importantly, the results demonstrate that perceptions of organizational culture are not uniform across generations. Statistically significant differences were identified between generational groups, with older cohorts generally reporting more favorable assessments, while the youngest respondents tended to provide lower evaluations.

The present study demonstrated significant generational differences in perceptions of whether management creates a professional climate in which medical staff are treated with respect (OC3). This dimension was evaluated more positively by representatives of Generation X and Baby Boomers compared to Generation Z, while Generation X also reported significantly higher ratings than Millennials. These findings indicate that older generations perceive the

professional and respectful climate created by management more favorably than younger cohorts.

Previous research consistently emphasizes that respect from leaders and supervisors constitutes a central element of how healthcare personnel evaluate their professional environment. Studies on workplace dignity indicate that being treated with respect by management and colleagues is a core component of perceived organizational culture in healthcare settings (de Beer et al., 2024). It has also been shown that medical staff are unable to fully uphold patients' dignity in work environments where their own professional dignity is not respected (Gallagher, 2004). Similarly, qualitative research among nurses has identified lack of respect and insufficient managerial support as frequently reported barriers to a respectful and professional work climate (Nouri et al., 2019).

Generational perspectives on respect in healthcare workplaces have also been documented in earlier studies. Research focusing on older cohorts of medical staff indicates that being valued and respected by management is regarded as a particularly important aspect of the work environment among more experienced professionals (Dols et al., 2010; Wieck et al., 2010). This aligns with the higher OC3 ratings observed among Generation X and Baby Boomers in the present study.

In contrast, evidence from studies involving younger cohorts suggests a less favorable perception of respect in the workplace. Tan and Chin (2023) reported that Generation Y and Generation Z healthcare staff obtained the highest recognition-related scores indicating feelings of insufficient respect or consideration, particularly in relation to age. More recent findings further suggest that Generation Z medical staff may experience a sense of inadequate respect and recognition that has not been widely reported in earlier research (Kanste et al., 2025). Qualitative evidence also indicates that younger staff, especially Generation Z, often perceive their opinions as undervalued by colleagues from other generations in clinical settings (Al-Moteri et al., 2025).

Overall, these findings from prior research are consistent with the results of the present study, which show that younger generations - particularly Generation Z - evaluate the professional and respectful climate created by management less positively than older cohorts. This convergence of evidence suggests that generational affiliation is an important factor differentiating how respect and professionalism within healthcare management are perceived by medical staff.

Generational differences were also observed in perceptions of work-life balance conditions (OC2). In the present study, representatives of Generation X assessed work-life balance more positively than Generation Z and Millennials. Comparable patterns were reported by Tan and Chin (2023), who identified statistically significant generational differences in perceptions of work-life balance among hospital nurses, with younger cohorts assigning higher importance to this aspect than older generations. Their findings demonstrated a progressive increase in work-

life balance ratings from Baby Boomers to Generation Z, indicating that perceptions of this dimension of the work environment vary systematically across generations.

Evidence from nursing research further suggests that work-life balance constitutes a central element of favorable working conditions for younger healthcare professionals. Campbell et al. (2020) and Dols et al. (2010) demonstrated that nurses from Generation Y perceive balance between professional and private life as a key component of a supportive practice environment, while disturbances related to excessive workload and staffing shortages are associated with less favorable evaluations of working conditions and care quality.

More broadly, previous research indicates that younger cohorts of employees, particularly Generation Y and Generation Z, attach greater importance to work-life balance compared to older generations, including Baby Boomers (Christensen et al., 2018; Pawlak et al., 2022; Sanches et al., 2024; Stevanin et al., 2018). Integrative reviews of the nursing workforce indicate that Generation X and Generation Y nurses have been consistently described as valuing the maintenance of an appropriate balance between professional and personal life as part of their work environment perceptions (Rollán Oliveira, Siles González, 2021).

Collectively, these findings support the view that generational differences in the assessment of work-life balance observed in the present study are consistent with broader patterns reported in healthcare workforce research.

In the present study, the dimension related to a friendly and supportive atmosphere in healthcare facilities (OC1) was rated significantly higher by Generation X compared to Generation Z, while differences between other generational groups were not statistically significant. This suggests that older employees perceive the workplace as slightly more supportive than the youngest generation.

Comparable findings regarding levels of supportive and collegial work environments have been reported in healthcare contexts internationally. For instance, a study conducted among nurses during the COVID-19 pandemic in Poland found that younger staff reported lower evaluations of supportive aspects of the workplace compared to older staff, with the overall mean for interpersonal support being moderately high but still lower than other components (Klukow et al., 2022). Similarly, research involving a large sample of nurses in Sweden documented measurable positive assessments of support within healthcare teams, indicating that supportive workplace atmospheres are generally recognized by staff, though levels vary across contexts (Larsman et al., 2024). In addition, Shahnavazi et al. (2021) reported that among nurses in multiple hospital settings in Iran, those in older age groups generally rated the organizational climate more positively than younger nurses, indicating that a friendly and supportive atmosphere is commonly perceived at a moderate to high level across the workforce.

In contrast to the present study, Stuenkel et al. (2005) reported that as compared with the older nurses, younger nurses significantly perceived their superiors to be supportive.

Taken together, these findings suggest that the moderately high scores observed in the current study for OC1 align with existing evidence from healthcare settings. They also confirm that generational differences, particularly the lower evaluations reported by Generation Z compared to Generation X, are consistent with broader patterns of variation in perceived workplace support.

In conclusion, fostering a positive and inclusive organizational culture requires recognizing and integrating the distinct strengths of each generational group among medical staff. Baby Boomers contribute extensive clinical expertise and often serve as important mentors. Generation X staff bring adaptability and openness to modernizing care delivery and may play a key role in responding to evolving organizational challenges. Generation Y employees contribute technological competencies and can strengthen teamwork when their skills are appropriately recognized. Finally, Generation Z approaches learning, work, communication, and opportunity creation in ways that differ from previous generations, prompting healthcare organizations to adapt work environments to better reflect generational diversity (Christensen et al., 2018; Sanches et al., 2024). This perspective highlights the importance of designing healthcare work environments that acknowledge generational diversity while fostering a professional, respectful, and supportive climate across all staff.

In summary, the study provides empirical evidence that perceptions of key dimensions of organizational culture in healthcare - supportive atmosphere, work-life balance conditions, and respectful professional climate - vary significantly across generations. This finding aligns with prior healthcare workforce research and underscores the relevance of generational analysis in studies of organizational culture in medical settings.

This research has several limitations. The cross-sectional design limits the ability to infer causality, and the analysis did not control for contextual variables such as type of healthcare facility, ownership model, or employment conditions, which may influence cultural perceptions. Similar limitations have been reported in other recent systematic reviews (Kiptulon et al., 2024; Rafi'i et al., 2025). Future longitudinal studies should therefore examine whether the observed generational differences are stable over time or reflect transitional phenomena linked to the post-pandemic transformation of healthcare work environments (Pawlak et al., 2025).

6. Conclusions

This study provides empirical evidence confirming H1, demonstrating that perceptions of organizational culture in Polish healthcare institutions differ significantly according to employees' generational affiliation. Older generations, particularly Baby Boomers and Generation X, consistently evaluated key dimensions of organizational culture - supportive

workplace atmosphere (OC1), work-life balance conditions (OC2), and a professional climate characterized by respect from management (OC3) - more positively than the youngest cohort, Generation Z.

The demographic and professional composition of Polish healthcare institutions provides essential context for understanding these differences. Key factors include generational diversity, feminization of care professions, and regional disparities. Younger medical staff, especially Generation Z, enter the workforce during periods of high workload, rapid technological change, and systemic pressures intensified by the COVID-19 pandemic, which may shape their perceptions of organizational culture differently than those of older generations, who are accustomed to more stable and hierarchical settings (Al-Moteri et al., 2025; Almutairi et al., 2022; Pawlak et al., 2025; Tietschert et al., 2024).

In sum, organizational culture in healthcare is shaped by workforce characteristics, including generational composition. Understanding how different generational cohorts perceive organizational culture is therefore essential to interpret cultural dynamics in healthcare institutions and to inform tailored management strategies (Godino et al., 2025; Tan, Chin, 2023; Tussing, Tornwall, 2024). Recognizing these differences can help healthcare managers design policies and practices that effectively support a professional, respectful, and supportive organizational culture across all generational cohorts.

References

1. Al-Ma'aitah, N. (2024). Impact of organizational culture on healthcare supply chain resilience in Jordan: Moderating role of technology integration. *Problems and Perspectives in Management, 22(4),* 68-82. DOI: 10.21511/ppm.22(4).2024.06
2. Al-Moteri M., et al. (2025). The workplace expectations and preferences of Gen Z nurses: exploratory factor analysis. *BMC Nursing, 24(1),* 1121. DOI: 10.1186/s12912-025-03761-y
3. Almutairi R.L. et al. (2022). Analysis of organizational culture factors that influence the performance of health care professionals: A literature review. *Journal of Public Health in Africa, 13(Suppl. 2),* 2415. DOI: 10.4081/jphia.2022.2415
4. Al-Shammary M.R. et al. (2023). The Impact of Leadership Styles on Healthcare Organizational Culture and Performance. *The Medical Journal of Cairo University, 91(12),* 1707-1714. DOI: 10.21608/mjcu.2023.356792
5. Azhar, Y., Erdiansyah, Z., Rudiman, R. (2022). Validation of Immune Status Questionnaire (ISQ) in Indonesian Bahasa Language as a Simple Assessment of Perceived Immune Status. *Asian Pacific Journal of Cancer Prevention, 23(10),* 3261-3263. DOI: 10.31557/APJCP.2022.23.10.3261

6. Başer A. et al. (2025). Adapting organizational culture scale into healthcare professional education: a scale validity and reliability analysis. *Human Resources for Health, 23(33).* DOI: 10.1186/s12960-025-01006-2
7. Bates D.W. et al. (2023). The Safety of Inpatient Health Care. *The New England Journal of Medicine, 388(2)*, 142-153. DOI: 10.1056/NEJMsa2206117
8. Braithwaite, J. et al. (2018). When complexity science meets implementation science: A theoretical and empirical analysis of systems change. *BMC Medicine, 16(1).* DOI: 10.1186/s12916-018-1057-z
9. Campbell, C.M., Patrician, P.A. (2020). Generational preferences in the nursing work environment: A dimensional concept analysis. *Journal of Nursing Management, 28(4),* 927-937. DOI: 10.1111/jonm.13024
10. Caron, C.D., Bowers, B.J. (2000). Methods and application of dimensional analysis: A contribution to concept and knowledge development in nursing. In: B.L. Rodgers, K.A. Knafl (Eds.), *Concept development in nursing: Foundations, techniques, and applications* (pp. 285-319). Philadelphia, PA: Saunders.
11. Christensen, S.S., Wilson, B.L., Edelman, L.S. (2018). Can I relate? A review and guide for nurse managers in leading generations. *Journal of Nursing Management, 26(6),* 689-695. DOI: 10.1111/jonm.12601
12. de Beer, J., Rawas, H., Beheri, W. (2024). Workplace dignity amongst clinical nurses. *BMC Nursing, 23*, 715. DOI: 10.1186/s12912-024-02376-z
13. Deshpande, R., Parasuraman, R. (1986). Linking corporate culture to strategic planning. *Business Horizons, 29(3),* 29.
14. Dols, J., Landrum, P., Wieck, K.L. (2010). Leading and managing an intergenerational workforce. *Creative Nursing, 16(2),* 68-74.
15. Gallagher, A. (2004). Dignity and respect for dignity-two key health professional values: implications for nursing practice. *Nursing Ethics. 11(6),* 587-599. DOI: 10.1191/0969733004ne744oa
16. Georgousopoulou, V. et al. (2025). The role of organizational culture and emotional intelligence: enhancing healthcare professionals' job satisfaction. *Social Sciences, 14(5),* 286. DOI: 10.3390/socsci14050286
17. Godino, L. et al. (2025). Analysis of generational traits and intergenerational dynamics in the nursing workforce in Italy. *British Journal of Nursing (Mark Allen Publishing), 34(9),* 458-465. DOI: 10.12968/bjon.2024.0464
18. Goodman, E.A., Zammuto, R.F., Gifford, B.D. (2001). The competing values framework: Understanding the impact of organizational culture on the quality of work life. *Organization Development Journal, 19(3),* 58.
19. Griffin, W.R. (2017). *Podstawy zarządzania organizacjami*. Warszawa: PWN, 116-117.
20. GUS (2025). *Zasoby kadrowe w wybranych zawodach medycznych na podstawie źródeł administracyjnych w 2024 r.,* Warsaw. Retrieved from: https://stat.gov.pl/obszary-

tematyczne/zdrowie/zdrowie/zasoby-kadrowe-w-wybranych-zawodach-medycznych-na-podstawie-zrodel-administracyjnych-w-2024-r-,28,4.html

21. Hofstede, G. (2000). *Kultury i organizacje. Zaprogramowanie umysłu.* Warszawa: PWE, 38-41.
22. Jacobs, R. et al. (2013). The relationship between organizational culture and performance in acute hospitals. *Social Science & Medicine, 76,* 115-125. DOI: 10.1016/j.socscimed.2012.10.014
23. Joseph, M. L. et al. (2023). Creating an Organizational Culture and Climate of Meaningful Recognition for Nurse Managers. *Journal of Nursing Administration, 53(7/8),* 370-377. DOI: 10.1097/NNA.0000000000001302
24. Juchnowicz, M. (2013). *Zarządzanie kapitałem ludzkim*. Warszawa: PWE, 36.
25. Kanste, O. et al. (2025). The perceptions of Generation Z professionals and students concerning health-care work: A scoping review. *Nurse Education Today, 150*, 106678. DOI: 10.1016/j.nedt.2025.106678
26. Kiptulon, E.K. et al. (2024). Transforming nursing work environments: the impact of organizational culture on work-related stress among nurses: a systematic review. *BMC Health Services Research, 24(1),* 1526. DOI: 10.1186/s12913-024-12003-x
27. Klukow, J. et al. (2022). Klimat organizacyjny w środowisku pracy pielęgniarek i pielęgniarzy w czasie pandemii Covid-19. *Państwo i Społeczeństwo, 1,* 127-140.
28. Larsman, P., Pousette, A., Törner, M. (2024). The impact of a climate of perceived organizational support on nurses' well-being and healthcare- unit performance: A longitudinal questionnaire study. *Journal of Advanced Nursing, 80(12),* 4921-4932. DOI: 10.1111/jan.16188
29. Lee, S.A., Lee, J. (2023). Differences in occupational values, communication types, job satisfaction, and organisational commitment among clinical nurses across generations. *Frontiers in Psychology, 14*. DOI: 10.3389/fpsyg.2023.1174197
30. Lewis, S. (1997). Family Friendly Employment Policies: A Route to Changing Organizational Culture or Playing About at the Margins? *Gender, Work and Organization, 4(1*), 13-23.
31. Likert, R., Likert, J. (1976). *New Ways of Managing Conflict*. New York: McGraw-Hill.
32. Lu, L. et al. (2022). Patient Safety and Staff Well-Being: Organizational Culture as a Resource. *International Journal of Environmental Research and Public Health, 19(6),* 3722. DOI: 10.3390/ijerph19063722
33. Mandal, S. (2017). The influence of organizational culture on healthcare supply chain resilience: moderating role of technology orientation. *Journal of Business & Industrial Marketing, 32(8)*, 1021-1037. DOI: 10.1108/JBIM-08-2016-0187
34. Mannion, R., Davies, H. (2018). Understanding organisational culture for healthcare quality improvement. *BMJ, 363*. DOI: 10.1136/bmj.k4907

35. Meterko, M. et al. (2004). Teamwork culture and patient satisfaction in hospitals. *Medical Care, 42(5),* 492-498. DOI: 10.1097/01.mlr.0000124389.58422.b2
36. Mondal, S. et al. (2022). How to Conduct Inferential Statistics Online: A Brief Hands-On Guide for Biomedical Researchers. *Indian Journal of Vascular and Endovascular Surgery, 9(1)*, 54-62. DOI: 10.4103/ijves.ijves_116_21
37. Morgan, G. (1997). *Obrazy organizacji*. Warszawa: PWN.
38. Nouri, A. et al. (2019). Challenges of respect as promoting healthy work environment in nursing: A qualitative study. *Journal of Education and Health Promotion, 8(1),* 261. DOI: 10.4103/jehp.jehp_125_19
39. Pawlak, N. et al. (2025). Generational differences in nurse stress and coping strategies in relation to perceived patient safety: A cross-sectional study. *International Journal of Nursing Studies Advances, 9*, 100385. DOI: 10.1016/j.ijnsa.2025.100385
40. Pawlak, N., Serafin, L., Czarkowska-Pączek, B. (2022). Analysis of the influence of intergenerational differences on cross-generational cooperation among nurses. *Nursing in the 21st Century, 21(1(78)),* 45-49. DOI: 10.2478/pielxxiw-2022-0007
41. Pettigrew, A.M. (1979). On studying organizational cultures. *Administrative Science Quarterly, 24(4)*, 570-581.
42. Pomaranik, W. (2022). Zarządzanie zasobami ludzkimi w polskich szpitalach. In: A. Stępniak-Kucharska, M. Kapela (Eds.), *Współczesne problemy gospodarcze - Zrównoważony rozwój*. Płock: Kolegium Nauk Ekonomicznych i Społecznych, Politechnika Warszawska, 109-119.
43. Praveena, A.A., Fonceca, C.M. (2023). *Organizational Culture and Its Influence on Employee Behavior, 14(4).* 2945-2949. DOI: 10.24327/IJRSR
44. Qin, X. et al. (2023). Organisational Culture Research in Healthcare: A Big Data Bibliometric Study. *Healthcare (Basel, Switzerland), 11(2),* 169. DOI: 10.3390/healthcare11020169
45. Rafi'i, M.R. et al. (2025). Exploring the link between healthcare organizational culture and provider work satisfaction: a systematic review. *BMC Health Services Research, 25*, 904. DOI: 10.1186/s12913-025-12973-6
46. Rollan Oliveira, S., Siles González, J. (2021). Nursing Professionals within the Intergenerational Context during the 20th and 21st Centuries: an Integrative Review. *Investigación Y Educación En Enfermería, 39(3).* DOI: 10.17533/udea.iee.v39n3e14
47. Rovithis, M. (2023). Interprofessional collaboration and organizational culture in healthcare organizations. *Health & Research Journal, 9(2),* 58-60. DOI: 10.12681/healthresj.34191
48. Sanches, D. et al. (2024). Generational diversity in nursing practice environments-scoping review. *BMC Nursing, 23(1),* 928. DOI: 10.1186/s12912-024-02607-3
49. Schein, E.H, Schein, P.A. (2017). *Organizational Culture and Leadership*. John Wiley & Sons, Ltd.
50. Schein, E.H. (1998). Organizational culture. *American Psychologist, 45(2),* 109-119.

51. Shahnavazi, A. et al. (2021). The effect of perceived organizational climate on the performance of nurses in private hospitals. *Journal of Clinical Research in Paramedical Sciences, 10(2),* e108532. DOI: 10.5812/jcrps.108532
52. Shanafelt, T.D. et al. (2017). Addressing Physician Burnout: The Way Forward. *JAMA. 317(9),* 901-902. DOI:10.1001/jama.2017.0076
53. Shortell, S.M. et al. (1995). Assessing the impact of continuous quality improvement/total quality management: Concept versus implementation. *Health Services Research, 30(2),* 377.
54. Siehl, C., Martin, J. (1984). The role of symbolic management: How can managers effectively transmit organizational culture? In: J. Hunt, D. Hosking, C. Schriesheim (Eds.), *Leaders and Managers: International Perspectives on Managerial Behaviour and Leadership* (pp. 227-239). New York: Pergamon Press.
55. Sikorski, C. (2002). *Kultura organizacyjna*. Warszawa: C.H. Beck.
56. Singer, S. et al. (2010). Identifying Organizational Cultures That Promote Patient Safety. *Journal of Healthcare Management, 55(4),* 298-299.
57. Sowińska-Domagała, K., Wolniak, R. (2025) Identyfikacja kluczowych elementów kultury organizacyjnej wpływających na jakość opieki zdrowotnej w Polsce. *Management and Quality - Zarządzanie i Jakość, 7(2)*, 71-86.
58. Stevanin, S. et al. (2018). Workplace- related generational characteristics of nurses: A mixed- method systematic review. *Journal of Advanced Nursing, 74(6),* 1245-1263. DOI: 10.1111/jan.13538
59. Stuenkel, D., Cohen, J., Cuesta, K. (2005). The multigenerational nursing work force: essential differences in perception of work environment. *Journal of Nursing Administration, 35(6),* 283-28. DOI: 10.1097/00005110-200506000-00003
60. Tan, S., Chin, G. (2023). Generational effect on nurses' work values, engagement, and satisfaction in an acute hospital. *BMC Nursing, 22(1),* 88. DOI: 10.1186/s12912-023-01256-2
61. Tietschert, M.V. et al. (2019). Can organisational culture of teams be a lever for integrating care? An exploratory study. *International Journal of Integrated Care, 19(4),* 10. DOI: 10.5334/ijic.4681
62. Tietschert, M. et al. (2024). Revisiting organizational culture in healthcare: Heterogeneity as a resource. *Social Science & Medicine, 356,* 117165. DOI: 10.1016/j.socscimed. 2024.117165
63. Tussing, T.E., Tornwall, J. (2024). Generational Differences in the Nursing Workforce: Strategies for Nurse Leaders. *Nurse Leader, 22(5),* 602-608. DOI: 10.1016/j.mnl. 2024.03.007
64. Wądołowska, L. (2013). Zasady obliczania i interpretacji wyników. In: A. Gronowska-Senger (Ed.), *Przewodnik metodyczny badań sposobu żywienia* (pp. 38-67). Warszawa: Wydawnictwo Komitetu Nauki o Żywieniu Człowieka Polskiej Akademii Nauk.

65. Wieck, K.L., Dols, J., Landrum, P. (2010). Retention priorities for the intergenerational nurse workforce. *Nursing Forum, 45(1),* 7-17. DOI: 10.1111/j.1744-6198.2009.00159.x
66. Wong, K.P., Chan, A.H., Teh, P.L. (2020). How Is Work-Life Balance Arrangement Associated with Organisational Performance? A Meta-Analysis. *International Journal of Environmental Research and Public Health, 17(12),* 4446. DOI: 10.3390/ijerph17124446

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MULTIDIMENSIONAL LOCAL RESILIENCE – ANALYSIS OF ENVIRONMENTAL, DEMOGRAPHIC AND INFRASTRUCTURAL FACTORS

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Purpose: The aim of this study is to assess the level and determinants of multidimensional local resilience in Polish municipalities between 2013 and 2023. The analysis focuses on the influence of environmental, demographic, and infrastructural factors on the adaptive capacity and socio-spatial cohesion of territorial units.
Design/methodology/approach: The study is based on secondary data obtained from Statistics Poland (GUS), encompassing environmental, demographic, and infrastructural variables. A synthetic local resilience index was constructed using the CRITIC–TOPSIS method, and the results were analyzed with descriptive statistics, regression tests, ANOVA, and Spearman's rank correlation.
Findings: Local resilience in Poland depends primarily on environmental and infrastructural components, while demographic factors play a supporting role. Urban municipalities demonstrate the highest levels of resilience, with rural and urban–rural units showing intermediate values. The results indicate a synergistic interaction between environmental quality, infrastructure, and demographic stability, with a limited negative impact of intensive industrial activity.
Research limitations/implications: The limitations concern insufficient data availability and challenges in capturing dynamic interactions. Future research should include cultural and institutional components, as well as predictive models for infrastructure, demographic, and environmental policy development scenarios.
Practical implications: The findings highlight the need to monitor migration, mitigate the negative effects of industrial activity, and invest in green areas and urban ecosystems. Integrated spatial and investment planning that takes into account infrastructure, environmental protection, and demographic support enhances the adaptive capacity and cohesion of local communities.
Originality/value: The innovative approach applies synthetic indicators covering three dimensions of local resilience—environmental, demographic, and infrastructural—in an analysis spanning 2013-2023 for all Polish municipalities. The study enables an assessment of trends, spatial disparities, and changes in the structure of interdependencies among components, demonstrating the growing importance of environmental quality and the significant role of infrastructure in shaping local resilience.

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Keywords: multidimensional local resilience, Polish municipalities, environmental factors, infrastructure, demography.
Category of the paper: Research paper.

1. Introduction

Local resilience in its multidimensional aspect constitutes the foundation of the capacity of local government units (LGUs) to maintain the continuity of development processes despite the occurrence of destabilizing factors. This concept aligns with the paradigm of sustainable local development, which—as emphasized by M. Güngör and Z. Elburz (2024)—should be understood as a process that balances environmental, social, economic, and infrastructural aspects, requiring the creation of mechanisms resistant to diverse disruptions. Similarly, S. Arzo and M. Hong (2024) define resilience as an evolutionary and adaptive process encompassing environmental, infrastructural, economic, social, human, and institutional dimensions. This process enables the absorption of disturbances, the restoration of functionality, and the establishment of lasting preventive mechanisms. According to G. Bristow and A. Healy (2014), the limits of resilience become apparent when the accumulation of crises exceeds the adaptive capacity of local authorities, exposing deficits in territorial, economic, and social cohesion. Consequently, this leads to developmental imbalance and the deepening of local disparities.

Adaptive capacity, as one of the principal components of local resilience, defines the potential of LGUs to survive and develop under conditions of uncertainty, manifested through flexible responses to change and the adjustment of local policies. As A. Busłowska and J. Marcinkiewicz (2023) indicate, the limits of this capacity emerge when there is a shortage of financial, technological, or competency-related resources, which constrains the effectiveness of adaptive actions. A. Choryński, I. Pińskwar, D. Graczyk, and M. Krzyżaniak (2022) highlight territorial cohesion as a key factor determining adaptive capacity, noting that the uneven development of central and peripheral regions negatively affects local resilience levels. According to J. Zaucha and T. Komornicki (2019), social, economic, and territorial cohesion constitute essential conditions for the effectiveness of adaptive actions, enabling the mobilization of social capital, stakeholder cooperation, and the building of trust between residents and local authorities. Deficits in these areas lead to weakened implementation capacity of LGUs and reduced legitimacy of their actions.

As Y. Lv and M.N. Islam Sarker (2024) emphasize, the effectiveness of local adaptive strategies largely depends on the integration of green infrastructure, stability of local policies, technological innovation, and the development of social competences. P. Chamusca (2023) notes that a fragmentary analysis focused on a single dimension of resilience proves less effective than an integrated approach encompassing physical, social, and institutional aspects

simultaneously. In this context, S.J. Birchall, S. Kehler, and S. Weissenberger (2025) stress that urban and regional planning integrating infrastructure, spatial development, and public services constitutes a key instrument for supporting adaptation and strengthening the resilience of local communities—particularly in the face of the growing risks associated with climate change.

The aim of the study is to assess the level and determinants of multidimensional local resilience in Polish municipalities between 2013 and 2023. Particular attention is given to the influence of environmental, demographic, and infrastructural factors on the adaptive capacity and socio-spatial cohesion of territorial units in the context of increasing socio-economic and environmental uncertainty. The study focuses on three main research questions. First, what are the spatial and temporal differences in the level of multidimensional local resilience among urban, rural, and urban–rural municipalities in Poland between 2013 and 2023? Second, which factors—environmental, demographic, or infrastructural—most strongly determine the level of local resilience, and how has their significance evolved over the analyzed period? Third, how does the differentiation of local resilience affect the balance between adaptability and socio-spatial cohesion of municipalities, and what are the implications for regional development policy and local resource management?

The innovative aspect of this study lies in the application of synthetic indicators of local resilience encompassing three complementary dimensions—environmental, demographic, and infrastructural—for all Polish municipalities in an analysis covering the years 2013-2023. This approach enables a comprehensive assessment of trends, determinants, and spatial variations in resilience, accounting for the type of municipality (urban, rural, or urban–rural) and the "resilience–cohesion trade-off" effect. Empirical findings indicate an increasing significance of the environmental component, alongside the sustained role of infrastructure, which carries important implications for spatial planning, environmental policy, and adaptive strategies under conditions of growing uncertainty.

2. Literature review

R. Martin (2012) emphasizes that the concept of resilience is inherently multidimensional, encompassing, among other aspects, the ability of economic systems to regain equilibrium following the occurrence of shocks. M. Boston, D. Bernie et al. (2024) observe that resilience, originally defined as the capacity of systems to absorb disturbances and maintain core functions, has evolved across disciplines—from disaster management and urban planning to socio-ecological research—adopting definitions and approaches tailored to the specific contexts of each field.

In the environmental and infrastructural dimensions, local resilience varies according to the degree of exposure to extreme weather events such as floods, droughts, or heatwaves. As N. Kapucu, Y. Ge, E. Rott, and H. Isgandar (2024) note, municipalities more severely affected by such phenomena tend to develop recovery resilience, whereas less exposed communities cultivate creative resilience, oriented toward the implementation of innovative adaptive measures. The long-term maintenance of ecosystem functions requires the preservation of biodiversity, which supports adaptation to climate change. T.H. Oliver, M.S. Heard et al. (2015) emphasize that environmental resilience reflects the capacity of ecosystems to regenerate after disturbances and to maintain key functions under increasing climatic pressures. In the social dimension, according to Y. Liu, L. Cao, D. Yang, and B.C. Anderson (2022), social capital, trust, and community ties play a pivotal role in fostering resilience by enabling collective action and cooperative adaptation in response to crises.

L. Briguglio, G. Cordina, N. Farrugia, and S. Vella (2009) define economic resilience as an economy's capacity—shaped by public policy—to counteract and recover from the effects of shocks. B. Eichengreen, D. Park, and K. Shin (2024) point out that factors such as flexible exchange rates, trade openness, stable current account balances, and high foreign reserves strengthen economic resilience, whereas excessive financial liberalization or rapid private credit growth during expansionary periods may weaken it.

Social resilience refers to the ability of communities to adapt and restore functionality after disruptions, grounded in social capital, trust, and community cohesion. It is strengthened by education, risk awareness, civic participation, and stakeholder integration. However, as S. Carrasco, Ch. Ochiai, and L.M. Tang (2024) observe, excessively strong intra-group ties may constrain external cooperation and foster exclusion. Social resilience tends to increase in response to disasters, though significant spatial disparities persist—higher in central areas and lower in peripheral regions. Its determinants include economic and demographic factors, access to public services, and the frequency of extreme events, the effects of which are nonlinear.

Multidimensional resilience encompasses the interactions between social, economic, environmental, infrastructural, institutional, and technological dimensions. As S.B. Tan (2021) highlights, the interdependence between resilience dimensions and public health determinants suggests that highly resilient communities possess integrated social, economic, and environmental resources, enabling effective prevention and mitigation of disaster impacts. J.E. Cinner and M.L. Barnes (2021) argue that a holistic approach must account for the feedbacks among these dimensions, allowing systems to respond flexibly to changes and disturbances. According to P. Sánchez-Zamora and R. Gallardo-Cobos (2020), the resilience of socio-ecological systems depends on assets, flexibility, social organization, learning capacity, and agency—all of which condition responses to environmental change and the effects of climate variability. At the same time, feedback loops between social and environmental factors may generate socio-ecological traps, perpetuating undesirable system states.

In the urban and regional context, A. Naderi and K. Khoshnevis (2025) observe that resilience integrates social, economic, and infrastructural dimensions, enabling the absorption of shocks, maintenance of core functions, and adaptation or transformation amid long-term change. Urban and regional resilience is therefore multidimensional, encompassing social, economic, ecological, infrastructural, institutional, and human components. Under conditions of accelerated urbanization and increasing risks such as climate change or resource depletion, effective resilience building requires interdisciplinary integration, cross-sectoral collaboration, and innovative governance strategies. N. Kapucu, Y. Ge, E. Rott, and H. Isgandar (2024) emphasize that such an approach necessitates identifying key challenges within each dimension, analyzing their interactions, and enhancing adaptive and recovery capacities while striving for long-term stability and sustainable development.

Natural resources function within complex socio-ecological systems that are vulnerable to change and unforeseen disruptions, posing significant governance challenges and underscoring the importance of systemic resilience. As S. Dressel, M. Johansson, G. Ericsson, and C. Sandström (2020) stress, adaptive resource management requires cooperation between public and private institutions, balanced power distribution, continuous learning processes, and adjustment to local conditions—all of which enhance a system's responsiveness to threats and strengthen its resilience.

F.E. Córdova, T. Krause et al. (2024) argue that the development of adaptive capacities and socio-ecological resilience requires systematic measurement that accounts for social capital, agency, knowledge transfer, and power relations—factors that enhance a community's ability to absorb, adapt, and transform in the face of hazards. X. Gong, W.-K. Wong, Y. Peng et al. (2023) note that sustainable economic development demands the integration of economic growth with ecological resilience, environmental protection, and social well-being. Diverse and stable ecosystems support survival and regeneration after disturbances, fostering long-term development, whereas environmental degradation constrains growth potential.

According to Z. Assarkhaniki, A. Rajabifard, and S. Sabri (2020), the Sustainable Development Goals (SDGs) insufficiently address resilience as the capacity to prepare for, absorb, recover from, and adapt to extreme events. J. Salomon, J. Behrensdorf, N. Winnewisser, M. Broggi, and M. Beer (2022) emphasize that improving the resilience of complex systems requires a rational analysis of available resources and intervention costs, as the potential for increasing resilience is inherently limited.

As P. Sánchez-Zamora and R. Gallardo-Cobos (2019) observe, adaptability and cohesion constitute two complementary dimensions of municipal resilience. Adaptability, understood as system flexibility, reflects the ability to modify functions in response to threats, while cohesion refers to social capital and the strength of community bonds. A municipality's resilience results from the synergy of these two dimensions, reinforced by institutional and organizational capacities that enable effective response, recovery, and long-term system transformation.

According to T. Gu, H. Zhao et al. (2025), traditional methods of resilience assessment—based on assumptions of homogeneity or simple linear relationships—fail to capture the complexity of adaptive processes and may lead to erroneous conclusions. The use of synthetic measure models or machine learning techniques allows for the identification of nonlinearity, heterogeneity, and local threshold effects, thereby improving the accuracy of assessments and supporting evidence-based decision-making in adaptive disaster management and urban planning.

The level of multidimensional local resilience in Polish municipalities varies by type, with urban municipalities exhibiting higher resilience than rural and urban–rural ones, due to more advanced infrastructural development and concentration of resources (H1). Environmental, demographic, and infrastructural factors significantly influence the level of local resilience; over the analyzed period (2013–2023), the importance of the environmental component increased, while that of the demographic component relatively declined (H2). Higher levels of environmental and infrastructural resilience strengthen the balance between adaptability and socio-spatial cohesion in local communities, whereas declining demographic resilience reduces adaptive capacity and may lead to potential destabilization of local systems (H3).

3. Materials and Methods

The subject of the study was multidimensional local resilience in Polish municipalities, encompassing environmental, demographic, and infrastructural components and their interrelationships in the context of municipal types (urban, rural, and urban–rural). Particular attention was devoted to the influence of these dimensions on the balance between adaptability and the socio-spatial cohesion of local systems. The analysis covered the period 2013-2023, which enabled the identification of changes in the level and structure of local resilience, the assessment of developmental trends, and the comparison of their significance across different types of municipalities. Furthermore, it facilitated the formulation of policy directions and practices that support sustainable and durable territorial resilience, thereby enhancing understanding of the evolution of the studied phenomenon.

Local system resilience is analyzed across several dimensions: economic (sectoral structure, financial liquidity, labor market stability, diversification of activities), demographic (human capital, migration, social capital, labor force participation), infrastructural (investment capacity, transportation, technology, energy security), and environmental. Strengthening resilience requires economic diversification, support for innovation, the development of human capital, targeted instruments for enterprises, and systematic monitoring of key economic and social indicators.

Multidimensional local resilience refers to the capacity of territorial units—such as municipalities or cities—to adapt to environmental, economic, and demographic changes and threats, to maintain socio-economic cohesion, and to effectively recover from crises. Its assessment is based on an integrated set of indicators encompassing economic, social, institutional, infrastructural, environmental, and demographic dimensions.

The study of local resilience provides insight into diverse spatial and social determinants, allowing the identification of factors that strengthen or constrain the capacity to respond to crises and the formulation of development and spatial planning strategies that promote long-term socio-spatial cohesion. Figure 1 illustrates the procedure for constructing the synthetic multivariate resilience index, which constitutes the methodological framework for the quantitative analysis. The process begins with a comprehensive literature review that defines the purpose and scope of the research.

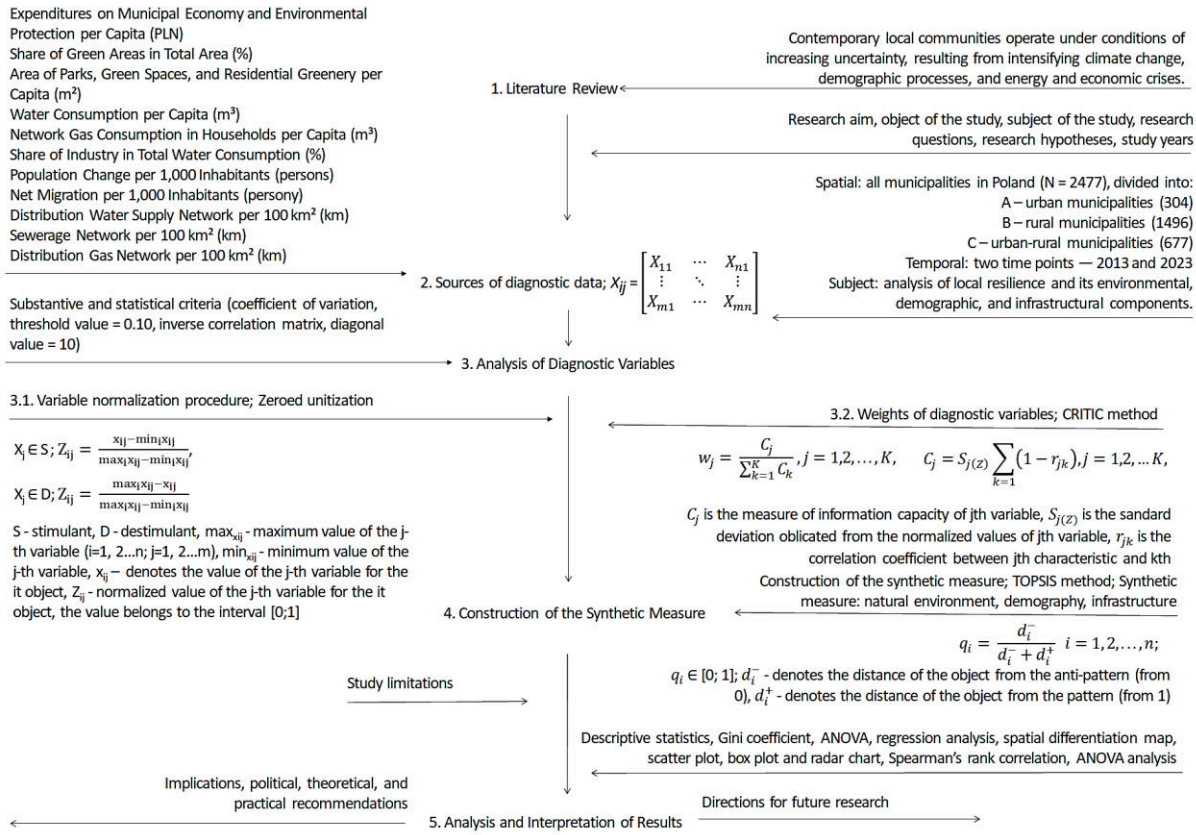


Figure 1. Methodology for Constructing a Synthetic Local Resilience Index for Polish Municipalities (TOPSIS–CRITIC).

Source: opracowanie wlasne na podstawie: Malina, Zieliaś, 1996, pp. 85-89; Poplawski, Glova, Dziekański, 2025, pp. 25-48; Hassan, Alhamrouni, Azhan, 2023, p. 4245; Kukuła, Bogocz, 2014; pp. 5-13; Yin, Wang, Wang, Wang, Chang, 2023; Grzelak, Popławski, Dziekański, 2024.

The resilience assessment process involves the identification and selection of diagnostic variables based on substantive and statistical criteria, including the coefficient of variation and the inverse correlation matrix analysis, ensuring their adequacy and informational independence. Each variable is subsequently normalized using the zero unitarization method, while its weights are objectively determined through the CRITIC method, which accounts for both the dispersion of characteristics and the correlations among them. The synthetic indicator is then aggregated using the TOPSIS method, which determines the distance of each object from the ideal and anti-ideal solutions, allowing for their comprehensive ranking and comparative evaluation. The final stage comprises the analysis of results employing descriptive statistics, rankings, and advanced analytical tools such as the Gini coefficient, forming the basis for the formulation of theoretical, practical, and policy conclusions, as well as for defining directions of further research.

4. Results

Between 2013 and 2023, an increase in environmental resilience has been observed, resulting from pro-ecological initiatives and investments in sustainable resource management. At the same time, a decline in demographic resilience has occurred in rural and urban–rural municipalities, reflecting processes of depopulation and the outflow of human capital. Infrastructural resilience has remained relatively stable but at a consistently low level, indicating persistent disparities in access to technical and digital services (Table 1). The results confirm that the growth of environmental resilience enhances adaptive capacity, yet it does not compensate for the demographic regression and infrastructural stagnation, leading to the erosion of cohesion within local communities. This phenomenon aligns with the theory of uneven development, according to which urban centers exhibit greater systemic stability than peripheral areas. These findings underscore the necessity of an integrated policy approach encompassing environmental, demographic, and infrastructural dimensions to support sustainable and enduring territorial resilience.

Table 1.
Spatial and temporal differentiation of local resilience components in Polish municipalities by type (2013-2023)

Synthetic measure			Number of units	Mean	Minimum	Maximum	Range	Interquartile Range	Variance	Standard Deviation	Skewness	Kurtosis
Natural env.	2013	All units	2477	0.59	0.33	0.82	0.49	0.02	0.00	0.04	-2.29	7.95
Demography			2477	0.71	0.00	0.94	0.94	0.08	0.01	0.09	-2.06	8.53
Infrastructure			2477	0.12	0.00	0.86	0.86	0.07	0.01	0.12	2.53	7.06
Local resilience			2477	0.51	0.33	0.69	0.36	0.02	0.00	0.03	-0.16	4.76
Natural env.		A	304	0.58	0.37	0.82	0.45	0.07	0.01	0.08	-0.81	0.88
Demography			304	0.75	0.37	0.93	0.57	0.05	0.00	0.06	-2.17	10.66
Infrastructure			304	0.35	0.02	0.86	0.85	0.23	0.03	0.17	0.21	-0.22
Local resilience			304	0.54	0.38	0.69	0.31	0.07	0.00	0.06	-0.33	0.09
Natural env.		B	1496	0.59	0.34	0.69	0.34	0.01	0.00	0.03	-3.32	13.86
Demography			1496	0.70	0.00	0.94	0.94	0.09	0.01	0.10	-1.89	7.42
Infrastructure			1496	0.09	0.00	0.44	0.44	0.05	0.00	0.06	2.10	6.99
Local resilience			1496	0.51	0.33	0.56	0.23	0.02	0.00	0.03	-2.28	7.33
Natural env.		C	677	0.58	0.33	0.66	0.33	0.03	0.00	0.05	-2.60	7.46
Demography			677	0.72	0.19	0.87	0.68	0.06	0.01	0.07	-2.20	9.50
Infrastructure			677	0.08	0.01	0.49	0.48	0.06	0.00	0.06	2.41	9.31
Local resilience			677	0.50	0.35	0.59	0.24	0.03	0.00	0.03	-1.99	5.11
Natural env.	2023	All units	2477	0.62	0.35	1.00	0.65	0.03	0.00	0.05	-2.29	9.25
Demography			2477	0.50	0.00	0.73	0.73	0.07	0.01	0.08	-1.92	5.82
Infrastructure			2477	0.11	0.00	1.00	1.00	0.06	0.01	0.12	2.59	7.58
Local resilience			2477	0.49	0.32	0.64	0.32	0.02	0.00	0.04	-0.85	4.15
Natural env.		A	304	0.61	0.39	1.00	0.60	0.08	0.01	0.08	-0.61	2.10
Demography			304	0.54	0.28	0.68	0.39	0.05	0.00	0.05	-1.16	3.71
Infrastructure			304	0.33	0.01	1.00	0.99	0.22	0.03	0.16	0.39	0.40
Local resilience			304	0.52	0.34	0.64	0.30	0.06	0.00	0.06	-0.64	0.18
Natural env.		B	1496	0.63	0.36	0.71	0.35	0.02	0.00	0.04	-3.44	14.89
Demography			1496	0.49	0.00	0.73	0.73	0.09	0.01	0.09	-1.67	4.44
Infrastructure			1496	0.07	0.00	0.46	0.46	0.04	0.00	0.06	2.68	10.03
Local resilience			1496	0.49	0.33	0.54	0.21	0.02	0.00	0.03	-2.38	7.19
Natural env.		C	677	0.61	0.35	0.68	0.33	0.03	0.00	0.05	-2.63	7.87
Demography			677	0.51	0.17	0.66	0.49	0.06	0.00	0.07	-2.31	7.75
Infrastructure			677	0.07	0.01	0.43	0.42	0.04	0.00	0.06	2.67	9.55
Local resilience			677	0.48	0.32	0.54	0.21	0.03	0.00	0.03	-2.00	4.52

A – urban municipalities, B – rural municipalities, C – urban-rural municipalities.

Source: own elaboration based on BDL GUS data (2013-2023).

The analysis of relationships in 2013 between the level of local resilience and its key dimensions—environmental, infrastructural, and demographic—reveals a clear spatial differentiation depending on the type of municipality. Across all types, the environmental dimension emerges as the strongest determinant of resilience, underscoring the enduring importance of natural capital quality for the stability and adaptive capacity of local systems. In urban municipalities, technical infrastructure plays a significant role, exhibiting a moderately strong correlation with resilience, which enhances the developmental potential and functional cohesion of urban centers. In contrast, within rural areas, demography constitutes the key factor—particularly population stability and reproductive capacity—while the impact of

infrastructure remains marginal and statistically insignificant. Urban–rural municipalities occupy an intermediate position, characterized by a strong dependence on environmental factors and weaker associations with demography, alongside a marginal contribution of infrastructure (Figure 2).

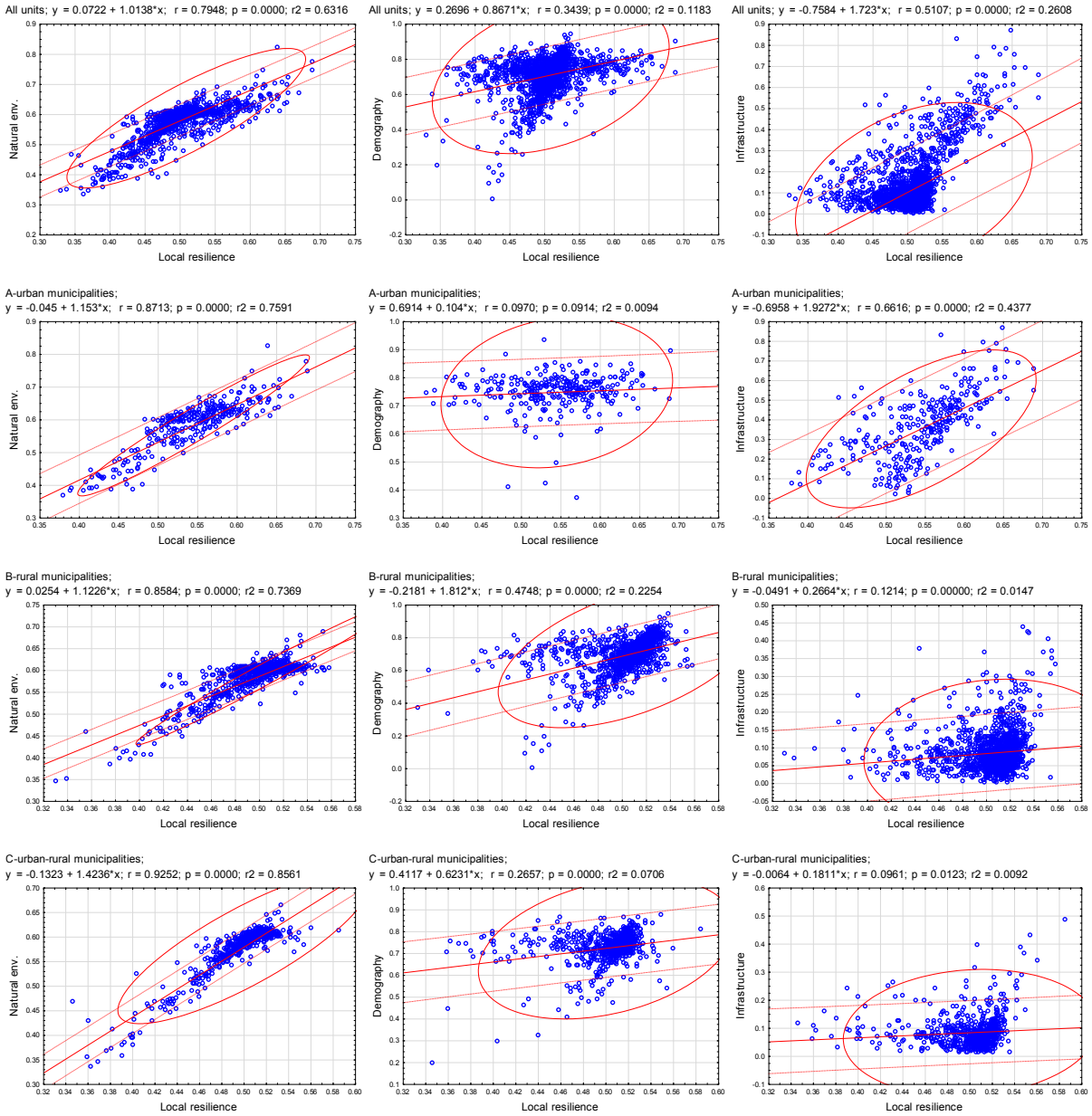


Figure 2. Variation in the relationships between environmental, demographic, infrastructural, and overall resilience in urban, rural, and urban-rural municipalities (Types of municipalities according to 2023; A – urban municipalities, B – rural municipalities, C – urban-rural municipalities).

Source: own elaboration based on BDL GUS data (2013-2023).

In 2023, the environmental dimension remains the strongest determinant of resilience across all municipalities, emphasizing the importance of natural capital. In urban municipalities, infrastructure plays a significant role, enhancing developmental potential. In contrast, in rural areas, demography is the key factor, while the role of infrastructure is marginal and statistically insignificant. Urban–rural municipalities occupy an intermediate position, characterized by

a strong dependence on the environment, weaker links to demography, and a marginal contribution of infrastructure (Figure 3).

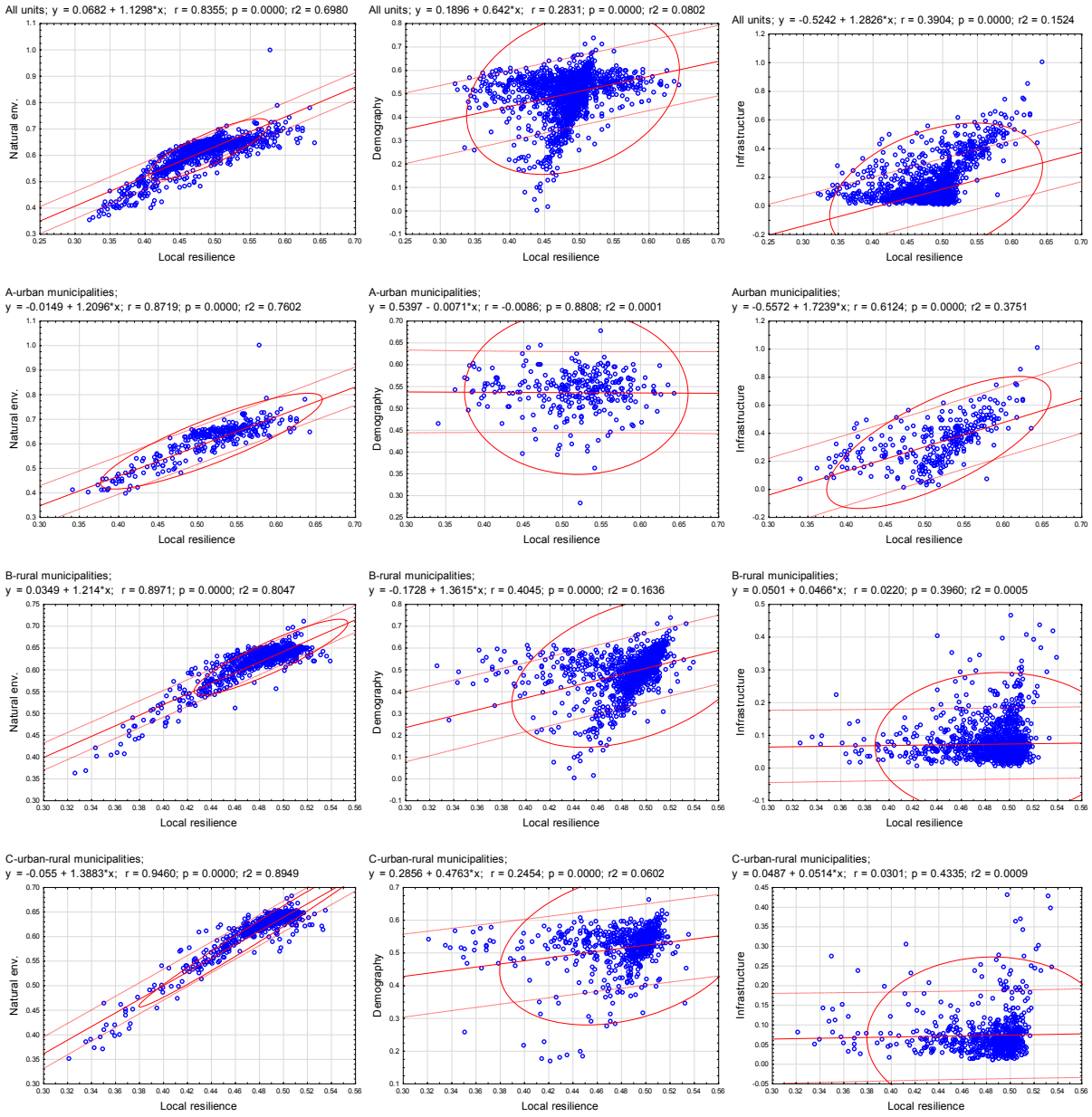


Figure 3. Variation in the relationships between environmental, demographic, infrastructural, and overall resilience in urban, rural, and urban-rural municipalities (Types of municipalities according to 2023; A – urban municipalities, B – rural municipalities, C – urban-rural municipalities).

Source: own elaboration based on BDL GUS data (2013-2023).

The correlation analysis between local resilience factors from 2013 to 2023 indicates a significant transformation in the structure of dependencies determining the stability of territorial systems (Table 2). The environmental dimension exerts the strongest influence on overall resilience, highlighting the importance of natural resources and spatial quality for the sustainability of local socio-economic systems, while demographic and infrastructural factors maintain a moderate, stable supportive role. The lack of significant correlations between public expenditures and resilience indicators suggests limited effectiveness of financial instruments,

whereas the growing importance of institutional and social dimensions emphasizes the role of management quality and local cooperation. Spatial differentiation of correlations reveals that in urban areas, resilience primarily results from the synergy between environmental and infrastructural factors, whereas in rural areas it stems from the interaction between natural and demographic capital. The findings are consistent with theories of sustainable development, the new institutional economics, and the "resilience–cohesion trade-off" model, indicating that long-term local resilience depends chiefly on the integration of environmental, social, and infrastructural dimensions, rather than on the mere scale of financial investments. In the local resilience analysis, expenditures on municipal economy and environmental protection were included as they reflect the capacity of local governments to maintain infrastructure and environmental quality during crises. The level of these expenditures thus constitutes an important indicator of the preparedness and responsiveness of local units, and consequently, their resilience.

Table 2.
Spearman's Rank Correlation Coefficient Matrix between Expenditures on Municipal Economy and Environmental Protection and Environmental, Demographic, Infrastructural Indicators, and Local Resilience (2013, 2023)

variable / synthetic measure	group	Expenditures on Municipal Economy and Environmental Protection	Natural env.	Demography	Infrastructure	Local resilience	Expenditures on Municipal Economy and Environmental Protection	Natural env.	Demography	Infrastructure	Local resilience
		2013					2023				
Expenditures on Municipal Economy and Environmental Protection	All units	1.00	-0.14	-0.06	0.10	-0.07	1.00	-0.06	-0.03	0.06	-0.01
Natural env.		-0.14	1.00	0.15	-0.06	0.65	-0.06	1.00	0.16	-0.19	0.69
Demography		-0.06	0.15	1.00	-0.17	0.44	-0.03	0.16	1.00	-0.22	0.43
Infrastructure		0.10	-0.06	-0.17	1.00	0.32	0.06	-0.19	-0.22	1.00	0.18
Local resilience		-0.07	0.65	0.44	0.32	1.00	-0.01	0.69	0.43	0.18	1.00
Expenditures on Municipal Economy and Environmental Protection	A	1.00	-0.06	-0.13	-0.21	-0.15	1.00	-0.01	-0.13	-0.21	-0.08
Natural env.		-0.06	1.00	0.09	0.28	0.83	-0.01	1.00	-0.04	0.25	0.82
Demography		-0.13	0.09	1.00	-0.04	0.11	-0.13	-0.04	1.00	-0.08	0.01
Infrastructure		-0.21	0.28	-0.04	1.00	0.69	-0.21	0.25	-0.08	1.00	0.66
Local resilience		-0.15	0.83	0.11	0.69	1.00	-0.08	0.82	0.01	0.66	1.00

Cont. table 2.

Expenditures on Municipal Economy and Environmental Protection	B	1.00	-0.15	-0.17	0.03	-0.17	1.00	-0.03	-0.12	0.05	-0.05
Natural env.		-0.15	1.00	0.22	-0.16	0.56	-0.03	1.00	0.28	-0.32	0.63
Demography		-0.17	0.22	1.00	-0.35	0.57	-0.12	0.28	1.00	-0.39	0.60
Infrastructure		0.03	-0.16	-0.35	1.00	0.19	0.05	-0.32	-0.39	1.00	-0.01
Local resilience		-0.17	0.56	0.57	0.19	1.00	-0.05	0.63	0.60	-0.01	1.00
Expenditures on Municipal Economy and Environmental Protection	C	1.00	-0.09	-0.08	0.04	-0.05	1.00	-0.02	0.07	-0.07	0.03
Natural env.		-0.09	1.00	0.13	-0.12	0.81	-0.02	1.00	0.15	-0.18	0.83
Demography		-0.08	0.13	1.00	-0.33	0.28	0.07	0.15	1.00	-0.35	0.29
Infrastructure		0.04	-0.12	-0.33	1.00	0.18	-0.07	-0.18	-0.35	1.00	0.09
Local resilience		-0.05	0.81	0.28	0.18	1.00	0.03	0.83	0.29	0.09	1.00

Correlation coefficients marked are significant at $p < .05000$. A – urban municipalities, B – rural municipalities, C – urban-rural municipalities.

Source: own elaboration based on BDL GUS data (2013-2023).

The analysis of the Kruskal–Wallis test results confirms statistically significant differences between types of municipalities in Poland across all dimensions of local resilience (Table 3). Urban municipalities exhibit the highest levels of infrastructural, demographic, and overall resilience metrics, reflecting their stronger economic potential, resource concentration, and greater adaptive capacity. Rural municipalities, despite infrastructural deficits, show a systematic increase in the environmental component and overall resilience, indicating a growing adaptive capacity in response to socio-economic and climatic changes. The observed partial convergence in environmental and demographic components suggests a gradual equalization of potentials between urban and non-urban units. The results reaffirm the established spatial hierarchy of local resilience alongside the intensification of adaptive trends in peripheral municipalities, emphasizing the role of institutional quality and governance mechanisms as factors strengthening long-term resilience within the frameworks of sustainable development theory, growth poles, and adaptive management.

Table 3.

Results of the Kruskal–Wallis ANOVA test comparing groups A, B, and C in terms of expenditures on municipal economy and environmental protection, as well as environmental, demographic, infrastructural indicators, and local resilience (2013 and 2023)

2013					**2023**				
Dependent variable: Expenditures on Municipal Economy and Environmental Protection	H (2, N= 2477) =184.5626 p =0.000				Dependent variable: Expenditures on Municipal Economy and Environmental Protection	H (2, N= 2477) =103.8762 p =0.000			
	Code	N (valid)	Sum of Ranks	Mean Rank		Code	N (valid)	Sum of Ranks	Mean Rank
A	1	A	486172	1599.25	A	1	304	443679	1459.47
C	2	C	956469	1412.81	C	2	677	947974	1400.26
B	3	B	1626362	1087.14	B	3	1496	1677350	1121.22

Cont. table 3.

Dependent variable: Natural env.	H (2, N= 2477) =68.81815 p =.0000				Dependent variable: Natural env.	H (2, N= 2477) =121.4166 p =0.000			
	Code	N (valid)	Sum of Ranks	Mean Rank		Code	N (valid)	Sum of Ranks	Mean Rank
A	1	A	404721	1331.32	A	1	304	379292	1247.67
C	2	C	707464	1045.00	C	2	677	667883	986.53
B	3	B	1956819	1308.03	B	3	1496	2021828	1351.49
Dependent variable: Demography	H (2, N= 2477) =142.5309 p =0.000				Dependent variable: Demography	H (2, N= 2477) =101.5145 p =0.000			
	Code	N (valid)	Sum of Ranks	Mean Rank		Code	N (valid)	Sum of Ranks	Mean Rank
A	1	A	491704	1617.45	A	1	304	472457	1554.13
C	2	C	907111	1339.90	C	2	677	899297	1328.36
B	3	B	1670188	1116.44	B	3	1496	1697249	1134.52
Dependent variable: Infrastructure	H (2, N= 2477) =626.2617 p =0.000				Dependent variable: Infrastructure	H (2, N= 2477) =642.5819 p =0.000			
	Code	N (valid)	Sum of Ranks	Mean Rank		Code	N (valid)	Sum of Ranks	Mean Rank
A	1	A	668722	2199.74	A	1	304	672723	2212.90
C	2	C	732899	1082.57	C	2	677	747376	1103.95
B	3	B	1667382	1114.56	B	3	1496	1648904	1102.21
Dependent variable: Local resilience	H (2, N= 2477) =233.9829 p =0.000				Dependent variable: Local resilience	H (2, N= 2477) =206.3725 p =0.000			
	Code	N (valid)	Sum of Ranks	Mean Rank		Code	N (valid)	Sum of Ranks	Mean Rank
A	1	A	550994	1812.48	A	1	304	530326	1744.49
C	2	C	732873	1082.53	C	2	677	701879	1036.75
B	3	B	1785136	1193.27	B	3	1496	1836798	1227.81

A – urban municipalities, B – rural municipalities, C – urban-rural municipalities.

Source: own elaboration based on BDL GUS data (2013-2023).

The linear regression analysis using synthetic indicators for all municipalities in Poland in 2013 and 2023 demonstrated high model accuracy (R^2 values of 0.983 and 0.971, respectively) and statistical significance of all variables ($p < 0.001$), confirming the stability and reliability of the results (Table 4). In both periods, the dominant determinant of local resilience remains the environmental component, whose importance increased in 2023. The technical infrastructure—comprising water supply, sewage, and gas networks—retains a significant positive impact, although slightly diminished compared to 2013, which may reflect the stabilization of its role within local systems. The demographic component maintains a positive but relatively lower influence, suggesting that adaptive management mechanisms and population structure stabilization reduce resilience sensitivity to demographic changes. The findings corroborate the theoretical assumptions of sustainable development and the socio-ecological resilience concept, indicating that municipal resilience arises from the synergy of natural environment quality, infrastructure development, and demographic stability. Systematic monitoring and management of these factors constitute the foundation for effective public policy, spatial planning, and adaptive strategies in environmental protection and human resource management.

Table 4.
Multiple regression results for models including environmental, demographic, and infrastructural factors (2013, 2023)

2013						
	R= .99124859 R^2= .98257376 Adjusted. R^2= .98255262 F(3,2473)=46480. p<0.0000 Standard error of estimate: .00462 d Durbin-Watson statistic1.760774					
N=2477	b*	Standard Error (z b*)	b	Standard Error (z b)	t(2473)	p
intercept			0.046	0.001	32.881	0.000
Natural env.	0.765	0.003	0.600	0.002	287.629	0.000
Demography	0.326	0.003	0.129	0.001	122.347	0.000
Infrastructure	0.514	0.003	0.152	0.001	193.242	0.000
2023						
	R= .98514236 R^2= .97050546 Adjusted. R^2= .97046968 F(3,2473)=27124. p<0.0000 Standard error of estimate: .00603 d Durbin-Watson statistic1.798738					
N=2477	b*	Standard Error (z b*)	b	Standard Error (z b)	t(2473)	p
intercept			0.023	0.002	13.240	0.000
Natural env.	0.852	0.003	0.630	0.003	245.810	0.000
Demography	0.271	0.003	0.120	0.002	78.286	0.000
Infrastructure	0.466	0.003	0.142	0.001	134.401	0.000

Dependent variable: synthetic measure of Local resilience.

Source: own elaboration based on BDL GUS data (2013-2023).

The primary determinants remain environmental and infrastructural factors, whose significance evolves over time. The increasing importance of the environmental component highlights the growing role of ecological policy, while the stable influence of technical infrastructure—including water supply, sewage, and gas networks—confirms its crucial role in the functionality of local systems. Simultaneously, a gradual weakening of the impact of demographic factors is observed, which may reflect the adaptive mechanisms of municipalities in response to population changes. The results indicate the need to strengthen green infrastructure, further develop technical networks, monitor migration processes, and reduce industrial pressure to enhance local resilience. The identified trends corroborate the premises of sustainable development and socio-ecological resilience concepts, emphasizing the complementary role of environmental quality, infrastructure, and demographic stability in shaping the adaptability of local systems. Moreover, this dynamic interplay aligns with the theory of complex adaptive systems, highlighting how local resilience emerges from the continuous interactions and feedback loops among environmental, infrastructural, and demographic components, enabling local systems to adapt and transform in response to changing external and internal conditions (Bristow, Healy, 2014; Nel, Taeihagh, 2024).

5. Discussion

Local resilience of Polish municipalities is primarily determined by environmental factors, which exert the strongest positive influence—particularly in urban and urban–rural municipalities. The impact of technical infrastructure and demographic factors remains moderate, showing a trend toward the stabilization of the infrastructural role and a slight decline in the significance of demography between 2013 and 2023. Expenditures on municipal management exert a weak yet locally significant effect, while intensive industrial activity, high gas consumption, and fluctuations in population and migration systematically constrain the adaptive capacity of territorial units.

An analysis of differences between types of municipalities using the Kruskal–Wallis test revealed statistically significant variation in resilience levels: urban municipalities exhibit the highest environmental, demographic, infrastructural, and overall resilience indices; rural municipalities display the lowest values; and urban–rural municipalities occupy an intermediate and relatively stable position over time. The results of synthetic regression analysis confirm the hierarchy of resilience determinants (MEnvironment > MInfrastructure > MDemography), indicating that environmental policy, technical infrastructure development, and demographic stabilization constitute key directions for strengthening adaptive capacities. At the same time, intensive industrial activity and population fluctuations necessitate targeted regulation and spatially oriented planning.

The findings substantiate the theoretical premises of sustainable development and social–ecological resilience, emphasizing the synergistic interplay between environmental, infrastructural, and socio-demographic factors as fundamental to the durability of local systems. The resilience of local governments should be analyzed in the context of their vulnerability to specific risks—some units, despite greater exposure, may exhibit higher resilience owing to stronger financial, infrastructural, and human capital resources. As Ziarko (2025) notes, examples from large cities such as Warsaw and Gdańsk demonstrate that in crisis situations, wealthier municipalities are capable of responding effectively despite higher levels of systemic risk. Importantly, resilience often manifests only under crisis conditions, revealing social and institutional characteristics that are difficult to predict ex ante. Case studies from Poland and Ukraine indicate that local communities can respond actively and collectively in unforeseen circumstances, confirming the importance of social capital and institutional competencies in shaping local resilience.

Resilience can be enhanced through the development of infrastructure, financial stability, competent leadership, and active citizen engagement. However, as noted in Local Governments Facing Contemporary Threats..., the effectiveness of these measures depends on the specific characteristics of each territorial unit. According to Malik, Szewczuk-Stępień, and Bębenek (2025a), the developed model for identifying smart economic specializations, supplemented

with resilience-strengthening criteria, addresses contemporary external challenges such as armed conflicts, climate change, mass migration, and pandemics. The authors present a model that establishes a framework for a policy of identifying smart specializations, supporting both short-term economic resilience and long-term sustainable development. As further emphasized by Malik, Szewczuk-Stępień, and Bębenek (2025b), sustainable development policy in this context facilitates the integration of long-term strategies with operational plans, thereby enhancing the capacity of regions to respond effectively to contemporary threats.

As Strzelecki (2013) argues, demographic structures play a crucial role in shaping resilience and sustainable development at both local and regional scales. Demographic processes in Poland reveal significant spatial disparities—positive in diversified metropolitan areas and negative in monocultural regions with low endogenous potential—thus constraining the resilience of those territories. Peripheral regions often display symptoms of unsustainable development, while urban areas accumulate factors conducive to regional resilience. Demography, as Strzelecki emphasizes, does not directly determine sustainable development but interacts with other systemic components, modulating the resilience and adaptive capacity of regions. Incorporating demographic structure into regional policy planning is therefore essential for strengthening socio-economic resilience and preventing the marginalization of areas with low development potential.

Masik (2022) highlights that regional resilience focuses primarily on economic dimensions, whereas urban resilience encompasses social and infrastructural systems. The author presents the evolution of research perspectives—from engineering-based interpretations toward systemic approaches—in which transformative capacities are recognized as a key dimension of social–ecological resilience. The integration of systemic and equilibrium methods with path-dependence analysis and long-term perspectives enables the identification of post-disruption equilibrium points and decision-making processes that shape relationships among the natural environment, infrastructure, society, economy, and institutions—thereby reinforcing both regional and urban resilience.

According to Rynio (2024), implementing the concept of "short-distance cities" in areas with diverse economic status supports the development of multidimensional resilience by integrating physical, environmental, and social systems. The decentralization of services and spatial organization enabling access to essential activities within a 15-minute walking or cycling distance improve quality of life, social resilience, and safety, while simultaneously reducing transportation pressure and enhancing environmental conditions.

As Ziarko (2025) further observes, the growing importance of community preparedness for responding to threats and mitigating their effects is evident. Critical factors include local action capacities, effective use of material and immaterial resources, availability of social support, preventive measures, and cultural values and norms that foster trust and reduce conflict. Research in this field enables a comprehensive assessment of local resilience, identification of its weaknesses, and the design of adaptive interventions. In addition, we examine the economic

and political factors related to country risk. Our assessment is based on the country's economic and financial challenges, as well as the investment climate it faces (Glova, Bernatik, Tulai 2020).

The research findings have significant policy, practical, and theoretical implications. At the policy level, they highlight the need for integrated spatial and investment planning that incorporates the development of technical infrastructure, environmental protection, and demographic stabilization, particularly in rural and urban–rural municipalities. At the practical level, they emphasize the importance of migration monitoring, reducing industrial pressure, and investing in green areas and urban ecosystems to enhance local resilience. At the theoretical level, they reaffirm the relevance of the social–ecological resilience framework, sustainable development theory, and the resilience–cohesion trade-off model, underscoring the interdependence of environmental, demographic, and infrastructural components depending on the level of urbanization and spatial context.

The limitations of this study stem from the restricted availability of administrative and statistical data, the lack of comprehensive indicators for social and cultural capital quality, and the difficulty of capturing dynamic institutional and economic interactions. Future research should incorporate analyses of institutional and cultural dimensions, social capital quality, and the long-term effects of adaptive policies, as well as employ predictive modeling to assess the impact of alternative scenarios for infrastructure, demographic, and environmental policy development on local resilience.

6. Conclusions

The analysis of multidimensional local resilience in Polish municipalities during the period 2013-2023 demonstrated that its level is primarily determined by environmental and infrastructural factors, while demographic factors play a complementary role. The type of municipality significantly modifies both the level of resilience and the relative influence of individual determinants—urban municipalities exhibit the highest resilience levels, whereas rural and urban–rural municipalities show intermediate values. The results of synthetic regression analysis, Spearman’s rank correlations, and Kruskal–Wallis tests are consistent, confirming the hierarchy of determinants as well as the spatial differentiation of local resilience.

The environmental component proved to be a universal and dominant factor enhancing resilience throughout the entire study period, reflecting the effectiveness of pro-environmental policies and the increasing importance of environmental actions. Technical infrastructure plays a crucial role particularly in urban municipalities, while in rural and urban–rural units it serves a supporting function. The demographic component exerts a weaker influence, reflecting depopulation processes and the outflow of the working-age population, which negatively affect

social cohesion and the adaptive capacity of local systems. Regression analyses and statistical tests indicate that local resilience results from the synergistic interaction between environmental quality, infrastructural development, and demographic stability, with a moderate positive effect of public expenditures on municipal management and environmental protection, and a negative impact of intensive industrial activity and high resource consumption.

The spatial differentiation of relationships among components depending on the level of urbanization underscores the necessity of incorporating local context into development policy planning. The results clearly demonstrate that the balance between adaptability and cohesion within local systems depends primarily on the interaction of environmental and infrastructural components, while limited demographic resilience reduces adaptive potential.

Strengthening multidimensional local resilience requires integrated actions encompassing spatial, environmental, and demographic policies, tailored to the specific characteristics and spatial diversity of different types of municipalities. This approach aligns with the principles of sustainable development theory, the resilience thinking framework, and the "resilience–cohesion trade-off" model.

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References

1. Arzo, S., Hong, M. (2024). Resilient green infrastructure: Navigating environmental resistance for sustainable development, social mobility in climate change policy. *Heliyon*, *Vol. 10, Iss. 13*, e33524, https://doi.org/10.1016/j.heliyon.2024.e33524
2. Assarkhaniki, Z, Rajabifard, A., Sabri, S. (2020). The conceptualisation of resilience dimensions and comprehensive quantification of the associated indicators: A systematic approach. *International Journal of Disaster Risk Reduction*, *Vol. 51,* 101840, https://doi.org/10.1016/j.ijdrr.2020.101840
3. Birchall, S.J., Kehler, S., Weissenberger, S. (2025). Sometimes, I just want to scream: Institutional barriers limiting adaptive capacity and resilience to extreme events. *Global Environmental Change*, *Vol. 91,* 102967, https://doi.org/10.1016/j.gloenvcha.2025.102967

4. Boston, M., Bernie, D. et al. (2024). Community resilience: A multidisciplinary exploration for inclusive strategies and scalable solutions. *Resilient Cities and Structures*, *Vol. 3, Iss. 1,* 114-130, https://doi.org/10.1016/j.rcns.2024.03.005
5. Briguglio, L., Cordina, G., Farrugia, N., Vella, S. (2009). Economic Vulnerability and Resilience: Concepts and Measurements. *Oxford Development Studies, 37(3),* 229-247. https://doi.org/10.1080/13600810903089893
6. Bristow, G., Healy, A. (2014). Building Resilient Regions: Complex Adaptive Systems and the Role of Policy Intervention. *Raumforschung und Raumordnung, Spatial Research and Planning, 72*, 93-102 https://doi.org/10.1007/s13147-014-0280-0
7. Busłowska, A., Marcinkiewicz, J. (2023). Social Cohesion of Functional Urban Areas (Example of Eastern Poland). *Soc. Indic. Res., 167*, 451-473, https://doi.org/10.1007/s11205-023-03119-4
8. Carrasco, S., Ochiai, Ch., Tang, L.M. (2024). Social Capital and Community Resilience in the wake of disasters, conflicts and displacements. *International Journal of Disaster Risk Reduction*, *Vol. 115*, 105049, https://doi.org/10.1016/j.ijdrr.2024.105049
9. Chamusca, P. (2023). Public Policies for Territorial Cohesion and Sustainability in Europe: An Overview. *Sustainability*, *15*, 6890. https://doi.org/10.3390/su15086890
10. Choryński, A., Pińskwar, I., Graczyk, D., Krzyżaniak, M. (2022).The Emergence of Different Local Resilience Arrangements Regarding Extreme Weather Events in Small Municipalities—A Case Study from the Wielkopolska Region, Poland. *Sustainability, 14*, 2052. https://doi.org/10.3390/su14042052
11. Cinner, J.E., Barnes, M.L. (2019) Social Dimensions of Resilience in Social-Ecological Systems, *One Earth*, *Vol. 1, Iss. 1,* 51-56, https://doi.org/10.1016/j.oneear.2019.08.003
12. Córdova, F.E., Krause, T. (2024) et al. Framing adaptive capacity of coastal communities: A review of the role of scientific framing in indicator-based adaptive capacity assessments in coastal social-ecological systems. *Ocean & Coastal Management*, *Vol. 259,* 107455, https://doi.org/10.1016/j.ocecoaman.2024.107455
13. Dressel, S., Johansson, M., Ericsson, G., Sandström, C. (2020). Perceived adaptive capacity within a multi-level governance setting: The role of bonding, bridging, and linking social capital. *Environmental Science & Policy*, *Vol. 104,* 88-97, https://doi.org/10.1016/j.envsci.2019.11.011
14. Eichengreen, B., Park, D., Shin, K. (2024). Economic resilience: Why some countries recover more robustly than others from shocks. *Economic Modelling*, *Vol. 136,* 106748, https://doi.org/10.1016/j.econmod.2024.106748
15. Glova, J., Bernatik, W., Tulai, O. (2020). Determinant Effects of Political and Economic Factors on Country Risk: An Evidence from the EU Countries. *Montenegrin Journal of Economics*, 16(1), 37-53. DOI: 10.14254/1800-5845/2020.16-1.3
16. Gong, X., Wong, W.-K., Peng, Y. et al. (2023), Exploring an interdisciplinary approach to sustainable economic development in resource-rich regions: An investigation of resource

productivity, technological innovation, and ecosystem resilience. *Resources Policy*, *Vol. 87, Part A,* 104294, https://doi.org/10.1016/j.resourpol.2023.104294

17. Gu, T., Zhao, H. et al. (2025), Attribution analysis of urban social resilience differences under rainstorm disaster impact: Insights from interpretable spatial machine learning framework. *Sustainable Cities and Society*, *Vol. 118,* 106029, https://doi.org/10.1016/j.scs.2024.106029
18. Güngör, M., Elburz, Z. (2024). Beyond boundaries: What makes a community resilient? A Systematic Review. *International Journal of Disaster Risk Reduction*, *Vol. 108,* 104552, https://doi.org/10.1016/j.ijdrr.2024.104552
19. Kapucu, N., Ge, Y., Rott, E., Isgandar, H. (2024). Urban resilience: Multidimensional perspectives, challenges and prospects for future research. *Urban Governance*, *Vol. 4, Iss. 3,* 162-179, https://doi.org/10.1016/j.ugj.2024.09.003
20. Liu, Y., Cao, L., Yang, D., Anderson, B.C. (2022). How social capital influences community resilience management development. *Environmental Science & Policy*, *Vol. 136,* 642-651, https://doi.org/10.1016/j.envsci.2022.07.028
21. Lv, Y., Islam Sarker, M.N. (2024). Integrative approaches to urban resilience: Evaluating the efficacy of resilience strategies in mitigating climate change vulnerabilities. *Heliyon*, *Vol. 10, Iss. 6,* e28191, https://doi.org/10.1016/j.heliyon.2024.e28191
22. Malik, K., Szewczuk-Stępień, M., Bębenek, P. (2025a). Smart specializing as key driver of sustainability and resilience of regional economy. *Economics and Environment*, *93(2),* 979. https://doi.org/10.34659/eis.2025.93.2.979
23. Malik, K., Szewczuk-Stępień, M., Bębenek, P. (2025b). Rethinking sustainable development (policy) towards integrated resilience (action plan): regional level. *Economics and Environment*, *91(4),* 959. https://doi.org/10.34659/eis.2024.91.4.959
24. Martin, R. (2012). Regional economic resilience, hysteresis and recessionary shocks. *Journal of Economic Geography, Vol. 12, Iss. 1,* 1-32, https://doi.org/10.1093/jeg/lbr019
25. Masik, G. (2022). Koncepcja odporności: definicje, interpretacje, podejścia badawcze oraz szkoły myśli. *Przegląd Geograficzny*, *3*, 1-28. doi: 10.7163/przg.2022.3.1
26. Naderi, A., Khoshnevis, K. (2025). The sustainable future of cities under uncertainty: identifying key factors of adaptive urban resilience in Yazd, Iran. *Ain Shams Engineering Journal, Vol. 16, Iss. 11*, 103732, https://doi.org/10.1016/j.asej.2025.103732
27. Nel, D., Taeihagh, A. (2024). The soft underbelly of complexity science adoption in policymaking: towards addressing frequently overlooked non-technical challenges. *Policy Sci., 57*, 403-436 https://doi.org/10.1007/s11077-024-09531-y
28. Oliver, T.H., Heard, M.S. et al. (2015), Biodiversity and Resilience of Ecosystem Functions, *Trends in Ecology & Evolution*, *Vol. 30, Iss. 11,* 673-684, https://doi.org/10.1016/j.tree.2015.08.009

29. Rynio, D. (2024). Wdrażanie koncepcji miast krótkich odległości jako element budowy odporności współczesnych ośrodków osadniczych. *Regional Development and Regional Policy*, *70*, 45-61. doi: 10.14746/rrpr.2024.70s.05
30. Salomon, J., Behrensdorf, J., Winnewisser, N., Broggi, M., Beer, M. (2022). Multidimensional resilience decision-making for complex and substructured systems. *Resilient Cities and Structures*, *Vol. 1, Iss. 3,* 61-78, https://doi.org/10.1016/j.rcns.2022.10.005.
31. *Samorządy wobec współczesnych zagrożeń, Odporność polskich gmin i miast.* Departament Badań i Analiz BGK (Czerwiec 2025). https://www.bgk.pl/files/public/user_upload/Raport_BGK_odporność_samorządów.pdf?utm_source=chatgpt.com (12.11.2025).
32. Sánchez-Zamora, P., Gallardo-Cobos, R. (2019). Diversity, Disparity and Territorial Resilience in the Context of the Economic Crisis: An Analysis of Rural Areas in Southern Spain. *Sustainability*, *11*, 1743. https://doi.org/10.3390/su11061743
33. Sánchez-Zamora, P., Gallardo-Cobos, R. (2020). Territorial Cohesion in Rural Areas: An Analysis of Determinants in the Post-Economic Crisis Context. *Sustainability*, *12*, 3816. https://doi.org/10.3390/su12093816
34. Strzelecki, Z. (2013). Demograficzne uwarunkowania rozwoju zrównoważonego w skali regionalnej i lokalnej. *Studia Komitetu Przestrzennego Zagospodarowania Kraju PAN*, *152*, 39-55.
35. Zaucha, J., Komornicki, T. (2019). Territorial Cohesion: The Economy and Welfare of Cities. In: E. Medeiros (ed.), *Territorial Cohesion*. The Urban Book Series. Cham: Springer, https://doi.org/10.1007/978-3-030-03386-6_3
36. Ziarko, J. (2025). Odporność społeczności lokalnej na zagrożenia kryzysowe – ku holistycznym ramom odporności. *Bezpieczeństwo. Teoria i Praktyka*, *1,* 145-160.

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IMPLICATIONS OF GREEN INVESTMENT FINANCING IN POLISH ENTERPRISES

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Purpose: The primary objective of the study is to explore the changes occurring between enterprises implementing green investments and banks financing this process in Poland.
Methodology: The presented research used a qualitative method of semi-structured individual interviews designed to deepen, enrich, and supplement the research conducted in recent years on ESG implementation strategies and models. The research methodology for the analysed problem was based on literature studies, empirical research from secondary sources, and participant observation.
Design approach: At the Paris meeting in 2015, sustainable development was adopted as an ESG strategy. It was based on the assumption that economic processes should lead to zero greenhouse gas emissions. The adopted formula has raised and continues to raise a series of concerns about the risks associated with implementing an ESG strategy. The imposed goals and targets of an ESG strategy are at odds with rational management, resulting in resistance to its adoption, particularly among micro-entities. The implementation of an ESG strategy is therefore constantly at risk. The process is accompanied by an intensification of EU regulations aimed at increasing the effectiveness of an ESG strategy and its adaptability by economic entities in EU member states. The research focuses on assessing the changes occurring between credit institutions financing the green economic deal and enterprises implementing green investments. It identifies their nature, propensity to adapt, and impact on the implementation of an ESG strategy in Poland.
Findings: The research results presented herein allow for the assessment of the scope and nature of barriers affecting the effectiveness of green investment financing in Polish enterprises. They highlight the direction of their impact on the adaptability of an ESG strategy in domestic enterprises and banks.
Research limitations: Research limitations stem from the methods used. The results of the semi-structured interviews allow for a deeper understanding and explanation of the existing limitations in the cognitive process of ESG implementation. However, it should be noted that the assessment of the analysed process is largely declarative in nature, which has an impact on the objectivity of the results obtained and the possibility of scientific inference. On the other hand, it is worth highlighting the cognitive value of the research conducted, as it enables an assessment of the current challenges related to financing green investments in Poland during the highly dynamic and largely chaotic process of ESG implementation. In-depth research on

the effectiveness and efficiency of ESG implementation will be an essential complement to the cognitive process.
Originality/value: The semi-structured individual in-depth interviews conducted in 2025 enrich the questionnaire research methods used previously, objectifying the research results in the field of an ESG strategy.
Keywords: commercial banks, implication of the strategy, ESG regulations, green investment financing.
Category of the paper: viewpoint.

1. Introduction

The ESG strategy implemented in all EU member states, connected with the publication of the European Green Deal in 2019, has transformed the concept of sustainable development into a new formula aimed at achieving climate neutrality in the EU economy by 2050. The solutions adopted in the business environment involve taking rapid and concrete actions to change their existing production profiles. Meanwhile, each calendar year sees an increase in the number of regulations relating to the implementation of the ESG strategy in EU member states. The year 2025 began with further regulatory changes in the European Union. They are related to the so-called Omnibus package (Directive (EU) 2025/794), which has far-reaching consequences for companies, investors, and financial market participants. They raise several controversies because they modify existing regulatory arrangements and change the conditions for implementing the ESG strategy. Thus, in turn, the risk of green investing increases, thereby hindering its implementation. Uncertainty relating to the geopolitical situation of the global economy is also growing. There is an increasing number of spectacular barriers to implementing the ESG strategy as well. Despite steadily increasing risks, the level of political sensitivity in assessing their impact on achieving ESG strategy goals and targets remains high. A review of the literature indicates that, despite the perceived weaknesses in implementing the ESG strategy, the conclusions drawn remain largely positive, and EU directives are accompanied by enforcement measures aimed at increasing green investments by economic entities. However, such measures do not increase the expected outcomes of green investment financing. The dominant view is that progress in implementing the ESG strategy is unsatisfactory. Therefore, there is an urgent need to launch large-scale research projects that will objectively verify the willingness of economic entities to adopt the ESG strategy. So far, research has lacked a systematic perspective. A significant part of the research conclusions are very similar, focusing only on certain aspects of the greening of the EU economy. As a result, research gaps emerge that require empirical investigation of entities implementing green investments. However, access to them is largely limited. The above-mentioned problems justify continuous monitoring of the ESG strategy and periodic verification of research results.

The publication concentrates on the analysis and evaluation of studies conducted in the first half of 2025. The research was based on semi-structured in-depth interviews. It was conducted among representatives of the 10 largest commercial banks in Poland. The scope of this study was broad, which allowed for the identification of the motives of domestic banks in greening the Polish economy and to verify the research findings against previously reported results based on questionnaire surveys (Pyka, Nocoń, 2023, 2024; Pyka, Pyka, 2023, 2024). The primary research objective is to explore the changes occurring between enterprises implementing green investments and banks financing this process. Therefore, only a small part of the research findings obtained was used in the study, supplemented with additional methods verifying the relationships between the economic entities included in the research. The research was guided by the hypothesis that domestic banks, by announcing the adoption of ESG strategies, consistently declare their willingness to implement them, whereas enterprises perceive ESG-related risks as a significant barrier when adapting to green investments.

2. Materials and Methods

2.1. Research methods

Previous team-based research conducted by the authors since 2020, focused on green financing, has so far relied in its empirical dimension primarily on questionnaire-based methods. The research covered the 10 largest commercial banks in Poland, including: PKO BP S.A., Bank Pekao S.A., Santander Bank Polska S.A., ING Bank Śląski S.A., mBank S.A., BNP Paribas S.A., Bank Millennium S.A., Alior Bank S.A., Citi Handlowy S.A. And Velo Bank S.A. Given that the total value of the assets of these institutions represents 79% of the total value of the assets of the Polish banking sector (KNF, 2022; Kotecki, 2025), it was assumed that the obtained research results are representative of the entire banking sector in Poland. In 2025, the empirical study employed semi-structured in-depth interviews. This is a technique used to collect qualitative data, particularly suitable for examining phenomena for which a comprehensive body of knowledge has not yet been established. The method facilitates flexible data collection while allowing respondents to raise issues that were not initially included in the interview scenarios (Griffith et al., 2015; Merriam, Tisdell, 2015; Bell et al., 2018). The findings of this research complement the results of previous stages, verifying and objectifying the research conclusions. Respondents were selected based on their knowledge and experience in the field of green finance. They are mainly people representing key positions in sustainable development and ESG, or the management division responsible for their implementation. The interviews lasted on average about 60 minutes. Finally, the data collected from the interviews was compared with information presented in annual ESG reports, on banks'

websites, in press releases, and other online sources related to each bank. The use of these secondary sources allowed us to integrate and verify the data collected during the interviews. Triangulation of data from various sources was essential to ensure the accuracy of the conducted analyses (Yin, 2003; Merriam, Tisdell, 2015). Only a small number of the research findings were used in the study, as most pertain to different banking challenges in green investment financing. Assuming that the ultimate effect of the green transition can only be achieved through the integration of financial institutions' activities and investments made by manufacturing enterprises, the research findings were selected based on this criterion. The publication also uses other research methods, including in-depth and critical analysis of the literature, secondary data analysis, observation, and synthesis.

2.2. Trends in the implementation of ESG business strategies

Since its emergence in the economic environment of EU member states, the ESG strategy has become the embodiment of the possibility of eliminating observed climate change and achieving high social prosperity. Only in a few cases was it pointed out that the burden of its implementation would fall primarily on micro-entities, uneven allocation of production factors, and their concentration in sustainable development sectors. New green technologies were closely linked to high levels of economic innovation, while the associated costs, primarily borne by small and medium-sized enterprises, were largely overlooked. The significance of restructuring, including the exit of many inefficient entities under the new climate protection conditions and the concentration of financing on large green investments, was similarly neglected. From the perspective of EU regulatory authorities, the primary condition for ESG implementation was the accumulation of significant financial resources. However, as time passed, the expected results did not materialize. The green transition is progressing, but its results are not satisfactory. ESG risk is increasing among economic entities that finance and implement green investments. Implementing strategic goals and targets is at risk due to systemic risk and the continuing instability of the global economy. Without a doubt, the energy crisis caused by Russia's aggression against Ukraine has been a significant factor in exacerbating the European Union's economic problems (Koczan, 2023; Nowak, Zaniewicz, 2021; Pronińska, 2014, 2022). This has contributed to rising inflation driven by higher energy prices, while simultaneously underscoring the need to enhance energy self-sufficiency within the EU economy. The trend towards replacing existing CO2-emitting energy resources with ecological sources, despite their 'shortcomings,' has become a major impetus for accelerating the implementation of the ESG strategy. However, this situation has become more complex over time. Replacing traditional energy sources with sustainable ones has proved costly and varied across the member states of the European Union.

At the same time, fairly broad estimates of the EU funds needed to finance the ESG strategy do not keep up with the identified needs. Initially, it was assumed that the majority of financing for the energy transition would be sourced from European Union funds (UN trade & development).

It is currently estimated that more than half (up to 56%) of the total green transition will have to come from the private sector, i.e., the own funds of companies and financial institutions. However, in Poland, the financial outlays required for the energy transition will undoubtedly be higher than in many other EU member states. This is a result of the extremely unfavourable structure of energy sources in Poland. Hard coal and lignite play a dominant role in the national energy mix, and although their share is decreasing, it still exceeds 50%[1]. Poland is one of the world's most emission-intensive countries in terms of unit emissions from primary energy consumption, which translates into CO2 emission costs and the competitiveness of Polish enterprises. Furthermore, financing the ESG strategy requires combining state capital with private financial resources. Meanwhile, the finances of our country remain consistently unbalanced. The very high public debt and an annually increasing fiscal deficit increase the likelihood of EU sanctions being imposed on Poland for non-compliance with treaty rules, mainly the so-called Six-Pack (Pronińska, 2014). At the same time, the high demand of the public sector for debt financing will result in a higher cost of financing the green transition in Poland. As a result, domestic green enterprises are increasingly dependent on private foreign financing. Meanwhile, the financial resources of the European Union are shrinking in the face of the needs of the green transition. According to the European Commission's estimates, Europe will need investments of EUR 350 billion per year by 2030 in the areas of climate and energy alone. Moreover, it is estimated that approximately EUR 130 billion will be required to achieve other environmental objectives. On a global scale, achieving all sustainable development goals is expected to require between EUR 5.4 and 6.4 trillion (Kotecki, 2025). Meanwhile, foreign green loan capital is also becoming more expensive for several reasons, one of which is unquestionably the green transition of the global economy. Given these circumstances, domestic enterprises implementing the ESG strategy are exposed to high investment risk. This is particularly significant given that the green energy transition is inherently capital-intensive. Domestic enterprises, however, do not own sufficient internal capital. They therefore direct the process of green investment towards external financing. The main source of this financing is the domestic banking sector. Consequently, mutual relations between banks and enterprises play a crucial role in this process. Meanwhile, banks are in a significantly better position in terms of green finance compared to enterprises. The universal nature of banking activities allows them to build a diversified portfolio of green assets. Green bonds can be an alternative to green loans. However, the geopolitical situation in the European Union has

[1] In 2024, it amounted to 56.2%. This is a decrease of 4.3% compared to 2023. It is worth noting that, compared to 2015, there was a 33% reduction in hard coal consumption.

resulted in bank capital being increasingly directed toward military expenditures (Ramotowski, 2025). Therefore, banks' financial resources may not be sufficient to cover the needs of green investment financing in our country. The study presents the findings of research conducted in the first half of 2025. The scope of this study was broad, allowing for the identification of the domestic banks' motives in greening the Polish economy and verifying previously published research results ((Pyka, Nocoń, 2023, 2024; Pyka, Pyka, 2023, 2024). This publication presents only a portion of the research findings, guided by the verification of the hypothesis that domestic banks, by announcing the adoption of an ESG strategy, continue to express their willingness to implement it. In contrast, enterprises are concerned about the high ESG-related risks in implementing green investments. The study indicates that domestic banks remain focused on implementing the ESG strategy. All respondents occupying key positions in sustainable development and ESG, or in the management divisions responsible for its implementation, are familiar with the concept of ESG and its components. All the banks included in the research have also implemented the ESG strategy. The research findings indicate that 35% of domestic banks have already implemented an ESG strategy in the form of a formal document, 56% have announced plans to adopt such a strategy in the near future, and 9% intend to do so contingent upon the introduction of further EU regulations (see Figure 1).

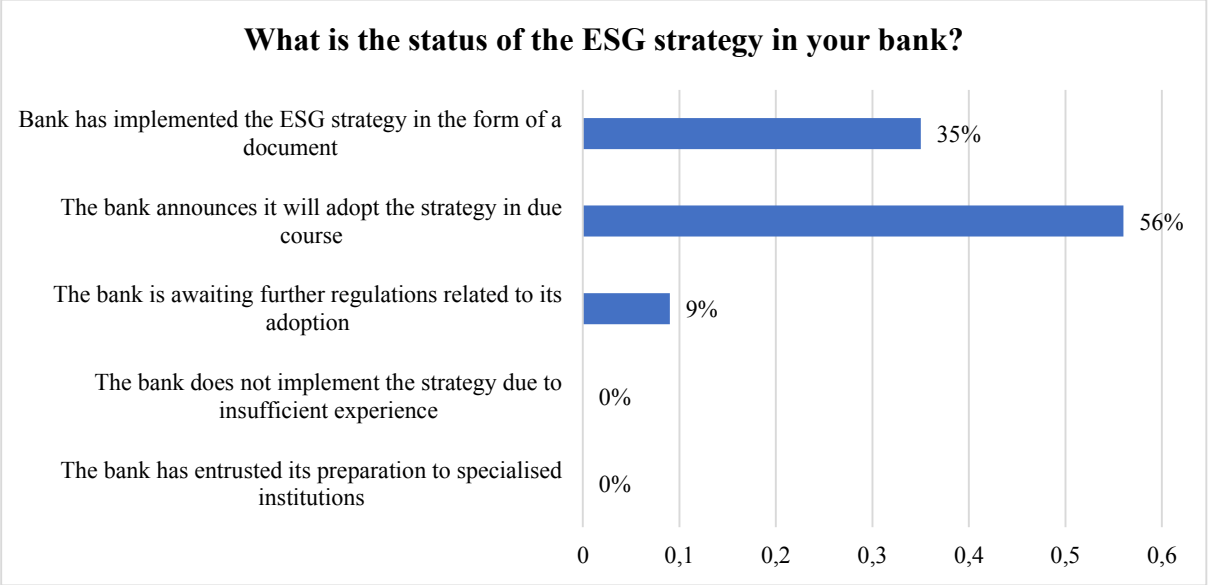


Figure 1. Status of the ESG strategy in banks.

Source: own elaboration.

Domestic banks are strongly interested in implementing the ESG strategy, although they approach it with great caution. They control their propensity to grant loans for green investments by indicating the areas in which they undertake environmental protection measures (Figure 2). Respondents place particular emphasis on green investments related to carbon dioxide emissions, targeting climate neutrality or the acquisition of alternative energy resources. They also finance investments that reduce environmental pollution with by-products or waste products.

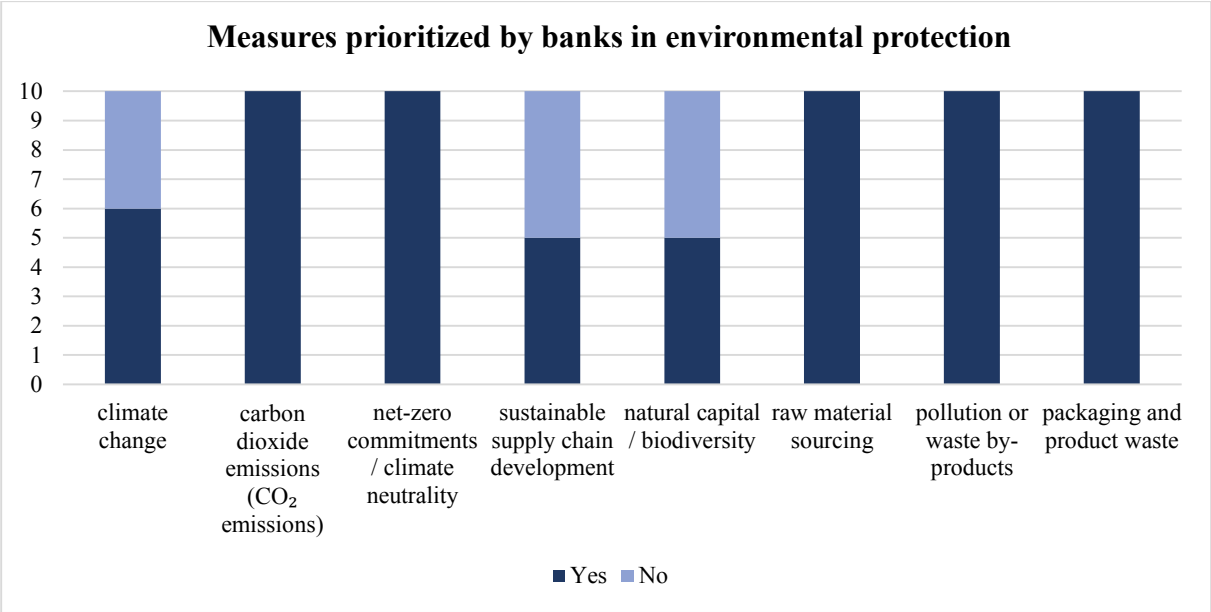


Figure 2. Banks' orientations regarding directions of support for environmental protection.
Source: own elaboration.

The objectives indicated vary in terms of expected ESG results, particularly given the innovative techniques and technologies needed to curb the trend of economic decline in EU member states (The future of…, 2025). Table 1 also shows the significant fragmentation of banks' financial resources for green transition. Respondents indicated that the ESG strategy is implemented in all areas, i.e., environment, social responsibility, and corporate governance. Banks assess the effectiveness of green financing through appropriate ESG KPIs (ESG Key Performance Indicators) that confirm their commitment to implementing the ESG strategy. These declarations primarily reflect the scale of banks' formal involvement in ESG strategy implementation, without necessarily translating into a clear reorientation of capital allocation toward green investments.

Meanwhile, the qualitative elements of this strategy, i.e., changes in corporate governance and social responsibility (SG), have no direct and significant impact on achieving green investment outcomes. Therefore, the ESG strategy requires, above all, political demystification and the establishment of a platform for its critical analysis. Only in such circumstances can the scale of greenwashing, perceived as one of the factors weakening the expected effects of the ESG strategy, be reduced (Kmita, 2024), or the contradiction between its administratively determined objectives and tasks and the rationality of investment decisions be limited. Research shows that the level of green investment financing in the Polish banking sector has indeed not changed significantly. 38% of respondents do not notice such changes, while 37% report that it is growing proportionally

Table 1.
Key ESG performance indicators (ESG KPIs) used in commercial banks in Poland

KPI - environment	KPI - social responsibility	KPI - corporate governance
– Green Asset Ratio (GAR) – share of assets compliant with the taxonomy in the bank's portfolio – Annual volume of new financing for green projects – Reduction of CO2 emissions – Share of electricity purchased with green certificates	– Share of women in managerial positions – Reduction of the gender pay gap – Employee turnover and voluntary resignation rate – Employment of people with disabilities – Digital education and social inclusion	– Organization of the ESG structure in management – ESG risk indicators – ESG compliance and audit

Source: own elaboration.

with the financing of other investments. Only 17% of respondents recognise the advantages of green investments, and 8% consider them superior to existing investments (see Figure 3). The results highlight the need for continuous identification of the factors underlying the slower-than-expected pace of the green transition. This is particularly important as these factors evolve over time, both at the macro and micro levels of economic activity in Poland. The research shows that domestic banks place strong emphasis on compliance with ESG requirements in their strategies. However, they do not recognise the significance of the ESG policy pursued.

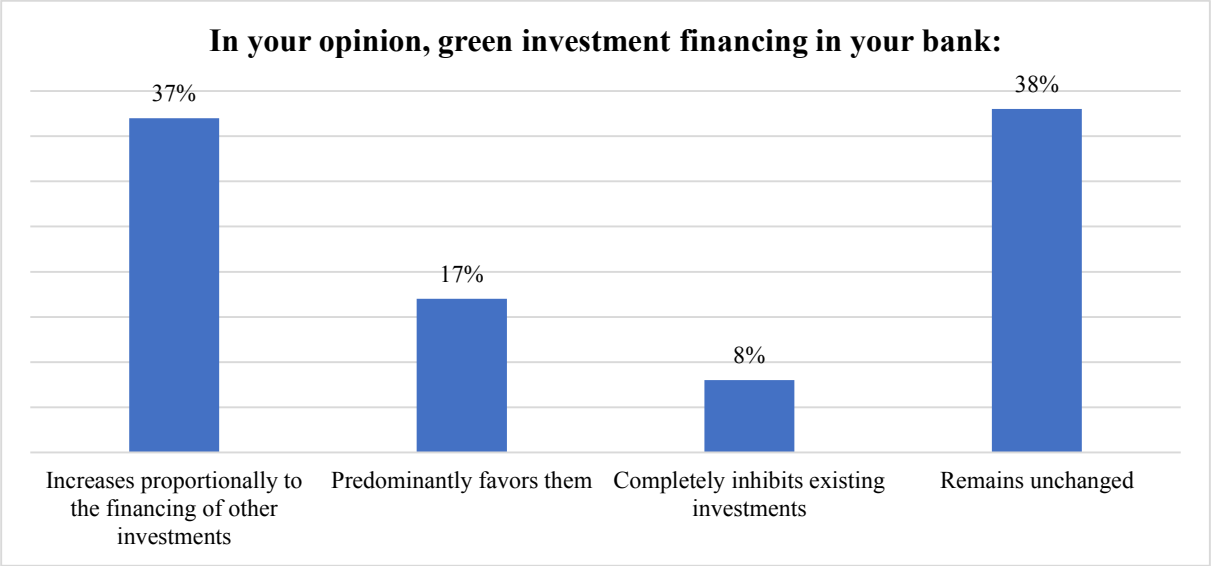


Figure 3. Scale of green investment financing in domestic banks.

Source: own elaboration.

Respondents, when asked about the possibilities of implementing the bank's ESG strategy in the current political climate, indicated both a lack of opportunities and a low, medium, and high level of impact. This means that they do not recognise the significant impact of political risk on the implementation of the adopted ESG strategies. In such circumstances, it can be expected that banks' behaviour regarding the implementation of the ESG strategy may not reflect their actual decisions concerning the allocation of capital resources to the green transition. It is challenging to determine the strength of this dichotomy. Its existence is

indirectly supported by statements from other respondents. All of them acknowledged that banks attach great importance to assessing their clients in the ESG implementation process (see Figure 4). This means that not every green investment project will be granted bank financing. By doing so, banks reduce the ESG risk associated with their green investment portfolio.

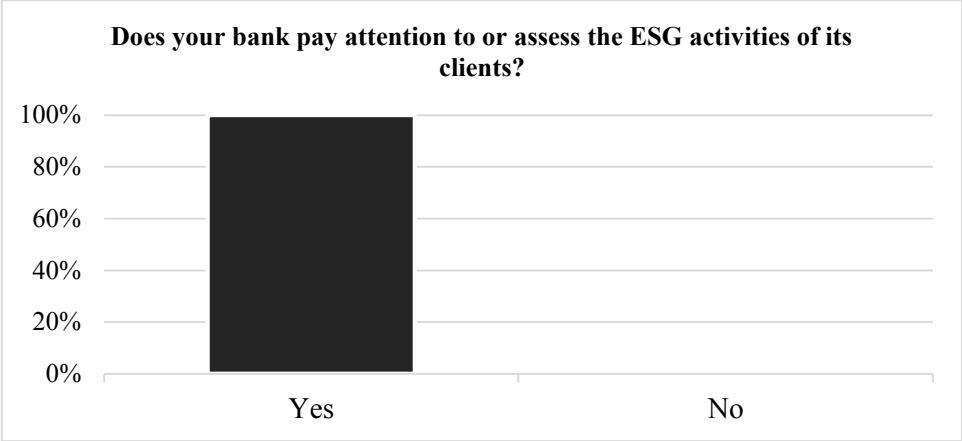


Figure 4. Banks' conduct in the process of green financing of corporate investments.
Source: own elaboration.

On the other hand, green investment projects that meet ESG criteria are willingly financed and rewarded in various ways (see Figure 5) with full awareness that they narrow the base of clients who could potentially benefit from them. They recognise that there are, on average, 27.3% fewer of them (on a scale of 0 to 100, where 0 = 'none' and 100 = 'completely').

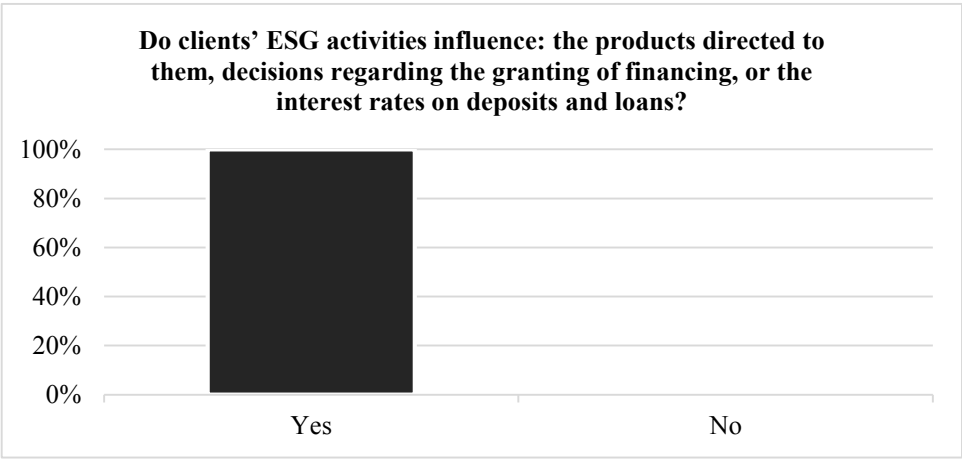


Figure 5. Bank ESG incentive tools.
Source: own elaboration.

That is why they do not exclude financially strong entities from their client base solely because they do not implement ESG activities (see Figure 6). This means that they intend to finance investments of enterprises that are in good manufacturing and financial condition and meet all the criteria for creditworthiness.

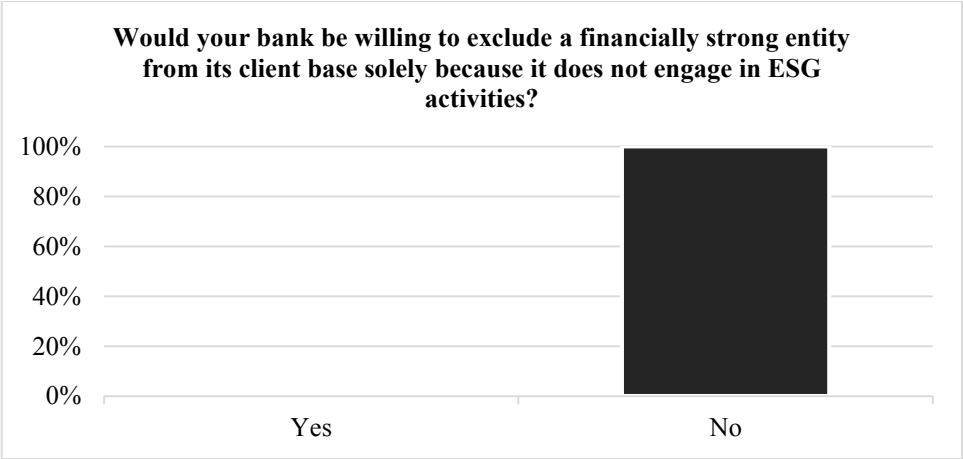


Figure 6. Banks' priorities in terms of financial capital allocation.

Source: own elaboration.

While these investments reduce the availability of funds in banks for the green transition, they have a positive impact on the efficiency of their business activities. They also clearly highlight the lending priorities of banks regarding domestic enterprises. Respondents, in turn, were asked whether the bank would accept as a client an entity that implements ESG activities, even if its financial standing alone does not make it an attractive investment. All respondents answered affirmatively (see Figure 7). Interpreting this response is not straightforward, however, as it contradicts the rational behaviour of banks to a certain extent. It can therefore be assumed that banks care about their image as reflected in their ESG strategies. Nevertheless, further research is clearly needed to explain the underlying causes of the observed inconsistency.

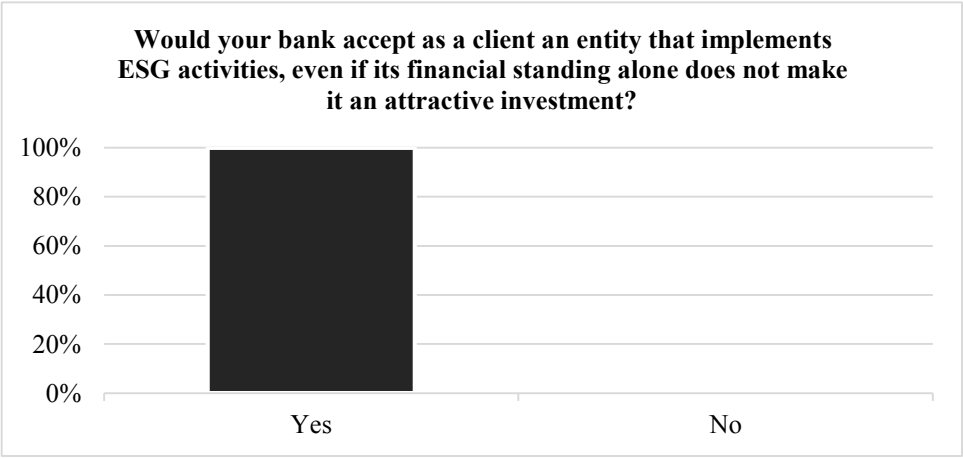


Figure 7. Banks' priorities in terms of financial capital allocation.

Source: own elaboration.

It cannot be ruled out that this is due to the constantly changing EU regulations on green corporate financing. In January 2023, the Omnibus Directive was introduced into the Polish legal framework (Directive (EU) 2019/2161). It imposed new obligations on businesses in consumer transactions. Simultaneously, on 5 July 2024, the Directive of the European

Parliament and of the Council on corporate sustainability due diligence and amending Directive (EU) 2019/1937 (Corporate Sustainability Due Diligence Directive, CSDD Directive) was published in the Official Journal of the EU (Directive (EU) 2024/1760). The directive entered into force on 25 July 2024. As of that date, EU member states have two years to transpose the provisions of the CSDDD into their national legal systems. Naturally, both enterprises and national banks are still obligated to comply with previous regulations related to the green transition. They are required to disclose and report on the implementation of their ESG strategies, adapt their operational plans accordingly, and introduce ESG risk management into their systems. The obligations of national economic entities, therefore, pose a serious challenge to the implementation of the ESG strategy. The problems are particularly noticeable when modified or new EU regulations change the rules of the green transition game. Large corporations tend to cope better with ESG legal instability, while SMEs lack specialist knowledge of green financing. They are usually concerned about the scale of the obligations that accompany green investment financing procedures. Their capacity to collect diverse data and prepare specific disclosures is extremely limited. Emerging information bureaus and various consulting firms offering such services tend to increase the cost of green financing, thereby discouraging these entities from making green investments. Small and medium-sized enterprises also frequently struggle to meet the requirements of the Taxonomy (Jeziolowicz, 2025). Therefore, a significant proportion of the adaptation problems associated with the ESG strategy arises in manufacturing enterprises, which block green financing in domestic banks.

3. Results

The method of semi-structured in-depth interviews used in the empirical research in 2025 enabled the collection of new qualitative data, expanding the existing knowledge base on green transition. This method enabled respondents to raise certain issues that were not initially included in the interview scenarios. In this article, the analysis of green investment financing focuses on changes in the relationships between enterprises implementing green investments and banks acting as financing institutions. The balance between the resources financing green investments and the demand for them constitutes a fundamental condition for the high effectiveness of implementing ESG goals and targets. Maintaining this balance, however, presents a significant challenge for all participants in this process. Research shows that estimating the total amount of financial resources for green investments is like predicting the next viral pandemic. There is a continuously growing demand for financing the implementation of an ESG strategy in the global economy and the European Union. The scale of financial burdens on individual economies remains uneven, public resources for financing the energy

transition are shrinking, and bank capital is taking over the role of the main source of financing. The observed trend generates significant investment risks across various segments of the financial market and system, while proponents of the concept remain convinced that managing this process through successive regulations on green financing of the economy is the solution to all challenges. Meanwhile, the implementation of green investment financing processes is taking place in conditions of high uncertainty and a deteriorating economic situation in EU member states. As a result, ESG risk is increasing, driving up the cost of green investment financing. While investment risk is a constant feature of manufacturing processes in large corporations, SMEs are generally unable to overcome such barriers. Banks financing green investments are also exposed to ESG risk. However, research indicates that they can hedge this risk. They have incorporated it into their banking risk management systems, drawing on the extensive experience gained to date. In this context, two distinct and incompatible ESG risk management systems emerge: one within banks and one outside the banking sector. Enterprises fall into the latter group, thereby incurring higher associated costs. In conclusion, it should be emphasized that ESG strategies, despite being founded on the contentious premise linking climate change to human economic activity, are being implemented consistently. Based on the contradiction between the administrative goals and targets of ESG and economic rationality, it inherently increases resistance to its adaptation by financial and non-financial economic entities. The consistently growing need for green investment financing requires the establishment of priorities in which the significance of S and G, social and governance, elements, is minimal or negligible. Therefore, an ESG strategy requires, above all, political demystification and the continual verification of its goals and targets.

References

1. Alberti, M. (1996). Measuring urban sustainability. *Environment Impact Assessment Review*, *No. 16*, pp. 381-424.
2. Bell, S.T., Fisher, D.M., Brown, S.G., Mann, K.E. (2018). An approach for conducting actionable research with extreme teams. *Journal of Management, Vol. 44, No. 7*, pp. 2740-2765, doi:10.1177/0149206316653805
3. Directive (EU) 2019/2161 of the European Parliament and of the Council of 27 November 2019 amending Council Directive 93/13/EEC and Directives 98/6/EC, 2005/29/EC and 2011/83/EU of the European Parliament and of the Council as regards the better enforcement and modernisation of Union consumer protection rules, L 328/7 18.12.2019
4. Directive (EU) 2024/1760 of the European Parliament and of the Council of 13 June 2024 on corporate sustainability due diligence and amending Directive (EU) 2019/1937 and Regulation (EU) 2023/2859

5. Directive (EU) 2025/794 of the European Parliament and of the Council of 14 April 2025 amending Directives (EU) 2022/2464 and (EU) 2024/1760 as regards the dates from which Member States are to apply certain corporate sustainability reporting and due diligence requirements.
6. Griffith, E.E., Hammersley, J.S., Kadous, K. (2015). Audits of complex estimates as verification of management numbers: how institutional pressures shape practice. *Contemporary Accounting Research, Vol. 32, No. 3*, pp. 833-863, doi: 10.1111/1911-3846.12104
7. Jeziolowicz, N. (2025). Deregulacja zrównoważonego finansowania z perspektywy sektora bankowego - oczekiwania vs. Rzeczywistość. In: L. Kotecki (Ed.), *Zielone finanse w Polsce 2025* (p. 74).
8. Kmita, J. (2024). Greenwashing jako przeszkoda w zielonej transformacji Unii Europejskiej. *Teoria i Praktyka Dydaktyki Akademickiej*, *tom 3, nr 3*, pp. 1-12.
9. KNF (2022). *Sprawozdanie z działalności Urzędu Komisji Nadzoru Finansowego oraz Komisji Nadzoru Finansowego w 2021 roku*. Warszawa.
10. Koczan, M. (2023). Działania Rosji pogłębiające kryzys energetyczny w 2021 r. jako element wielokierunkowej presji na Unię Europejską. *Wschód Europy*, *Vol. 9, No. 2,* http://dx.doi.org/10.17951/we.2023.9.2.235-247
11. Kotecki, L. (Ed.) (2025). *Zielone Finanse w Polsce 2025*. Retrieved from: https://www.efcongress.com/wp-content/uploads/2025/06/publikacja_Zielone_ finanse_www_2025.pdf, 10.12.2025.
12. Merriam, S.B., Tisdell, E.J. (2015). *Qualitative Research: A Guide to Design and Implementation.* San Francisco, CA: John Wiley and Sons.
13. Nowak, Z., Zaniewicz, M. (2021). Rola Rosji w europejskim kryzysie gazowym. *Biuletyn PISM, No. 186(2384)*, 5 November.
14. Pronińska, K. (2014). *Świat i Europa w obliczu kryzysu energetycznego: konsekwencje wojny, sankcji i rosyjskiej broni energetycznej. Przegląd sześciopaku i dwupaku*. Parlament Europejski, Posiedzenie plenarne. 5/12/2014.
15. Pronińska, K. (2022). Bezpieczeństwo energetyczne w warunkach gwałtownego wzrostu cen i kryzysu klimatycznego. *Rocznik Strategiczny 2021/22.* Warsaw: Scholar.
16. Pyka, I., Nocoń A. (2024). Exposure to the ESG Risk of the Polish Banking Sektor. *Economics and Environment, No. 1(88), 701*, pp. 1-14. https://doi.org/10.34659/ eis.2024.88.1.701
17. Pyka, I., Nocoń, A. (2023). Green lending policy from the perspective of a holistic approach to bank risk. *Ruch prawniczy, ekonomiczny i socjologiczny, Rok LXXXV, zeszyt 3, 85(3),* pp. 71-99. https://doi.org/10.14746/rpeis.2023.85.3.06
18. Pyka, I., Pyka, J. (2023). ESG risk management in the corporate lending process in Poland. *Scientific Papers of Silesian University of Technology, Organization and Management Series, No. 187.* Silesian University of Technology Publishing House, pp. 549-563.

19. Pyka, I., Pyka, J. (2024). The Financial Context of Corporate Green Investments in the Polish Banking Sector. *Scientific Papers of Silesian University of Technology, Organization and Management Series, No. 217*. Silesian University of Technology Publishing House, pp. 419-433.
20. Ramotowski, J. (2025). *Czy inwestycje pociągną za sobą kredyt – relacja z II. dnia Kongresu Bankowości Korporacyjnej i Inwestycyjnej 2025*. Bank.pl, 28.11.2025.
21. The future of European competitiveness. Part A. Competitiveness strategy for Europe. Part B. In-depth analysis and recommendations, September 2024. Publication Office of the European Union, Luxembourg, 2025.
22. UN trade & development. *The Costs of Achieving the SDGs 2030.* Retrieved from: https://unctad.org/sdg-costing/about (28.07.2025).
23. Yin, R.K. (2003). Designing case studies. *Qualitative Research Methods, Vol. 5, No. 14*, pp. 359-386.

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MANAGING LOGISTIC SERVICE QUALITY IN AN E-COMMERCE ENVIRONMENT: THE PERSPECTIVE OF GENDER DIFFERENCES IN QUALITY ASSESSMENT

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Purpose: The purpose of this study is to examine the role of gender in service quality perceptions, an example of e-logistic service quality. The paper attempts to study the various dimensions of e-service quality affecting online shopping satisfaction and to examine whether gender differences exist in the perceptions of e-service quality dimensions in online shopping.
Design/methodology/approach: The research was conducted on a group of 127 young consumers in October 2025. The research group consisted of women (52.75%) and men (47.25%), aged from 19 to 23. The survey was used to determine satisfaction levels concerning logistic service quality in an e-commerce environment. The study was based on a five-point Likert scale. The following determinants of logistic service quality have been taken into consideration: delivery conditions (cost and time of ordered product delivery, possibility and conditions of product return), e-commerce website design, reliability and online transaction security. In order to get a better look at which factors are related to each other, a data analysis was carried out, which determined the correlation between the level of satisfaction with selected factors and the division of groups with respect to gender. The analysis of the correlation of individual factors affecting the satisfaction level was carried out at the 0.05 level of significance.
Findings: Similar to the findings in past research, this study confirms the differences between genders in the assessment of different dimensions of e-logistic service quality. Men and women have different preferences related to delivery conditions (time and cost of delivery, return of goods), e-commerce website features and its reliability, as well as transaction security.
Research limitations/implications: The findings of this study are beneficial from the practitioners' perspective, because they indicate considerable differences in quality assessment between male and female customers. Such conclusions may affect the managers handling the e-commerce companies to match their offer individually, depending on the customer's gender. Understanding the most influential elements for customers' decision-making is not only beneficial for the future development of e-logistics but also for increasing customer satisfaction in e-commerce and the successful improvement of quality management in e-commerce companies.
Originality/value: Some research has investigated the effects of gender differences between service quality and satisfaction relationships; however, the study on gender roles remains infrequent. Therefore, the exploration of this research problem is necessary in order to provide

a suitable, comprehensive and measurable framework for assessing logistic service quality in e-commerce and to indicate the gender differences in e-logistics service quality assessment. Furthermore, improving the understanding of gender differences is a beneficial marketing strategy which aims to improve e-commerce companies. Several studies have noted that gender is a valid variable sufficiently strongly connected with service quality perception. For marketing purposes, gender differences may be noteworthy to be considered as a separate dimension, which plays an important role in quality perception and customer satisfaction. For that reason, this study attempts to extend the previous studies by examining the gender differences effect in quality assessment and customers' requirements fulfilment on the example of logistic service quality in e-commerce.
Keywords: e-commerce, consumer satisfaction, quality management, logistic service quality, gender differences.
Category of the paper: research paper.

1. Introduction

Quality is a vital and intricate component of e-business strategy, particularly when it comes to customer experiences. The primary factor in fulfilling e-commerce customers' needs is the combination of prompt delivery and exceptional service. The internet significantly impacts consumers' ordering processes, requirements, expectations, and shopping behaviours, while also creating new opportunities within the e-commerce landscape. As online retail continues to expand rapidly, the quality of service provided by e-retailers has become a crucial determinant of success for e-commerce businesses.

The exponential growth of e-commerce and e-logistics has fundamentally transformed consumer purchasing behaviours and expectations. As online shopping platforms become increasingly competitive, understanding the nuanced factors that influence customer satisfaction and loyalty becomes paramount. Service quality has emerged as a critical determinant of competitive advantage in e-commerce environments, yet empirical evidence suggests that consumer expectations and perceptions of service quality are not uniform across demographic segments (Lee, Lin, 2005).

Service quality in e-commerce can be defined as the consumers' overall evaluation and perception of the excellence and e-service quality offerings in the virtual marketplace (Santos, 2003). Customer satisfaction in e-commerce, as in traditional services, depends on the gap between customers' expectations and the actual e-service experience (Zeithaml, 2003). Researchers suggest that logistics service quality (LSQ) can influence customer satisfaction, indicating that the quality of logistics services can have a positive and significant impact on fulfilling customers' requirements in e-commerce transactions (Saura, Ruiz-Molina, 2011). Most of the studies on e-retail service quality have concentrated on developing measures for the evaluation of websites, but measuring e-service quality should go beyond the website interface. The customer's online experience encompasses everything from information search,

product evaluation, decision-making, transaction security, delivery, return conditions, and customer service. Measures for evaluating just websites may not be sufficient for measuring service quality across various stages of the online retail service delivery (Rafiq et al., 2012).

Studies related to the issue of customer satisfaction and quality assessment are sensible due to the dynamic nature of the business environment and customer preferences. Service quality is generally considered a significant explanatory factor for customers' satisfaction in online shopping (González et al., 2007; Meng, Elliott, 2009; Chotisarn, Phuthong, 2025). It is necessary to explore the problem of e-service quality evaluation in the context of different customers' characteristics. Demographic variables, such as age, gender, education and socioeconomic status, are known as customer characteristics. These characteristics are significant determinants of consumer behaviours, requirements and preferences (Juwaheer, 2011; Mokhlis, 2012; Aslam et al., 2024). Therefore, this study seeks to exploit gender differences to determine the level of satisfaction in response to service quality, for example, e-logistic service quality. Males and females can be different in traits, attitudes, and activities that are able to influence consumer behaviour because each gender observes the environment, evaluates and retrieves information, and makes decisions in different ways (Karatepe, 2011). The current literature dealing with the interaction of gender with service quality and satisfaction is, however, still lacking (Mokhlis, 2012; Rajaratnam, 2020).

Some research has investigated the effects of gender differences between service quality and satisfaction relationships; however, the study on gender roles remains infrequent. For example, Im and Ha (2011) called for further studies on gender differences in quality perception and customer satisfaction fulfilment because their analysis pointed out significant gender differences in several aspects of service quality.

Therefore, the exploration of this research problem is necessary in order to provide a suitable, comprehensive and measurable framework for assessing logistic service quality in e-commerce and to indicate the gender differences in e-logistics service quality assessment.

Furthermore, improving the understanding of gender differences is a beneficial marketing strategy which aims to improve e-commerce companies. Several studies have noted that gender is a valid variable sufficiently strongly connected with service quality perception (Juwaheer, 2011; Mokhlis, 2012; Nieves-Pavón et al., 2025). For marketing purposes, gender differences may be noteworthy to be considered as a separate dimension, which plays an important role in quality perception and customer satisfaction. For that reason, this study attempts to extend the previous studies by examining the gender differences effect in quality assessment and customers' requirements fulfilment on the example of e-logistic service quality. Understanding the most influential elements for customers' decision-making is not only beneficial for the future development of e-logistics but also for increasing customer satisfaction in e-commerce and successful improvement of quality management in e-commerce companies.

The purpose of this study is to examine the role of gender in service quality perceptions, an example of e-logistic service quality. The paper attempts to study the various dimensions of e-service quality affecting online shopping satisfaction, and to examine whether gender differences exist in the perceptions of e-service quality dimensions in online shopping.

This study applies the following research methods: analysis of scientific literature, online survey, and statistical analysis of data (correlation analysis).

The study is structured as follows. After this introduction, the theoretical foundations and hypotheses that support the study have been described. The next section details the methodological procedures, followed by an analysis of data, and defines the dimensions of the proposed framework and its indicators. The results of the research have been presented and discussed. Finally, a conclusion and suggestions for the continuation of the research have been presented.

2. Literature review and hypotheses development

An e-commerce platform serves as a fundamental base for multi-channel transactions, where multiple third parties provide product or service information, and the platform operator processes transactions. Due to its role in supplying product and service details, an e-commerce platform operating company can also be regarded as a service provider. Consequently, an e-platform exhibits various characteristics as a service provider and can be assessed based on its service quality (Choi, Mai, 2018). Logistic service quality is measured by comparing customers' expectations with their perceptions of service quality. Before placing an order, customers already have expectations of what the service provider should deliver. Therefore, the perceived quality of logistic services by the client is the difference between their expectations and their perception of actual performance (Wolfinbarger, Gilly, 2003).

Understanding how consumers perceive and evaluate online consumer service is critical for providing superior service quality (Marimon et al., 2010). Traditional service quality assessment is based on the well-known SERVQUAL model, which proposes five dimensions of service quality: responsiveness, assurance, tangibles, empathy, and reliability (Pasuraman, Berry, 1988). However, this service quality assessment model focuses on traditional buyer-seller interactions rather than on the interaction between customers and websites, which is a distinguishing feature of e-commerce service quality. As a result, researchers expanded this model to other dimensions specific to the online environment, such as information quality (Kim et al., 2012), transaction security, transaction cost savings, convenience, reliability, accessibility, ease of use, responsiveness, usefulness, or interaction possibilities (Anderson, Swaminathan, 2011).

The website serves as the primary communication channel between customers and retailers in e-commerce. As a result, online shopping websites create and fulfil customer expectations, transfer value, and communicate. As a result, a good e-commerce site design can attract more customers with a positive first impression and make the purchase process easier to access for any part, from searching, ordering, paying, tracking, receiving, and after-sales (Kalia et al., 2017; Lee et al., 2025).

Although research on service quality has been popular for many years, it has only recently begun to be conducted in the e-commerce environment. In fact, there is a wide range of opinions about the most important factors influencing online consumer behaviour and satisfaction. The dominant factors influencing consumer perceptions of online purchasing are website characteristics, privacy, security, and the quality of logistical services, which is one of the most important elements in meeting the needs of customers in e-commerce (Querin, Göbl, 2017).

Many studies have been conducted to investigate the impact of gender differences on perceptions of e-service quality, with the goal of better understanding gender-based differences in attitude, perception, belief, and behaviour toward online purchasing. Gender, as a fundamental demographic characteristic, significantly influences how consumers assess and evaluate service quality in online environments. Research has consistently demonstrated that men and women differ in their shopping preferences, risk perception, trust development, and response to website design elements. These differences are rooted in distinct information processing patterns, varying expectations shaped by social roles and cultural norms, and divergent preferences regarding service attributes (Hsu, 2012; Moss et al., 2006).

Previous research on gender effects on customer perceptions of service quality yielded conflicting results. According to Stafford (1996), service quality may be more important to women than men. In contrast, another study discovered that male customers were more likely to rate service quality higher for given services than their female counterparts (Snipes et al., 2006). Other research has shown that male clients have a more positive perception of service quality than female clients (Spathis et al., 2006). Furthermore, there are several other examples of studies that show that female customers tend to rate service quality lower when compared to both genders (Lin et al., 2001; Tan, Kek, 2004; Juwaheer, 2011).

Previous studies have shown that men and women have different psychological predispositions related to online purchases, with males being found to have more positive attitudes toward online shopping (Wolin, Korgaonkar, 2003). Men and women have different perceptions of security issues in e-commerce environments, resulting in different purchasing behaviour (Garbarino, Strahilevitz, 2004).

Studies have revealed that gender plays an important role in e-commerce platforms (Pascual-Miguel et al., 2015; Ulbrich et al., 2011; Trabelsi-Zoghlami et al., 2020). For example, men are more focused on value gained through purchases, whereas women focus on trustworthiness and ability to socially interact (Slyke et al., 2010).

Gender influences online purchasing behaviour, and female purchasing behaviour is related to their attitude toward online service providers. However, in the case of males, this was found to be the opposite (Sebastiannelli et al., 2008). However, Cyr and Bonanni (2005) found no significant difference between men and women in terms of transaction security, trust, and e-loyalty.

In their study, Kolsaker and Payne (2002) discovered that trust is the factor on which most people express concern when making online purchases, and there was no significant difference between men and women. Gender-based differences were discovered in online purchases in terms of emotions, trust, and convenience (Rodgers, Harris, 2003; Kim et al., 2011). It is possible to argue that women place more emphasis on quality because they consider and evaluate in detail every single aspect of the services they acquire, whereas male customers evaluate the overall aspects (Karatepe, 2011; Teo et al., 2025). As a result, female customers are more likely to have higher expectations for service quality than male customers (Juwaheer, 2011; Liana et al., 2023). Other research found that women and men have different associations with the functional and relational dimensions of service quality in terms of satisfaction and loyalty. Male customers had higher functional service quality, whereas female customers had higher relational service quality (Sánchez-Hernández et al., 2010; Kanwal et al., 2022; Mayori, Handrito, 2024).

However, the study found that male respondents rated perceived service quality higher than female respondents. Five SERVQUAL dimensions explained 48.1 per cent of the variance in male customer satisfaction and 53.8% of the difference in female customer satisfaction (Mokhlis, 2012). Furthermore, the results of Karatepe's (2011) study demonstrated the importance of gender in the relationship between service quality and customer satisfaction.

As a result, the relationship between service quality and satisfaction appears to differ between male and female customers. Given all of the findings, the available literature suggests that men and women have different attitudes and perceptions about online shopping. Based on a review of the collected literature, the following hypotheses were developed for this study:

Hypothesis 1 (H1): *Gender affects the assessment of e-logistic service quality in online shopping, which in turn impacts customer satisfaction related to website design and reliability*.

Hypothesis 2 (H2): *Gender plays a role in the evaluation of e-logistic service quality in online shopping and influences customer satisfaction concerning delivery conditions, including delivery time, cost, and the return process*.

Hypothesis 3 (H3): *Gender influences the assessment of e-logistic service quality in online shopping, thereby affecting customer satisfaction related to transaction security*.

This paper examines the most widely acknowledged evaluation criteria for assessing logistic service quality within the e-commerce context and proposes a comprehensive framework for evaluating the quality of any e-commerce service, taking into account gender

differences in quality assessment. The following determinants of e-logistic service quality have been considered: delivery conditions (including the cost and time of product delivery, as well as the conditions and procedures for product returns), the design and reliability of e-commerce websites, and the security of online transactions. Understanding gender-based differences in e-logistics service quality assessment holds substantial theoretical and practical importance. From a theoretical perspective, it advances knowledge about how demographic characteristics shape consumer perception and decision-making in digital environments. Practically, it enables e-commerce organisations to tailor their service delivery, website design, and quality management strategies to address the distinct preferences and priorities of male and female consumer segments, thereby enhancing overall customer satisfaction and competitive positioning.

3. Materials and methods

The research was conducted on a group of 127 young consumers in October 2025. The data was collected in the form of a survey carried out on the e-learning website. Each participant of the study was asked to answer the survey questions. The research group consisted of women (52.75%) and men (47.25%), aged from 19 to 23. The survey was used to determine satisfaction levels concerning time invested in waiting for delivery, to assess the quality of services related to the delivery process, and to identify factors that affect the lack of satisfaction with purchases. The study was based on a five-point Likert scale (from 1- not important to 5- very important). The following determinants of e-logistic service quality have been taken into consideration: delivery conditions (cost and time of ordered product delivery, possibility and conditions of product return), e-commerce website design, reliability and online transaction security. Because the collected data came from 127 participants of the study, it was checked whether the respondents had any undesirable convergence between answers and questions. For that purpose, Cohen's kappa coefficient was used, which was determined for all 5 pairs of observations occurring in the scope of a given respondent. The average value was 0.147, and the average value for all respondents did not exceed 0.062. This indicates a low convergence of these answers. The reliability was assessed using Cronbach's Alpha (α). For all research variables, the obtained values exceeded 0.8. Cronbach's alpha demonstrated strong internal consistency; therefore, the measurements are reliable, and the assessment tool is suitable for research purposes.

Based on a previous literature study, five e-logistic service quality attributes influencing customers' satisfaction in online shopping were selected and then subjected to examination (Table 1). The distribution of attributes related to delivery conditions (cost and time of delivery, return of goods), e-commerce website design and reliability, and transaction security was

divided on the basis of gender, because previous literature studies indicate significant differences in the shopping satisfaction of both men and women.

Table 1.
The arithmetic mean of the customer satisfaction level

Arithmetic mean		**Delivery cost**	**Delivery time**	**Easy return of products**	**E-commerce website design and reliability**	**Security of online transactions**
	women	4.72	4.51	4.57	4.81	4.68
	men	3.96	4.83	4.21	3.92	4.36

Source: own study.

In order to get a better look at which factors are related to each other, a data analysis was carried out, which determined the correlation between the level of satisfaction with selected factors and the division of groups with respect to gender. The analysis of the correlation of individual factors affecting the satisfaction level was carried out at the 0.05 level of significance. The results of the correlation matrix are presented in Tables 2 and 3.

Table 2.
Correlation matrix for men

Variables	**Correlations (men) Marked correlation coefficients are significant at p < 0.05**						
	Mean	Standards deviation	Delivery cost	Security of online transactions	Website design and reliability	Delivery time	Easy return of products
Delivery cost	3.846	0.821	1.000	**0.732**	0.217	**0.641**	0.187
Security of online transactions	3.357	1.517	**0.732**	1.000	**0.683**	**0.921**	**0.773**
Website design and reliability	4.132	0.751	0.217	**0.683**	1.000	0.372	0.324
Delivery time	4.783	0.396	**0.641**	**0.921**	0.372	1.000	0.000
Easy return of products	4.526	0.693	0.187	**0.773**	0.324	0.000	1.000

Source: own study.

Table 3.
Correlation matrix for women

Variables	**Correlations (women) Marked correlation coefficients are significant at p < 0.05**						
	Mean	Standards deviation	Delivery cost	Security of online transactions	Website design and reliability	Delivery time	Easy return of products
Delivery cost	4.251	0.832	1.000	0.000	0.046	-0.152	-0.457
Security of online transactions	4.000	0.917	0.000	1.000	**0.531**	**0.693**	**0.428**
Website design and reliability	4.273	0.983	0.046	**0.531**	1.000	**0.457**	-0.248

Cont. table 3.

Delivery time	4.217	0.649	-0.136	**0.693**	**0.457**	1.000	-0.049
Easy return of products	3.891	0.857	-0.459	**0.428**	-0.237	-0.049	1.000

Source: own study.

The findings of the correlation analysis will be discussed in the following section of this paper. The study highlights key differences in how female and male customers evaluate different quality dimensions. This insight can significantly enhance quality management practices in e-commerce companies, thereby improving overall customer satisfaction with the online shopping experience.

4. Results and discussion

The delivery conditions in online shopping have a direct impact on customer satisfaction within the e-commerce market (see Table 1). The selected delivery features have been appropriately chosen, reflecting average satisfaction ratings ranging from 3.92 to 4.83 on a five-point scale. Analysing delivery features reveals that men and women have differing expectations and preferences. For both genders, the most critical aspects related to delivery conditions are the delivery time and the ease of returning rejected products. This information is vital for online shop managers, as it highlights the necessity of ensuring convenient delivery times and facilitating the immediate return of goods.

The cost of delivery, a crucial aspect of shopping satisfaction, has not been definitively established. The study reveals that women place greater importance on this factor, scoring it at 4.72 points and 3.96 in the case of male customers. In contrast, men prioritise delivery time more significantly, with a score of 4.83 points, compared to a lower score of 4.51 for female customers. Thus, viewing delivery through the lens of cost is merely one element in the broader context of customer satisfaction.

Another vital contributor to customer satisfaction in online shopping is the design and reliability of e-commerce websites. This aspect holds greater significance for women, who rate it at 4.81 points, compared to men, who rate it at 3.92 points. These results indicate notable differences between the preferences of men and women regarding the design, aesthetics, functionality, and reliability of e-commerce sites. Similar discrepancies are observed in the realm of transaction and payment security, where women exhibit a greater concern for the safety of online transactions, rating this factor at 4.68 points, while men rate it at 4.36. Easy return of product is also more important for women (4.57) compared to male customers (4.21).

The correlation analysis provided insights into various phenomena. For male customers (as shown in Table 2), the security of online transactions shows a strong correlation with delivery time (0.921) and ease of product return (0.773). The visible correlation also exists between the security of online transactions and delivery cost (0.732). Also, the security of online transactions is visibly correlated with website design and reliability (0.683). In addition, in the case of male customers, the delivery time and cost are also notably correlated (0.641). A significantly smaller correlation was observed between website design and delivery time (0.372), easy product return (0.324) and delivery cost (2.17). Moreover, among male customers exists a weak correlation between easy product return and delivery cost (0.187). As individual consumers, men are particularly concerned about transaction security due to the inherent risks associated with online purchases. Consequently, e-commerce companies should prioritise solutions that enhance payment security and facilitate product returns to minimise transaction risk. Men seek a seamless and quick purchasing experience with a low level of uncertainty.

In the case of female customers (refer to Table 3), the security of online transactions is notably correlated with delivery time (0.693). There also exists a visible correlation between website design and the reliability and security of online transactions (0.531). Moreover, in the case of female customers, the correlation between website design and reliability and product delivery time is 0.457. In addition, in the case of women, there also exists a notable correlation between the security of online transactions and the easy return of the product (0.428). There is also a little correlation between website design and reliability and product delivery cost (0.046). This trend aligns with the modern consumer's preference for quick and efficient transactions, reflecting a limited availability of time. These aspects of online customer satisfaction should be carefully considered in collaborations with courier services and online payment providers. Additionally, the return of goods demonstrates a negative correlation with delivery costs and time, as well as the design and reliability of e-commerce websites. This suggests that women exhibit a practical approach; the ease of returning items is a crucial factor contributing to their satisfaction (as indicated in Table 1), implying that they place less importance on the time and costs associated with item collection. This insight is valuable for e-commerce entrepreneurs, as it indicates that facilitating easy returns can grant greater flexibility in delivery times and costs without compromising customer satisfaction.

Service quality has emerged as a critical determinant of competitive advantage in e-commerce environments. Yet, empirical evidence suggests that consumer expectations and perceptions of service quality are not uniform across demographic segments.

Gender, as a fundamental demographic characteristic, significantly influences how consumers assess and evaluate service quality in online environments. This study has demonstrated that men and women differ in their shopping preferences, risk perception, trust development, and response to website design elements. These differences are rooted in distinct information processing patterns, varying expectations shaped by social roles and cultural norms, and divergent preferences regarding service attributes.

The significant role of gender in the relationship between service quality dimensions and customer satisfaction has been discussed and empirically proven. Similar to the findings in past research, this study confirms the differences between genders in the assessment of different dimensions of e-logistic service quality. Men and women have different preferences related to delivery conditions (time and cost of delivery, return of goods), e-commerce website features and its reliability, as well as transaction security. Thus, all research hypotheses were supported at the significance level of 0.05. Furthermore, the findings of this study are beneficial from the practitioners' perspective as well, because they indicate considerable differences in quality assessment between male and female customers. Such conclusions may affect the managers handling the e-commerce companies to match their offer individually, depending on the customer's gender.

Gender influences service quality assessment through a variety of interconnected mechanisms, including differences in information processing, divergent expectations shaped by social roles, varying risk perception, and a distinct trust-building process in relations with customers. Gender differences exist in the evaluation of website design. Women place a higher value on thorough information, unambiguous instructions, and professional presentation, while men place a higher value on functional efficiency and quick access to important information.

Also, e-commerce website reliability dimensions receive differential emphasis, with female consumers assigning substantially greater weight to reliability in service quality assessment and exhibiting higher sensitivity to reliability failures. This pattern reflects females' higher perceived risk in e-commerce and their more comprehensive trust-assessment processes.

When it comes to security, trust, and risk assessment, gender disparities in service quality perception are especially noticeable. The study has shown that women are more concerned about privacy and security risks in online transactions than men. Women's stronger emphasis on security dimensions has implications for how they assess logistics service quality, as they may place greater weight on assurances regarding package security, confidential handling of personal information, and transparent data protection policies. Women tend to have stronger negative reactions to privacy concerns and security breaches, implying that logistics service providers targeting female customers should prioritise demonstrating security competence and data protection measures. Communication about security measures may be essential in addressing female customers' concerns, given the moderating effect of gender on the relationship between security perceptions and consumer behaviour.

While the significance of timeliness is widely acknowledged within the context of e-commerce logistics, this study reveals that gender serves as a moderating variable influencing the weighting attributed to delivery speed.

Men generally prioritise fast delivery as a key indicator of service quality, perceiving speed as a fundamental measure of operational efficiency and excellence. This study suggests that logistics service providers may enhance female customer satisfaction by focusing on reliable and consistent delivery within reasonable timeframes, rather than solely pursuing high speed at

a greater cost. Order accuracy and the assurance that products arrive undamaged are vital dimensions of logistics service quality. The findings indicate that women place particular importance on these dimensions, perceiving errors in order fulfilment as lapses in attention to detail and care. This perspective aligns with the broader trend of women valuing reliability and meticulous execution in service delivery. Women tend to experience greater dissatisfaction when they receive incorrect items or encounter product damage. In contrast, men, while also preferring accurate orders and undamaged products, exhibit a slightly higher tolerance for occasional mistakes, provided the logistics provider demonstrates responsiveness in addressing these issues.

The extent to which perceived service performance meets or exceeds customer expectations reveals distinct gender-related antecedents and formation processes within logistics service contexts. For female customers, satisfaction is shaped by a combination of both functional performance aspects, such as accurate order fulfilment and timely delivery, as well as relational elements, such as the ease of product returns. In contrast, male customers' assessment of e-logistics service quality relies more heavily on functional performance metrics and the achievement of specific service outcomes. While relational dimensions are not altogether irrelevant for male customers, their absence is less likely to lead to dissatisfaction if functional performance aligns with expectations. This differentiation indicates that distinct satisfaction optimisation strategies are necessary for male and female customer segments.

Understanding these gender-based differences in e-logistics service quality assessments is of considerable theoretical and practical significance. Theoretically, it enhances the comprehension of how demographic characteristics influence consumer perceptions and decision-making in digital environments. Practically, it empowers e-commerce companies to customise their service delivery, website design, and quality management strategies to cater to the unique preferences and priorities of male and female consumers, thereby improving overall customer satisfaction and strengthening competitive positioning.

5. Conclusion

Gender differences in consumer behaviour and service quality perception stem from a complex interplay of sociological, psychological, and cultural factors. In this paper, the perceptual differences in e-logistic service quality dimensions across genders have been studied, and significant differences between male and female customers have been found. The study successfully verified the positive relationship between service quality and satisfaction, as well as the role of gender as a factor which determines quality perception. Analysis of the collected data answered the study's hypotheses, contributing to the knowledge about the dependency between gender, customer satisfaction, and the considered dimensions of

e-logistic service quality, such as delivery conditions (delivery cost and time, return of goods), e-commerce website design and reliability, and online transaction security.

This study confirms that gender significantly affects how male and female customers perceive, evaluate, and respond to logistics service quality in e-commerce environments. While both genders appreciate effective logistics service quality, consistent empirical evidence indicates that women emphasise relational dimensions, whereas men prioritise functional aspects. These gender differences are evident across various service quality dimensions, including expectations regarding delivery conditions, transaction security, e-commerce website design, customer service responsiveness, and considerations of trust and data protection.

By understanding these gender-specific patterns, logistics service providers and e-commerce retailers can implement more effective and targeted quality management strategies. Recognising that different customer segments prioritise distinct service quality dimensions enables organisations to make more strategic resource allocation decisions, design service improvements that deliver maximum satisfaction for specific customer segments, and develop communication strategies that resonate with their target audiences.

Differences in responses between male and female customers should send a clear message to e-commerce company managers that they are dealing with two distinct customer segments and that these differences need to be taken into account if they want to enhance customers' perceptions of e-logistic service quality. This study helps to understand the perceptual differences across genders related to quality requirements and experiences during online purchases. The paper attempts to identify factors that distinguish gender identity and are important from the point of view of supply chain management in e-commerce. It becomes very obvious that this subject is a huge field for further scientific research related to, among other things, a different attitude to the product, ecology, or responsibility and management.

The findings of this study are beneficial from the practitioners' perspective because they indicate considerable differences in quality assessment between male and female customers. Such conclusions may affect the managers handling the e-commerce companies to match their offer individually, depending on the customer's gender. Understanding the most influential elements for customers' decision-making is not only beneficial for the future development of e-logistics but also for increasing customer satisfaction in e-commerce and successfully improving quality management in e-commerce companies.

Understanding gender-specific preferences in the assessment of logistics service quality is essential for developing targeted strategies that enhance customer experiences. This study highlights the managerial implications that logistics service providers must pursue excellence not through a one-size-fits-all model of service quality but by strategically customising their approaches based on an evidence-based understanding of what different customer segments prioritise. E-commerce companies should simultaneously uphold minimum acceptable standards across all service quality dimensions while strategically emphasising those areas that yield the greatest satisfaction improvements for specific gender-segmented customer groups.

Female customers tend to be more sensitive to communication quality and exhibit greater concerns regarding security and privacy. Given the heightened security and privacy concerns identified among female e-commerce customers, logistics providers should craft explicit communications that underscore their security measures, data protection protocols, and confidentiality practices. This might include featuring certification displays, security badges, transparency in privacy policies, and proof of compliance with data protection regulations in communications aimed at female customers.

While male customers also value security, they may respond sufficiently to more succinct security messaging, provided there are positive indicators of reputation and past performance. Customising security communication to address gender-specific concerns presents an opportunity to mitigate privacy anxiety without unnecessary redundancy for segments that have lower baseline security concerns.

To achieve practical improvements, organisations should adopt gender-informed strategies that recognise and accommodate these differences. This study suggests that uniform approaches to service quality enhancement are suboptimal. Organisations that aim for superior competitiveness are increasingly acknowledging that excellence in service quality requires a nuanced understanding of the diverse preferences across different customer segments, with gender serving as a significant basis for such segmentation.

This work is exploratory and aims to draw attention to fixed delivery attributes. The relatively small size of the research sample does not allow generalisation of results. Future research should be based on a larger sample and, in addition, increase the number of features describing the level of satisfaction and apply multi-indicator latent variables. In addition, even though gender is an important aspect to be considered during the stage of marketing strategy development, it is not the only characteristic on which the marketing efforts should be based. Due to this reason, the inclusion of only one demographic factor, that is, gender, is considered a limitation of the study. Other demographic variables, such as age, culture, education level, and income, must also be considered in future studies and when developing marketing strategies.

The direction for future research would be to examine the effect of all electronic service quality dimensions across the other demographic variables. Additionally, this study does not cover all the e-service quality dimensions in detail because of the scarcity of time and resources, so there is scope for future research on the same aspect, taking other dimensions which have not been discussed in the study. E-commerce environments continue to evolve rapidly, with emerging technologies including artificial intelligence, augmented reality, and sophisticated personalisation algorithms transforming service delivery. Whether traditional gender differences persist in these novel contexts remains an open question. Future research should also examine how gender differences in service quality assessment evolve as technology and consumer expectations change.

References

1. Albino, V., Berardi, U., Dangelico, R.M. (2019). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of Urban Technology*, *22*(1), 3-21.
2. Anderson, R., Swaminathan, S. (2011). Customer satisfaction and loyalty in e-markets: a PLS path modeling approach. *Journal of Marketing Theory and Practice*, *19*, 221-234.
3. Aslam, W., Arif, I., Farhat, K. (2024). The journey of service quality to loyalty: a gender-based multigroup analysis in car-hailing service. *International Journal of Business Environment*, *15*(1), 1-24.
4. Choi, Y., Mai, D. (2018). The Sustainable Role of the E-Trust in the B2C E-Commerce of Vietnam. *Sustainability*, *10*, 291-308.
5. Chotisarn, N., Phuthong, T. (2025). Logistics service quality and customer behavior in cross-border e-commerce: a thai consumer perspective. *Cogent Business & Management*, *12*(1), 2486581.
6. Cyr, D., Bonanni, C. (2005). Gender and Website Design in E-Business. *International Journal of Electronic Business*, *3(6),* 565-582.
7. Garbarino, E., Strahilevitz, M. (2004). Gender differences in the perceived risk of buying online and the effects of receiving a site recommendation. *Journal of Business Research*, *57*, 768-775.
8. González, M., Comesaña, L., Brea, J. (2007). Assessing Tourist Behavioral Intentions through Perceived Service Quality and Customer Satisfaction. *Journal of Business Research*, *60(2),* 153-160.
9. Hsu, M.H., Chang, C.M., Chu, K.K., Lee, Y.J. (2014). Determinants of repurchase intention in online group-buying contexts. *Journal of Electronic Commerce Research, 15*(1), 40-59.
10. Im, H., Ha, S. (2011). An Exploration of the Cognitive-Affective Model of Satisfaction in a Shopping Context: A Test of Competing Models. *The Service Industries Journal*, *31(13),* 2273-2288.
11. Juwaheer, T.D. (2011). Gender Bias in Hotel Guests' Perceptions of Service Quality: An Empirical Investigation of Hotels in Mauritius. *E-Review of Tourism Research*, *9(5),* 164-189.
12. Kalia, P., Kaur, N., Singh, T. (2017). Consumer satisfaction in e-shopping: An overview. *Indian Journal of Economics and Development*, *13(2),* 569-576.
13. Kanwal, M., Burki, U., Ali, R., Dahlstrom, R. (2022). Systematic review of gender differences and similarities in online consumers' shopping behavior. *Journal of Consumer Marketing*, *39*(1), 29-43.
14. Karatepe, O.M. (2011). Service Quality, Customer Satisfaction and Loyalty: The Moderating Role of Gender. *Journal of Business Economics and Management*, *12(2),* 278-300.

15. Kim, Ch., Galliers, R., Shin N., Ryoo, J.-H., Kim, J. (2012). Factors influencing Internet shopping value and customer repurchase intention. *Electronic Commerce Research and Application*, *11*, 374-387.
16. Kim, M., Kim, J.H., Lennon, S.J. (2011). E-service attributes available on men's and women's apparel web sites. *Managing Service Quality: An International Journal*, *21*(1), 25-45.
17. Kolsaker, A., Payne, C. (2002). Engendering Trust in ECommerce: A Study of Gender-Based Concerns. *Marketing Intelligence and Planning*, *20(4),* 206-214.
18. Lee, C.H., Chiu, M.C., Chu, C.H. (2025). Effect of gender on usability, purchase intention, perceived usefulness and perceived ease in using SVVR e-commerce. *International Journal of Mobile Communications*, *26*(3), 291-319.
19. Lee, G.G., Lin, H.F. (2005). Customer perceptions of e-service quality in online shopping. *International Journal of Retail & Distribution Management, 33*(2), 161-176.
20. Liana, P., Jaensson, J.E., Mmari, G. (2023). Service quality dimensions as predictors of customer loyalty in mobile payment services: moderating effect of gender. *Future Business Journal*, *9*(1), 98.
21. Lin, N.P., Chiu, H.C., Hsieh, Y.C. (2001). Investigating the relationship between service providers' personality and customers' perceptions of service quality across gender. *Total Quality Management, 12(1),* 57-67.
22. Marimon, F., Vidgen, R., Barnes, S., Cristóbal, E. (2010). Purchasing behavior in an online Supermarket: The applicability of E-S-QUAL. *International Journal of Market Research*, *52(1),* 111-129.
23. Mayori, C., Handrito, R.P. (2024). E-service quality in m-Health applications: The moderating effect of gender and domicile area. *International Journal of Research in Business & Social Science*, *13*(5).
24. Meng, J., Elliott, K. (2009). Investigating Structural Relationship between Service Quality, Switching Costs, and Customer Satisfaction. *The Journal of Applied Business and Economics*, *9(2),* 54-66.
25. Mokhlis, S. (2012). The Influence of Service Quality on Satisfaction: A Gender Comparison. *Public Administration Research*, *1(1),* 103-112.
26. Moss, G., Gunn, R., Heller, J. (2006). Some men like it black, some women like it pink: Consumer implications of differences in male and female web site design. *Journal of Consumer Behaviour, 4*(6), 475-487.
27. Nieves-Pavón, S., Sánchez González, M.J., López-Mosquera, N. (2025). Social and Cognitive Factors Influencing Trust and Purchase Intention in Organic E-Commerce: A Gender-Based Analysis. *Sustainability*, *17*(23), 10489.
28. Pascual-Miguel, F.J., Agudo-Peregrina, Á.F., Chaparro-Peláez, J. (2015). Influences of gender and product type on online purchasing. *Journal of Business Research*, *68*, 1550-1556.

29. Pasuraman, A., Berry, L. (1988). SERVQUAL: A Multiple item scale for measuring customer perception of service quality. *Journal of Retailing, 64*, 12-40.
30. Querin, F., Göbl, M. (2017). An analysis of the impact of logistics on customer service. *Journal of Applied Leadership and Management*, *5,* 90-103.
31. Rafiq, M., Lu, X., Fulford, H. (2012). Measuring Internet retail service quality using E-S-QUAL. *Journal of Marketing Management*, *28(9),* 1159-1173.
32. Rajaratnam, A. (2020). The effect of e-service quality on customer satisfaction and the moderating role of gender: Banking sector Trincomalee, Sri Lanka. *International Research Journal of Advanced Engineering and Science*, *5*(1), 94-97.
33. Rodgers, S., Harris, M.A. (2003). Gender and ECommerce: An Exploratory Study. *Journal of Advertising Research*, *43(3),* 322-329.
34. Sánchez-Hernández, R.M., Martínez-Tur, V., Peiró, J.M., Moliner, C. (2010). Linking Functional and Relational Service Quality to Customer Satisfaction and Loyalty: Differences between Men and Women. *Psychological Reports*, *106(2),* 598-610.
35. Santos, J. (2003). E-service quality: a model of virtual service quality dimensions. *Managing Service Quality*, *13(3)*, 233-246.
36. Saura, G., Ruiz-Molina**,** M. (2011). Logistics service quality and buyer–customer relationships: the moderating role of technology in B2B and B2C contexts. *The Service Industries Journal*, *31(7),* 1109-1123.
37. Sebastianelli, R., Tamimi, N., Rajan, M. (2008). Perceived Quality of Online Shopping: Does Gender Make A Difference? *Journal of Internet Commerce*, *7(4),* 445-469.
38. Slyke, C.V., Lou, H., Belanger, F., Sridhar, V. (2010). The influence of culture on consumer-oriented electronic commerce adoption. *Journal of Electronic Commerce Research*, *11*, 30-40.
39. Snipes, R.L., Thomson, N.F., Oswald, S. (2006). Gender bias in customer evaluations of service quality: An empirical investigation. *Journal of Service Marketing*, *20(4),* 274-284.
40. Spathis, C., Petridou, E., Glaveli, N. (2004). Managing service quality in banks: customers' gender effects. *Managing Service Quality*, *14(1),* 90-102.
41. Stafford, M.R. (1996). Demographic discriminators of service quality in the banking industry. *Journal of Services Marketing*, *10(4),* 6-22.
42. Tan, K.C., Kek, S.W. (2004). Service quality in higher education using an enhanced SERVQUAL approach. *Quality in Higher Education*, *10(1),* 17-24.
43. Teo, S.C., Cheng, K.M., Chow, M.M. (2025). Unlocking repurchase intentions in e-commerce platforms: the impact of e-service quality and gender. *Cogent Business & Management*, *12*(1), 2471535.
44. Trabelsi-Zoghlami, A., Berraies, S., Ben Yahia, K. (2020). Service quality in a mobile-banking-applications context: do users' age and gender matter? *Total Quality Management & Business Excellence*, *31*(15-16), 1639-1668.

45. Ulbrich, F., Christensen, T., Stankus, L. (2011). Gender-specific online shopping preferences. *Electronic Commerce Research*, *11*, 181-199.
46. Wolfinbarger, M., Gilly, M. (2003). e-TailQ: Dimensionalizing, measuring and predicting e-tail quality. *Journal of Retailing*, *79*, 183-198.
47. Wolin, L.D., Korgaonkar, P. (2003). Web advertising: gender differences in beliefs, attitudes and behavior. *Internet Research*, *13*, 375-385.
48. Zeithaml, V. (2002). Service excellent in electronic channels. *Managing Service Quality, 12(3),* 135-138.

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THE POWER OF ESG: CHALLENGES AND OPPORTUNITIES FOR ENTERPRISES IN POLAND

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Purpose: The purpose of this manuscript is to track the increasing importance of the ESG approach among Polish companies. It presents the primary challenges and opportunities of ESG integration in light of present legal standards, changing market demands, and corporate sustainability goals. It combines legal developments (CSRD, ESRS), corporate cases studies and bibliometric ESG research trends.
Design/methodology/approach: The present study represents a three-dimensional research structure: a review of law and policy on ESG reporting in Poland and the European Union, multiple case study of three companies consistently implementing ESG approaches and a bibliometric study with VOSviewer of Web of Science data (2012-2025), investigating leading keywords, co-occurrence networks and international research patterns on ESG and sustainability.
Findings: The results indicate that ESG in Poland is becoming both a regulatory pressure and strategic tool. ESG is becoming more embedded into larger companies and their operations, but the SME sector isn't quite as prepared. Despite barriers to implementation – including being short on expertise and scarce funding, ESG is recognised as increasingly being a source of competitive advantage, better access to sustainable financing options and further enhancing the credibility of corporations in the market.
Research limitations/implications: The downside of the article is its lack of anchor in primary empirical research (e.g., interviews or surveys with company representatives). The study is based on secondary data, at official reports of big companies and in case towards some real cases selected among large corporates that may not fully represent the whole market especially at micro and small enterprises level. In addition, the rapidly changing regulatory landscape could also limit the long term applicability of some observations.
Practical implications: The manuscript contributes with practical implications and recommendations for business leaders, regulators, and CSR/ESG practitioners in relation to concrete reporting requirements (CSRD, ESRS), as well as on best practices of ESG implementation. It also points to areas in need of institutional, educational, and technological support to help especially SMEs adopt and comply with ESG.
Originality/value: The manuscript's originality is in the integrated approach towards ESG in Poland, i.e., legal, practical and bibliometric analysis. It is uncommon to find above mentioned study that on one hand reveals context of ESG implementation practice in UE and references ongoing international research. This is why it is a contribution to the interdisciplinary debate on sustainable management and responsible business conduct in Central and Eastern Europe. Additionally, the paper introduces an original conceptual framework – the ESG CIRCLE–

POWER Model – which integrates the internal and external dimensions of ESG performance. The model provides a novel perspective on how credibility, innovation, resilience, competitiveness, leadership, and environmental awareness (CIRCLE) generate purpose, openness, worth, ethics, and resilience (POWER), thereby explaining the transformative potential of ESG within organizational strategy and culture.
Keywords: ESG, sustainable development, CSR, NFRD, CSRD compliance, Wosviewer analysis.
Category of the paper: Research paper.

1. Introduction

Over the last few years ESG (Environment, Social and Governance) has become one of the most important topics in Poland's academic, economic and regulatory discussions (Baran et al., 2022; Celary, Piwowarczyk, 2025; Petelczyc, 2022a; Tylec, 2022). The rising significance of ESG in Poland is an effect of the growing regulation pressure from the European Union and a change in public awareness on the social and environmental responsibility of companies as well as on sustainable business (Wolf Theiss, 2022; Accace, 2024 (Waldau, 2024; Wang et al., 2023). The application of ESG framework is especially significant in the light of Corporate Sustainability Reporting Directive (CSRD) that imposes a series of new and more far-reaching non-financial reporting obligations on companies active in Europe (European Commission, 2022).

In the case of Poland, around 3500 companies will be covered by CSRD directive, among which a large number of medium-sized enterprises (PARP, 2024). This is one aspect of the larger series of structural and technological changes being implemented as a result of the European Green Deal and the move towards a low carbon economy (Sahu et al., 2025; Li et al., 2024; Gidage, Bhide, 2025). It's an indication not just of regulatory evolution but also a rising social tide around transparency, ethical governance and value creation that has levels to rise further (Oluwakemi, Mishelle, 2025; Prasek, 2024; Diego, Montes-Sancho, 2025; Chong, Loh, 2023).

Many industry sources report that polish companies' readiness for the introduction of ESG is varied and often inadequate (Koralun-Bereźnicka, Orcholski, 2025; Tylec, 2022). Research by Crowe & Envirly (2023) showed that as few as 14% of Polish companies are well-prepared for ESG reporting according to CSRD needs. The level of preparedness illustrates the obstacles companies are encountering in complying with new sustainability requirements — from poor understanding or inadequate environmental data management systems, to financial and organizational barriers. Besides, it has been noted that failure of (ESG) compliance might have other significant implications ranging from fines and punishments to such threats as loss of international competitiveness and harm on the reputation (Crowe, Envirly, 2023).

This evidence, while raising significant challenges, also suggests some opportunities. It can also improve managerial effectiveness, stimulating innovation and building stakeholder confidence. Polish companies increasingly see ESG not only as a compliance burden but also as a means to create long-term competitive advantage and sustainable business models (Crowe, Envirly, 2023).

The relevance of ESG in Poland can also be seen at the level of corporate strategies and capital market regulations. In 2023, the Warsaw Stock Exchange (GPW) issued revised Environmental Social Governance ESG Reporting Guidelines to assist listed companies in standardizing and improving transparency regarding non-financial information provided by them on a voluntary basis (GPW, 2023). Likewise, data from KPMG Poland (2023) suggests that over 80% of large companies in Poland disclose ESG indicators at some level; but the quality and specificity of reporting as well as strategic approach to integrating ESG issues into corporate strategy differs significantly.

Nevertheless, the speed and extent of ESG integration differ significantly by industry, size of company, and the level at which ESG is integrated into practices in Poland. However, as stated by the Polish Agency for Enterprise Development (PARP, 2024), only approximately 30% of Polish small and medium-sized enterprises (SMEs) have started to take measures related to ESG. These small and medium-sized enterprises are generally resource poor, inexperienced and low in advisory support; all of which hamper their ability to comply with reporting and sustainability requirements. As SMEs constitute more than 90% of all companies in Poland, engaging them in the process of transforming towards ESG is necessary to reach national sustainability targets (Dmuchowski et al., 2023; Prasek, 2024; Kulej-Dudek, Dudek, 2024).

A second significant development is the growing involvement of the financial industry in advancing sustainable investment. More and more banks and financial institutions are including ESG factors in their lending, risk management, underwriting and investment analysis (PwC Poland, 2024). Similarly, the study by Sustainalytics and SEC Newgate (2023) argues that investors in Poland are increasingly identifying ESG issues as more than just legal requirements and instead as a key factor in creating long-term value (Rosak-Szyrocka, Żywiołek, Shahbaz, 2023, 2024).

The introduction of ESG standards in Poland is thus a challenge and an opportunity for enterprises. On the one hand, companies encounter regulatory and organizational/financial hurdles; on the other hand, ESG provides new avenues for innovation, efficiency and sustainable growth. It is important to comprehend this two-sidedness of constraints and opportunities in the age of sustainability transformation when developing proper strategies.

Beyond its regulatory implications, the rise of ESG also demonstrates a sea change in how companies are measured — not just by their fulfillment of regulations, but increasingly by the legitimacy of their values and practices.

This paper aims to present an overview of the challenges and opportunities that are faced by Polish companies when attempting ESG and sustainable development implementation in light of new trends that affect those processes and explicate how ESG transforms from a complex regulatory requirement into a strategic and cultural change accelerator in an organization based on a conceptual framework represented by six organizational dimensions as proposed in the study—the ESG–CIRCLE–POWER Model.

The novelty of the manuscript in its three-dimensional ESG approach to Poland (EU regulatory analysis, comparative firm-level case studies a subsequently bibliometric mapping of global research trends) supported by the original ESG-CIRCLE-POWER conceptual framework.

Despite the rising relevance of ESG in EU policies framework, as well as global corporate strategies, Polish academic literature is still missing synthesizing papers which would link approach to ESG implementation from legal-political one with managerial and sectoral scopes. The majority of extant literature provides either theoretical considerations or empiricisms on the effects of regulatory changes (Petelczyc, 2022b; Celary, Piwowarczyk, 2025; Baran et al., 2022), and does not offer solid analyses of how ESG frameworks work in practice in Polish enterprises.

Furthermore, in the Polish academic environment are not available holistic case study-driven analyses of ESG adoption at a company level in a cross-sectional manner across their plethora sectors (e.g.: finance, e-commerce or food servicing), either. There is, however, a surprising dearth of bibliometric studies that chart the development of ESG-related issues in Polish academic discourse in comparison to global trends. This contribution addresses this lack by providing a tri-dimensional:

- an update on the current and upcoming ESG regulations (CSRD, ESRS, EU Taxonomy),
- a study of chosen corporate case studies on the Polish market (McDonald's Poland, Allegro, Santander Bank Poland),
- bibliometric mapping through VOSviewer software, to visualize thematic clusters, knowledge gaps and the trends related to ESG research in global perspective and in Poland.

Through incorporation of these elements, this research makes a methodological contribution to the literature by establishing an empirically grounded interdisciplinary understanding of how ESG is reshaping firm behaviour and regulatory compliance in a post-transition economy.

Based on the above considerations, this paper seeks to answer the following research questions:

RQ1: What are the key challenges and opportunities in relation to implementation of ESG in Polish enterprises, following new regulations such as CSRD or ESRS?

RQ2: How does ESG work as a strategic instrument of corporate governance for adding long-term value to companies?

RQ3: Which research hotspots and frontiers exist in the global ESG and sustainable development studies according to bibliometric analysis?

RQ4: How the ESG–CIRCLE–POWER model justifies relationship between internal organizational values and external effects from ESG sustenance?

2. Literature review

2.1. ESG – current regulatory framework in Poland

The ESG concept covers three corporate responsibility dimensions: environmental, social and corporate governance (Kandpal et al., 2024; Arduino, Buchetti, Harasheh, 2024; Almadadha, 2024a). Given the changing expectations of society, the threat posed by climate change, and the increase in systemic risks, ESG is an essential element of evaluating the organization's potential to function in the long term and its credibility (Fig. 1) (Al Amosh, 2025; Oncioiu et al., 2020).

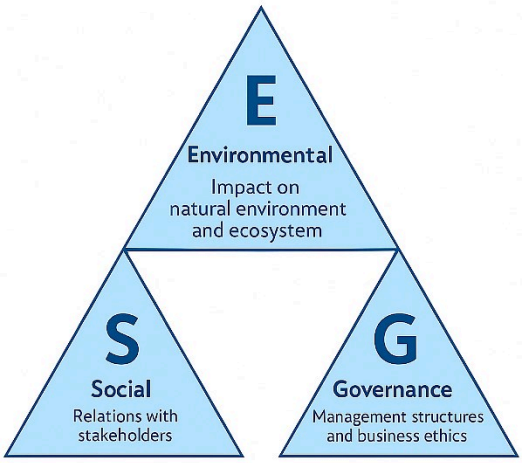


Figure 1. ESG elements.

Source: own study.

While they were generally recommended entities and not required to implement them ten years ago, now, their mandatory nature is inscribed in more and more formal acts, both at the level of the European Union and individual countries. The international origins of non-financial reporting include such standards as the Global Reporting Initiative and the Task Force on Climate-related Financial Disclosures. The development of ESG practices was stimulated by, inter alia, the adoption of the United Nations Sustainable Development Goals and the European Union European Green Deal, which enshrines ambitious EU climate goals. In response to the growing demand for standardization and the obligation to submit reports on sustainability, the European Parliament in 2022 passed the Corporate Sustainability Reporting Directive. The directive extends the scope of reporting entities and obliges EU member states to apply

European standards. The planned schedule for introducing the ESG reporting obligation in Poland according to the European Commission looks as follows:

- From 2024 – large listed companies so far covered by the NFRD directive.
- From 2025 – all large companies meeting at least two of the following three criteria: 250+ employees, revenue €40 million or total assets €20 million.
- From 2026 – listed small and medium-size enterprises, with the possibility of voluntary deferral until 2028.

In the following years – indirectly, other small, and medium-size enterprises whose suppliers are large companies or whose financing is subject to ESG criteria. The subjects of reporting on ESG are obliged to present a wide range of data, including: the competent authorities supervising compliance with ESG in Poland are the Polish Financial Supervision Authority, and the Warsaw Stock Exchange, which in 2021 modified the Best Practice for GPW Listed Companies document for the first time to include the principles of sustainable development and make reference to them. In practice, despite the growing interest, the readiness of an enterprise – especially an SME – to fulfill these new obligations is different. According to market research, entities indicate a lack of qualified personnel, insufficient expertise, high implementation costs, and problems with interpreting requirements. Thus, there is an urgent need for support from the state and an advisory system, the involvement of educational institutions, and the creation of digital solutions facilitating ESG. The regulation of the ESG system is, therefore, a new stage in the activity of Polish enterprises, in which the key word is transparency, comprehensive risk management, and business continuity. ESG is not a marketing element but a key to financing, investor-relation mechanisms, and future market positioning in a country in which, according to the concept, sustainable economy is to be built.

ESG rests on the basic legal act, the Corporate Sustainability Reporting Directive (CSRD), which was transposed into Polish law by means of an amendment to the Accounting Act enacted in December 2024. The revised Act prescribes detailed rules for the creation and publication of sustainability related information, as well as for ESG reports audit (assurance). It requires companies not already covered by financial reporting to report data on environmental, social and governance issues in the management report based on consistent European Sustainability Reporting Standards (ESRS).

The Polish Accounting Act sets out a phased timetable for the introduction of the new reporting requirements: from 2024 on large public-interest entities, from 2025 on other large companies, and from 2026 on listed SMEs (with an optional postponement until 2028). We also need that sustainability reports are prepared in structured electronic format, tagged (XBRL) for the transparency, and comparability of ESG data (Seele, 2016; Faccia, Manni, Capitanio, 2021).

The CSR Directive supplanted its predecessor, the Non-Financial Reporting Directive (NFRD), and broadens the range of companies that are obliged to report non-financial information. It also introduces the double materiality principle, which requires companies to

report on how their operations are affected by sustainability issues as well as how their operations affect people and the environment (Almadadha, 2024b; Saam, Rosenstein, 2024).

Other EU legal acts additionally reinforce this regulatory architecture: the Sustainable Finance Disclosure Regulation (SFDR) for financial institutions; the EU Taxonomy Regulation (2020/852) that defines environmentally sustainable economic activities; and the Corporate Sustainability Due Diligence Directive (CSDDD), introducing due diligence obligations along corporate value chains.

In the legal sphere it follows that ESG is no more a set of voluntary guidelines, but a system of compulsory norms and procedures which determines how businesses behave. Compliance of ESG with the regulations is currently not only a formal obligation, but also a strategic precondition to access to financing, market competition and credibility, which means a new stage in the process of integrating sustainable development into corporate governance in Poland (Ingaldi, Ulewicz 2025).

3. Methodology

The research is characterised by a qualitative, multi-method orientation which seeks for a holistic perspective towards ESG implementation in the activities of companies operating on the Polish market. The case studies were purposively selected, considering criteria such as company size and prominence in the market, representativeness of a variety of economic sectors, showing a high level of ESG maturity characterized by routine non-financial reporting according to internationally recognized standards, and advanced preparedness for complying with the CSRD and ESRS. According to these indications, McDonald's Poland, Allegro and Santander Bank Poland were chosen for analysis. The research is based on secondary data which has been accessed through open sources. The empirical material is composed by ESG and non financial reports, sustainability reports, corporate documents (ESG strategies, Codes of Ethics) and industry reports released by regulatory, advisory and market entities. The author did not collect any primary data such as interviews or surveys. The case study analysis was descriptive and comparative in nature, focusing primarily on the overview of corporate ESG actions within each of the three dimensions (environmental, social, governance) with a specific reference to the extent ESG was integrated into strategic management process and the degree of formalisation of ESG related policies/procedures/governance mechanisms.

In order to select the most relevant studies in the ESG field, bibliometric analysis was used, with the principal source of scientific manuscripts selected being the academic platform Web of Science. The content of 1027 research manuscripts has been taken into consideration from 2012 and 2025 years. The search documents related to "ESG" and "sustainable development" issue in title, abstract and keywords. In order to highlight the structure of the scientific field

a content analysis was used, inspecting the most common words and the relationships between words. Additionally, a network of co-occurrences was taken into account. The analysis was performed using the VosWiever program **(**version 1.6.20**).**

4. Results

The figure 2 is presented all keywords co-occurrence network diagram and reflects the thematic structure of scientific research on sustainable development (SD), ESG, corporate social responsibility (CSR), and innovation. This network-based analysis helps to determine the main research areas, their interrelationships, and integration and dependence in terms of economic, social, technological and environmental dimensions. To respond to the following main research question by exploring the valuable information the world's clouds provided:

1. Which are the most common all keywords found in the full scientific manuscripts on ESG and SD?
2. What are main key words used by authors?
3. What does network visualization look like between co-authorships network and countries?

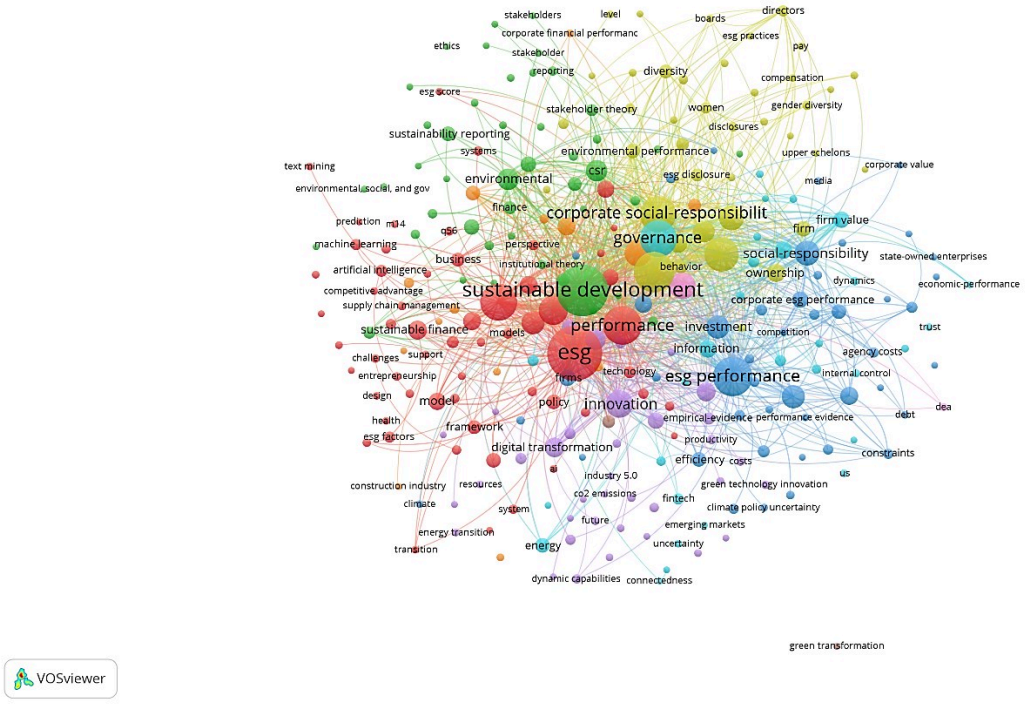


Figure 2. Co-occurrence all key words (minimum number of occurrence 5).

Source: own study.

The conceptual structure is conceptually centered on 'ESG' (the central node in the map). Its strong linkages to concepts such as “sustainable development”, “performance”, “corporate social responsibility” and “governance” attest to ESG’s role in providing the integrating framework through which various dimensions of Sustainable Development are brought together. And around this nucleus are several subthemes interconnecting reporting, corporate ethics, sustainable finance and the effects of ESG practices on company performance. The visualization shows a few related and separate clusters of themes.

The yellow cluster revolves around corporate social responsibility and governance (corporate social responsibility, governance, disclosure, diversity, ethics, stakeholders); it mirrors an increasing interest in management transparency and accountability towards society trust.

The green cluster is made of Keywords that deal with environmental performance and sustainability reporting (environmental performance, sustainable reporting, CSR systems, stakeholders), which stress the role played by integrated environmental management.

The blue cluster focuses on economic rationality and firm performance (firm value, corporate ESG performance, Economic performance, efficiency, costs) which illustrate a growing concentration on the financial consequences of ESG activities and their value realization.

The red cluster, at the left side of the map, connects terms related to technological innovation and digital transformation (digital transformation, artificial intelligence, machine learning, sustainable finance, energy transition and industry 5.0).

The appearance of such terms clearly indicates the growing linkage between ESG and new technology, highlighting digital transformation’s shift toward being a source of sustainability (Rosak-Szyrocka, Knop, 2024; Xue et al., 2025). The spatial layout of the network demonstrates that sustainable development and ESG are in the most central positions, which represent high-level concepts that integrate all thematic areas into a coherent knowledge map. The closely-packed linkage among nodes indicates the subject interdisciplinarily research field, wherein financial and environmental concerns need to be interconnected with social and technology viewpoints. The fact that the terms innovation, digital transformation are so close to sustainable development also suggests that they deem innovation as an important facilitator of ESG adoption and sustainability transitions.

The key co-occurrence map has confirmed that the research in this area is increasing toward a holistic approach in which, innovation, digitalization and responsible management started to be revealed as important elements of strategies for sustainable development of countries during economic transformation and technology development. Figure 3 presents **c**o-occurrence author key words.

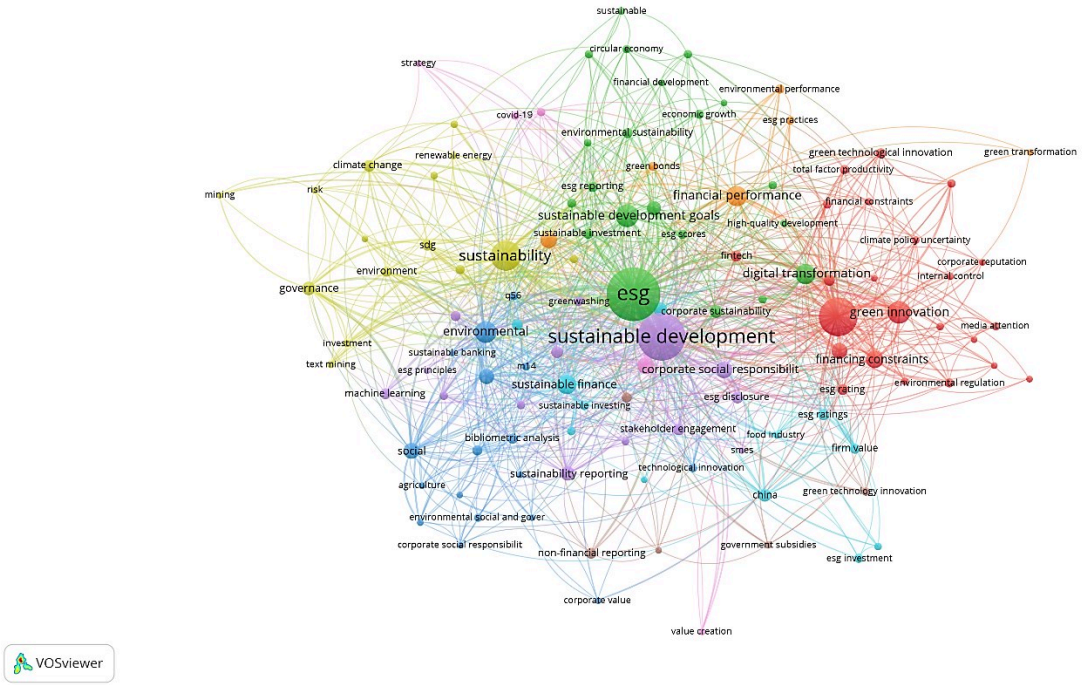


Figure 3. Co-occurrence author key words (minimum number of occurrence 5).

Source: own study.

In the middle of the map, ESG and sustainable development are conceptual foundation which integrate various research streams. The close interconnectedness of these terms with corporate social responsibility, sustainable finance, financial performance and digital technology suggests that there is a trend towards a convergence of 'responsible' management practices with tangible economic results as well as technological advancement. The centrality of these terms among the others, illustrates how ESG has moved from a relatively narrow reporting concept to a broad paradigm that is helping shape business strategy and policy.

There are a number of different but interconnected thematic clusters visible in the visualization. The green cluster includes sustainable development goals, financial performance, environmental performance and sustainable investment keywords, signifying the relationship between the sustainable finance and corporate outcomes and environmental efficiency. This category reflects advancing progress toward quantifying the financial and operational value of sustainability-focused activities. The red cluster on the right links digital transformation, green innovation and related concepts (technological innovation, environmental regulation and capital market constraints). This connection implies that digital technologies and innovation processes are seen as drivers of change for the environment and organizations.

The blue cluster focuses on corporate social responsibility, sustainability reporting, stakeholder engagement and non-financial disclosure. It mirrors academic interest in the governance and the social dimensions of ESG central to transparency, accountability and sustainability performance communication to diverse stakeholders. The yellow cluster, meanwhile, includes terms like sustainability, climate change, renewable energy and

governance – the more environmentally-focused or policy-driven aspect of sustainability studies. These terms emphasizes the ongoing relevance of climate action, renewable energy transition and governance arrangements to sustainable development.

There is also apparently a relatively heavy interconnection among the clusters in the networks. Because digital transformation and green innovation is closely related to sustainable development, there is a strong recognition that the role of policy instruments and drivers for innovation contributes a great deal in enabling ESG integration and sustainability transitions. Likewise, the connections between financial performance and social responsibility signal the growing interconnectedness of economic, social and environmental factors in corporate strategy formulation and policy development.

The co-occurring network highlights the dynamic and mixed characteristics of the research field. It identifies ESG as a conceptual nexus that connects multiple branches of academia and practice – finance, corporate governance, innovation, environmental management. The density and richness of linkages indicate that contemporary research is trending toward an archetypal systems perspective on sustainable development, in which economic change, digitalization and responsible governance are seen as the reciprocal constituents of endogenous processes driving towards long-term sustainability. Figure 4 presents co-authorship and countries.

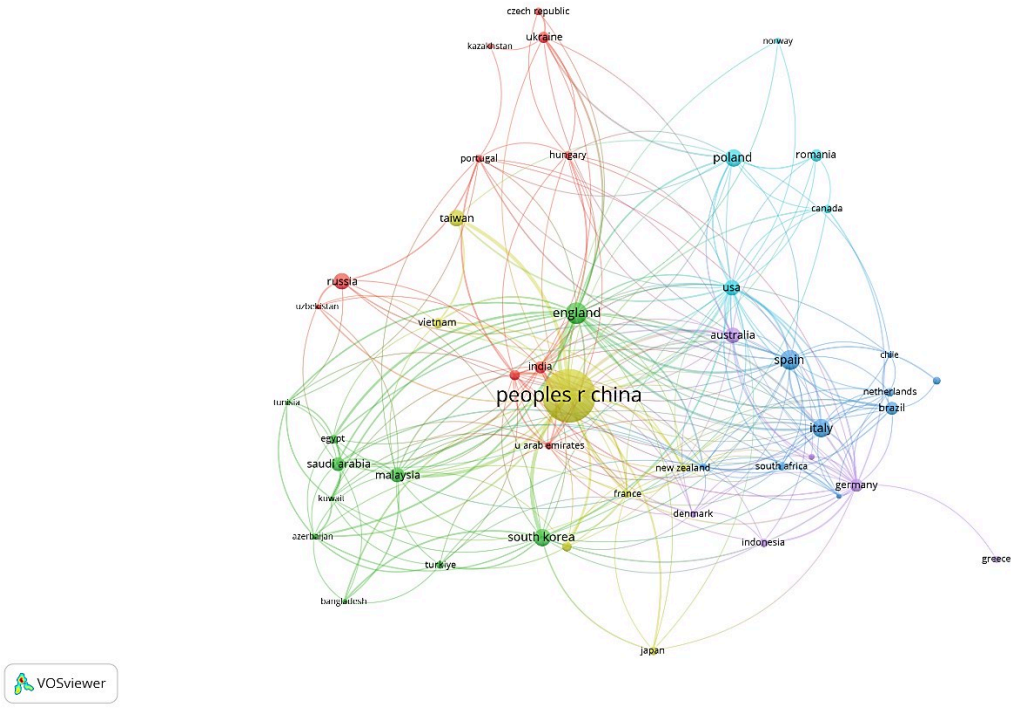


Figure 4. Co-authorship - countries (minimum number of occurrence 5).

Source: own study.

China is the largest and most influential node in this network. This reflects its central position in coordinating and contributing to international research on ESG and sustainable topic. China's research partnerships with countries such as England, India, the United States, Malaysia, Saudi Arabia, South Korea, Australia and France reflect strong relationships of

collaboration. The prominence of China confirms its status as one of the world's leading science producers, and an axis for Asia, Europe and North America. The map shows different clusters of international collaborative patterns, which indicates the regional and thematic research groups.

The green cluster consists of China, India, Malaysia, Saudi Arabia, South Korea, Turkey and the United Arab Emirates demonstrating a strong regional network in Asia and Middle East. This cluster has been particularly active on the research and policy fronts in respect of energy transition, sustainable finance, and new technologies that promote ESG implementation.

The second cluster in red includes Russia, Ukraine, the Czech Republic, Hungary and Portugal and represents the relation with CEE countries to one another and also how they relate with Asian research institutions (in which China / Taiwan show particularly strong links to European scientific output).

The blue cluster comprises advanced economies with strong academic traditions, the United States, Germany, Spain and Poland alongside Australia, Canada, Netherlands and Italy representing a dense network of cooperation addressing applied research-technological innovation-finance reporting (ESG reporting) in corporate settings.

The yellow one is composed of countries such as England, France, Japan, Vietnam Taiwan and New Zealand which show collaboration between Western Europe and Asia-Pacific region with regard to sustainability'corporate governance'social responsibility.

The spatial network structure identifies that collaboration between the Asian and European countries prevail describing Asia—especially, China—as the main driving region of the research agenda in this field. The large number of links with Western countries (notably the USA, UK and Germany) also highlights that sustainability and ESG-based research has implications beyond simply China, reinforcing the apparent trend towards internationalisation of research. The participation of such emerging countries as Saudi Arabia, Malaysia, India and the United Arab Emirates offers a clear picture of how new non-Western actors continue to become actively involved in international scientific communication about sustainable development.

The co-authorship network indicates that ESG and sustainable development research has become increasingly global in nature, with growing international collaboration. China is at the center of this system and plays an integrative role as a scientific engine, which brings together scholars from diverse continents. Simultaneously, the map reveals the emergence of new regional research centres in Asia and Middle-East; indicating a re-orientation of the geography of science production and the growing importance of emerging economies to direct future research on global sustainability.

Figure 4 shows the corresponding partnerships map in ESG and sustainable development research. The network of countries participating in the scientific co-operation is clearly visible with the visualization, where line thickness indicates level of collaboration and node size represents number of publications. We find that research on ESG is clearly internationalized,

but with Western European North American and East Asian countries in a dominant position. These geographical clusters create strong co-operation networks that account for most of the globally cited publications on ESG reporting, sustainable finance and governance systems. The core position of the United States, the United Kingdom, Germany and China in the network demonstrates their leading roles in academic output and worldwide influence. In this international division of work, Poland occupies the position in terms of scientific output core-periphery emerging. The number of publications of Polish authors is growing, while Polish scientists are now taking part in European research programs focused on sustainable development and responsible management. The most intense links are to Germany, Spain, Italy and the UK. Yet, given the relatively small network density around Poland, we may consider that Polish international collaboration might be increased to increase the visibility and impact of its research in the field. Enhancing collaboration at international level would help to disseminate best practices in ESG among other things, improving diversity of methods and bringing Polish research more into alignment with the European community research agenda on sustainability. Figure shows 5 number of citations and publications on ESG and Sustainable Development in 2012-2025.

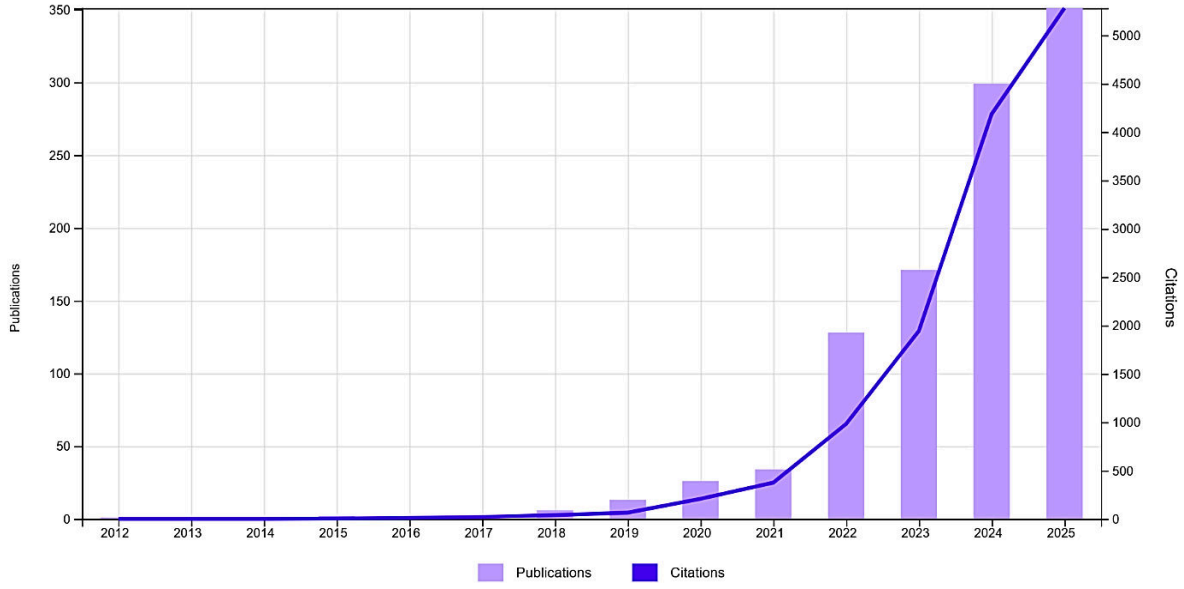


Figure 5. Number of citations and publications on ESG and Sustainable Development (2012-2025). Source: own study.

According to the statistics, there is a steady increasing trend in publications and its citation number, especially since 2020. This trend reflects the growing and recognized academic and practical relevance of ESG-related studies in the continuing studies into sustainability.

Also, during the early phase of the sample period (2012-17), there had been low publication numbers showing this nascent process of ESG research development as an emerging academic discipline. At that point, researches continued to concentrates on the broad issues related to sustainable development and corporate social responsibility. The trend towards higher numbers of papers started around 2018, when the global debate on responsible investment and corporate

transparency was moving to a new level with respect to the implementation of sustainable governance frameworks.

The turning point was obvious after 2020, as the growth in publications accelerated quickly. This dramatic surge can be attributed to a combination of factors, including greater use of ESG reporting frameworks by finance institutions and businesses, the increased relevance of the United Nations' Sustainable Development Goals (SDGs), and advances in digital technologies that are enabling greater analysis and dissemination of ESG data. More specifically, the trajectory of increase from 2022 through to 2025 is particularly steep indicating that ESG has increasingly been directed at as a significant echoing theme among various disciplines including economics, management, finance, environmental science and public policy.

The trend of citations is consistent with that of publications; however, its growth appears to be expanse after 2021, which indicates studies on ESG have become more influential and visible in the worldwide academia. The sharp increase in the citations reveals that research in this field is growing not only in numbers but also in scholarly attention and conceptual development. Figure 6 presents a treemap visualizing the primary research categories of ESG and sustainable development.

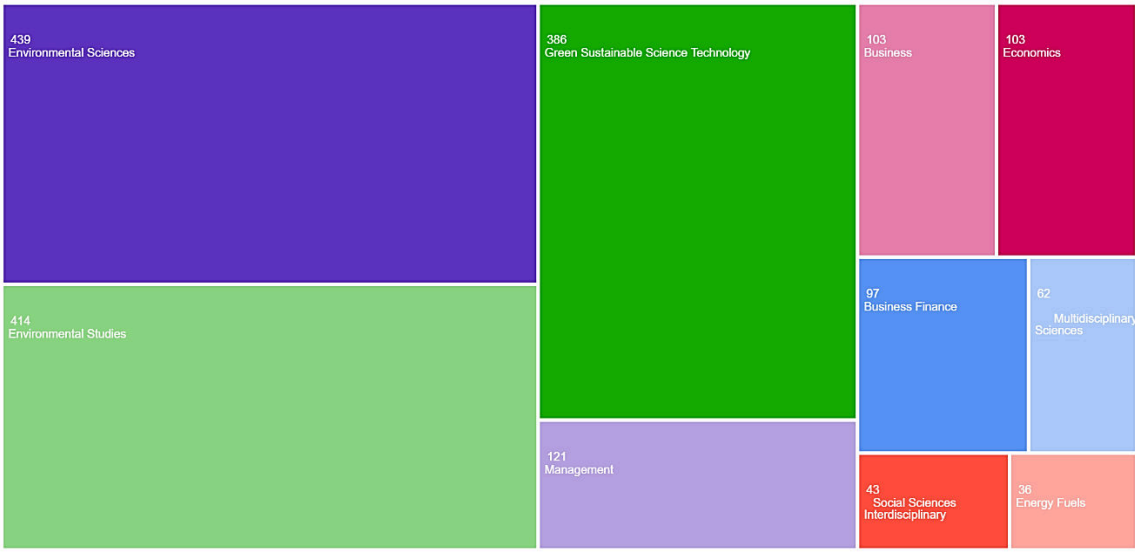


Figure 6. Treemap chart for categories.

Source: own study.

The visualization presents a clear picture of the thematic architecture of the field, and demonstrates that modern research challenges in this domain are characterized by disciplinary diversity and interdisciplinarity. Each rectangle represents a main research category; its size indicates how many publications in the analyzed dataset are indexed under that category and thus indicates the relative importance of each field to the body of literature considered.

The biggest blocks on the treemap are Environmental Sciences (439 publications) and Environmental Studies (414 publications), which account as a pair for the core literature in ESG and sustainability research. The next largest category, Green and Sustainable Science & Technology (386 publications) reflects the growing influence of technology on meeting goals of sustainability. This is a testimony of the increasing hybridization which characterizes environmental and technological research including renewable energy, sustainable materials, circular economy and environmental engineering among others. This cluster is a testament to the fact that sustainable technologies have assumed a leadership role in academic research as well as policy development.

A substantial part of literature as well as in the environmental and technological areas, is contribution from Management (121), Business (103), Economics (103) and Business Finance (97). These categories are useful for identifying the proliferation of ESG research into economic and managerial context featuring corporate sustainability strategies, ESG performance measurement, green finance as well as sustainability and financial performance. Such a diversification of research fields demonstrates that ESG is no longer confined to issues in environmental sciences but has truly been incorporated into management, business ethics, and corporate governance scholarship.

Smaller but still prominent fields such as Multidisciplinary Sciences (62), Social Sciences, Interdisciplinary (43) and Energy & Fuels (36) point to ESG's cross-sectoral relevance. These fields are helping to connect knowledge across disciplines by drawing on social sciences, energy policy and systems research. Their participation illustrates the growing awareness that solving sustainability problems calls for larger, inclusive cross-sectoral strategies that consider environmental, social and economic parts.

5. Good practices of ESG implementation in Poland

Businesses based in Poland increasingly wish to align their business plans with ESG standards as sustainable reporting expectations change across the European Union. Despite barriers around preparedness, scale and sectoral constraints – especially for small and medium-sized enterprises (SMEs) – there already exist a number of large companies that provide examples of more integrated, tangible ESG action. The Polish cases of multinational companies and leading domestic firms exemplify how ESG can be incorporated into long-term strategy, organizational culture and operational practice.

Two cases from different industries of the Polish economy will be used as illustrations: McDonald's Poland (food service and hospitality) and Allegro (the CEE region's largest e-commerce platform). Though working in different industries, both businesses have shown commitments to structured, transparent and data-based strategies on ESG aligned with global

standards such as the GRI (Global Reporting Initiative), the SDGs (Sustainable Development Goals), the EU Taxonomy, and upcoming requirements due with the CSRD (Corporate Sustainability Reporting Directive).

The section offers a lens through which readers can review ways in which corporates operating in Poland are putting ESG principles into practice — ranging from decarbonisation programmes and circular economy approaches to inclusive employment practices, ethical supply chains and governance structures based on measurable responsibility. These practices also cater to compliance purposes and offer transferable learnings on building sector ESG frameworks among the wider Polish business environment.

Case Study 1: ESG Implementation by McDonald's Poland

An illustrative example of ESG practice in the Polish market is given by McDonald's Poland. Embedded in a worldwide corporate structure, the company offers region specific and verifiable sustainability measures. Its Sustainability Report 2022-2023 offers a complete overview of environmental, social and governance-related activities according to international references such as GRI, SDGs or the EU Taxonomy, and captures continuous preparations for CSRD fulfilment.

In the area of environment, McDonald's Poland activities are aimed at minimizing greenhouse gas emissions and increasing resource efficacy. Six restaurants had become climate neutral by 2023 using heat pumps, solar panels and carbon off-set projects. New stores are fitted with energy efficient features like LED lighting and heat-recovery mechanisms on kitchen equipment. These initiatives are consistent with SDG 13 and GRI 305 reporting.

Another important environmental approach is the circular economy. By 2023, all paper-based packaging in Polish restaurants would come from recycled or renewable sources. The company disposed of all plastic straws and lids, imposed selective waste collection systems in its entire network, managing to separate more than 3400 tons for recycling or energy production.

Socially, McDonald's Poland has more than 31,000 employees and works to promote diversity and equal opportunities. It has introduced programs to recruit people aged over 50 and young workers who are new to the job market. Internally, the company does diversity and anti-discrimination training. Outwardly, it conducts educational initiatives for customers such as encourages appropriate sort of waste and sustainable consumption behaviors. On governance, the company adopts GRI reporting and describes both remedial measures from the past as well as strategic objectives for the future. It sends the clear signal that this company operates as a system with all of its resources leaning in to create sustainable continuous improvement.

The supply chain meets strict environmental and ethical assessment models, with over 80% of its products sourced from Polish suppliers, supporting local development and reducing transport emissions (McDonald's Poland, 2023).

Case Study 2: ESG Implementation by Allegro Poland

Allegro, the biggest e-commerce platform in Central and Eastern Europe and also a market leader in Poland, is a great example of company that incorporates sustainability into its business that's been doing so as part of strategic planning for eight consecutive years. The company is listed on the Warsaw Stock Exchange and publishes non-financial reports in line with international standards (GRI, SASB), as it pursues full compliance with the Corporate Sustainability Reporting Directive (CSRD). In 2022, Allegro has refreshed its ESG strategy which revolves around five key pillars: Sustainable commerce Low – emission operations Social responsibly Ethical partnerships Transparent governance.

Allegro has launched a number of environmental initiatives to decarbonize its business and lower its logistics footprint. The company's 2022 ESG report also listed greenhouse gas emissions by scope: Scope 1 emissions of 1311 tCO_2e; scope 2 (market-based) at 2298 tCO_2e, and scope 3—namely parcel delivery and supplier activity—of more than 144,000 tonnes of CO_2e.As a result of these findings, Allegro ramped up its climate activities. All power used in its offices and logistics centers in 2022 came from renewable energy. The company also initiated tests of reusable packaging in certain collaborations with merchants, as well as expanded its "Eco Delivery" offering, which gives customers the option to choose lower-carbon delivery ways like parcel locker pickup. Furthermore, Allegro performed 68% better in terms of marketing materials plastics than it did the previous year.

On social side, Allegro is extremely focused on supporting small and medium businesses, which are the core base for sellers. By 2022, the service had more than 135,000 active merchants, many of which were SMEs. Almost 15,000 companies took advantage of free courses and online training sessions offered by Allegro Biznes to improve their digital sales skills and learn how to use data analytics tools. In addition, the company funded charity, giving over PLN 1.8 million to aid war in Ukraine. Within its walls, Allegro implemented some diversity policies. Women made up 52% of the company's workforce in 2022, and held 33% of its managerial roles. And it initiated the "Allegro Inclusive" policy along with DEI (diversity, equity, inclusion) training programs.

Allegro's governance of the ESG strategy is very integrated across the organization. ESG is managed at the executive level with quarterly reporting against targets. The Company has introduced a Code of Ethics for all employees and business partners. Over 80 percent of Allegro's top suppliers went through ESG compliance screening in 2022, and the company introduced risk assessment tools designed to assess non-financial risks in its supply chain. Taken together, they signal systematic integration of ESG at strategic and operational levels (Allegro.eu, 2023).

Case Study 3: ESG Implementation by Santander Bank Poland

Santander Bank Poland is one of the largest financial players in the country that demonstrates a mature and comprehensive approach to ESG issues. The bank's sustainable development strategy is not a forced response to regulatory pressure but represents a long-term vision of transforming its business model. The assessment of Malos says that Santander is working conscientiously in this direction and is one of the few Polish institutions that report not only based on domestic standards but also according to global indicators such as the Global Reporting Initiative and the Task Force on Climate-Related Financial Disclosures.

At the same time, the bank's promises of sustainable development are confirmed not by general phrases or intentions but by specific, calculated, and measured actions that fundamentally change its relationship with the environment and society. In terms of environmental indicators, Santander provides financing for the energy transition of its clients. In 2022, the bank financed renewable energy projects worth in total more than PLN 1.7 billion. Over 50 percent of its new investments went to solar and wind energy. In terms of its own carbon footprint, the bank also sees improvement: 100 percent of the electricity used in its premises was from renewable sources, resulting in a 34 percent decrease in CO_2 emissions compared to the year base.

The bank promotes green financial products on favourable terms, including eco-loans for individual and corporate clients. On the social front, Santander's flagship is accessibility. Over seven million individual customers use bank services, but the institution also carries out many educational and outreach activities. In 2022, almost 90 thousand people participated in financial education programs implemented by the Santander Foundation, from seniors through youth to primary school students.

Internally, gender policy is also consistent: among the bank's 3,393 employees, 58 percent were women, and in management, they accounted for almost 40 percent; Santander is one of Poland's leading financial institutions in terms of gender diversity governance. Governance at Santander Bank Poland is also a clear line of responsibility for ESG. The ESG Risk Committee, a body at the executive level. The bank presents periodic monitoring reports on the achievement of its climate, social, and governance goals. In the reporting year, it analysed 95 percent of key suppliers for non-financial risk. The bank expanded its control systems over the achievement of sustainability throughout its value chain. Ethics obviously is also part of the corporate culture; all employees are obliged to complete annual anti-corruption and ethical conduct training.

While the above case studies revolve around large corporations already under obligatory ESG reporting today, it is important to mention that Poland's SME sector is also gradually gearing up for upcoming sustainability obligations. Although up to now SMEs are largely not directly subject to the Corporate Sustainability Reporting Directive (CSRD), many operate in the supply chains of larger companies or they apply for financing that increasingly requires

ESG compliance. Hence, their involvement in ESG actions appears to be a source of competitive advantage and adaptation imperativeness.

A good example is ML System S.A., a Polish SME which is active in the field of clean technology and especially on building – integrated photovoltaics. It adopts different environmental practices (energy efficiency and waste minimisation) but also engages with governance and social responsible tools (transparent reporting, diversity policies). Listed on the national ESG list, ML System engages in public consultations on sustainable development strategies and illustrates a proactive approach of SMEs to environmental and social responsibility (PARP, 2024).

More generally, 18% of Polish SMEs know what ESG is, and around 9% have implemented some type of action already—so far mainly environmental one (PARP, 2024). Although these numbers are currently small, they point to an upward trajectory and indicate the increasing significance of specialist advisory services, education and digital applications in supporting ESG adoption among SMEs.

6. Discussion and Conclusion

This manuscript is consistent with previous research on the growing incorporation of ESG in the strategic management process (Eccles, Ioannou, Serafeim 2014; Kotsantonis, Serafeim, 2019). Prior research has also highlighted the increasing significance of regulatory regimes and non- financial reporting in both corporate governance mechanisms as well as long-term value creation (Friede, Busch, Bassen, 2015).

Based on the analysis structured in this manuscript, one may conclude that ESG in the Polish context is qualitatively different from the previous forms of involvement in the economy. It is no longer an issue of CSR but a legally and strategically prescribed arrangement. Through the CSRD and ESRS, the authorities have ensured that ESG becomes a formal requirement for a wider pool of companies. Simultaneously, it changes the logic of risk management, governance, relations with stakeholders, and long-term value generation (Rosak-Szyrocka et al., 2022).

It is important to note that ESG is not primarily a question of compliance. Rather, it is a powerful trend that stimulates innovation, transparency, integration of E, S, and G aspects at the heart of corporate strategy. This is demonstrated by the experience of several leading companies – Allegro, Poland's McDonald's, Santander Bank Poland – which developed a comprehensive ESG approach working within global standards: GRI, SDGs, EU Taxonomy. Their approaches set an example for the more comprehensive implementation of ESG and show substantial advantages that such compliance generates for the business and the economy in general.

Nonetheless, there is a substantial gap in execution, as the analysis above demonstrates. There is also a convergence opportunity: the consumer demand for responsible production and investment provides additional business value to the ESG strategies. Given the fragmentation of governance across sectors, the pervasive underestimation of ESG relevance by the existing businesses, and the financial limitations in the small and medium companies, this system can only work if supported by purpose-specific advisory and digital tools. Table 1 presents challenges and opportunities for enterprises in Poland.

Table 1.
Challenges and Opportunities for Enterprises in Poland

Challenges	Opportunities
Cumbersome and changing legal regulations (CSRD, EU Taxonomy etc.)	Better position in sustainable and innovative markets
SMEs' limited capacity for reporting on ESG	Access to ESG-aligned financing and green investment instruments
ESG illiteracy and knowledge at management level	Improved risk management and long-term business resilience
Cost of compliance and adjusting to new norms is high	Strengthened brand reputation and stakeholder trust
Non-financial dimensions of data availability and quality	Strategic alignment with EU climate and sustainability goals
Pressure from invested interests and global supply chains	Market differentiation through transparency and ethics

Source: own study.

The progression of ESG expectations, as evident in the table, corroborates these complexities while indicating on the other side the enormous potential for value generation, resilience, and competitive edge within both domestic and global marketplaces. In summative terms, ESG in Poland is ceasing to remain merely profile-driven or tokens – it is rapidly evolving into a central pillar of governance strategy and legitimacy. As governance bodies intensify the pressure through regulations and stakeholder expectations soar, firms that embody ESG principles today will find themselves in a better position for capital access, systemic risk experience, and systematic relevance for the long-term.

The study contained in this manuscript has demonstrated that the ESG concept in Poland has transformed from voluntary corporate social responsibility activities to a fundamentally based and strategically driven system of management. ESG is now about much more than compliance; it is a tool for changing corporates in the right direction toward sustainability, transparency and long-run resilience. The consideration of ESG in business strategy puts new demands on leadership, risk management and stakeholder dialogue. To better demonstrate this multidimensional attribute of ESG, the author also develops a novel conceptual model – the ESG–CIRCLE–POWER Model (Fig. 7).

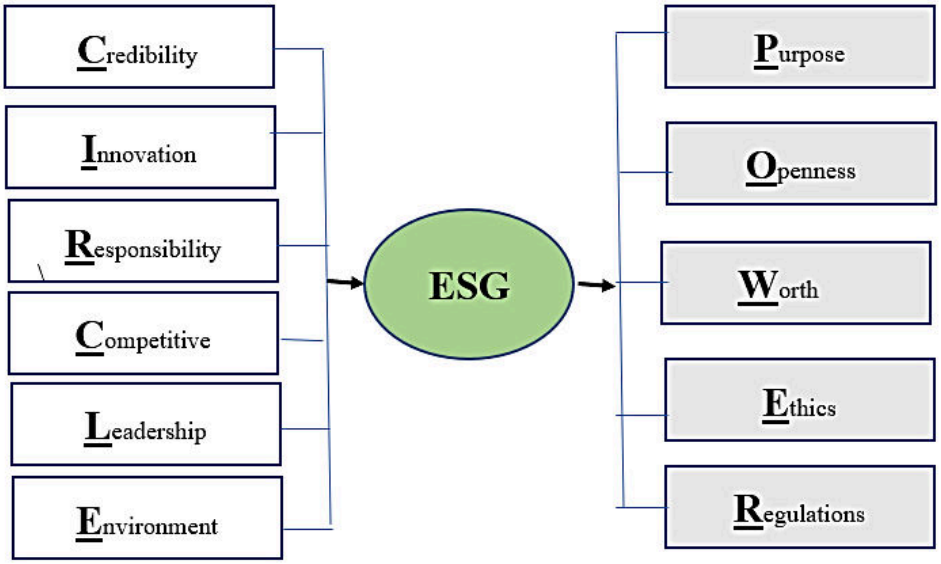


Figure 7. The ESG–CIRCLE–POWER Model.

Source: own study.

The model encompasses the internal mechanisms that feed the ESG culture and external results triggered by its efficient execution. CIRCLE are the core DNA and organizational culture of ESG -based on Credibility, Innovation, Responsibility, Competitiveness, Leadership, Environment. These dimensions constitute the inner base of coherence, ethics and trust for sustained growth. CIRCLE in the conceptual model does not only stands for the 6 internal main dimensions of ESG, but also represents a closed-loop system of value circulation of an enterprise. It represents the notion of circular economy in which good conduct, innovation and environmental stewardship act as force amplifiers to reinforce and renew each other generating internal consistency, trust and organizational resilience.

This reading also fits nicely into the circular economy and sustainable development logic, where resources (and values or relations) are not used up but regenerated and substained for further usage. In this definition the acronym of internal values becomes an iterative cycle that makes a revolution in continuous ethical improvement and sustainability transformation.

POWER in turn represents the outside results of ESG application— described as Purpose, Openness, Worth, Ethics and Regulations. These dimensions illustrate how ESG creates tangible value through transparency, ethicalness, as well as a purpose-focused strategy.

According to the CIRCLE–POWER Model, the enabling mechanism of ESG is not its external appearance but rather an internal authenticity and consistency of values (CIRCLE) that flows through organizational practices and manifests in external trust, competitiveness and regulations (POWER). From this standpoint, ESG will be seen as a strategic arrangement for value creating, trustworthiness and sustainable governance.

Based on the analysis, the author concludes that **the power of ESG lies** not in external reporting but **in the authenticity of internal values that create trust, transparency, and competitive strength within the company.**

However, the manuscript aiming to provide a comprehensive scope of the ESG history in the Polish business environment combined with the critical evaluation of both the achievements and barriers is still constrained by several limitations. The first and foremost is the sources used for the analysis. The research is mostly based on the vast number of books, academic manuscripts, and industry reports, added to three selected case studies: McDonald's Poland, Allegro and Santander Bank Poland. Despite the selection of companies representing various industries, the chosen corporations do not cover the vast diversity of the Polish market. In particular, being the backbone of the country's economy, micro, small and medium-sized enterprises are not presented. Secondly, the manuscript does not involve primary data, such as interviews, surveys, or comparative field research. The lack of empirical research prevents from evaluating the actual organizational readiness and barriers, especially in connection to the recent legal frameworks, CSRD and ESRS. Finally, the rapidly changing regulatory agenda and the growing importance of non-financial performance measurement mean that some of the data and findings included in the manuscript can be outdated rather quickly. Therefore, continuous research and data update are required to evaluate the effectiveness of ESG strategies from the businesses' side and the actual value influence, stakeholder motivation, and business model robustness.

In future work focusing on ESG, in the context of Polish and Central European capital markets, we should investigate in more detail the practical effects of such regulatory shifts as introduced by CSRD and ESRS. When Polish companies start to adjust to these new rules, longitudinal research would yield insight into how forcing companies to integrate ESG factors may influence firm performance, innovation and competitiveness over time.

Furthermore, there is an increasing demand for comparative studies of large corporations and SMEs in relation to their preparedness, resourcing and digitalisation capacity that backs ESG reporting. Such interdisciplinary research in law, management and data science would enable the construction of more holistic models for ESG compliance and impact measurement.

One other logical direction would be to validate empirically and elaborate additional of the ESG–CIRCLE–POWER Model put forth in this paper. Research in the future could challenge the application of (CIRCLE-POWER) interrelation in different sectors and regions, examine the association between internal values (CIRCLE) and external output (POWER), employ it as a diagnostic matrix to measure ESG maturity.

Thirdly, subsequent research should also unravel the changing influence of digital technology (including AI-based analytics and stakeholder engagement tools) in promoting ESG transparency and authenticity. This research has the potential to help close the divide between compliance-oriented practices and authentic sustainability-driven change inside organizations.

References

1. Accace (2024). *ESG obligations in Poland: Corporate sustainability and reporting requirements.* Retrieved from: https://accace.com/esg-obligations-in-poland
2. Al Amosh, H. (2025). The Power of Words: How CEO Speech Length and Frequency Shape ESG Transparency. *International Journal of Business Communication.*
3. Allegro.eu (2023). *Sustainability at Allegro.* Retrieved from: https://allegro.eu/sustainability
4. Almadadha, R. (2024a). Blockchain Technology in Financial Accounting: Enhancing Transparency, Security, and ESG Reporting. *Blockchains, vol. 2, no. 3,* pp. 312-333. Retrieved from: https://www.mdpi.com/2813-5288/2/3/15
5. Arduino, F.R., Buchetti, B., Harasheh, M. (2024). The veil of secrecy: Family firms' approach to ESG transparency and the role of institutional investors. *Finance Research Letters*, *vol. 62,* p. 105243.
6. *Aspects of Quality Management in Value Creating in the Industry 5.0 Way* (2024). CRC Press.
7. Baran, M., Kuźniarska, A., Makieła, Z.J., Sławik, A., Stuss, M.M. (2022). Does ESG Reporting Relate to Corporate Financial Performance in the Context of the Energy Sector Transformation? Evidence from Poland. *Energies, vol. 15, no. 2,* p. 477. Retrieved from: https://www.mdpi.com/1996-1073/15/2/477
8. Celary, O., Piwowarczyk, Z. (2025). The role of digital initiatives in advancing ESG in Polish industrial companies. *Scientific Papers of Silesian University of Technology. Organization and Management Series, no. 225*, pp. 55-70.
9. Chong, T., Loh, L. (2023). Innovating ESG Integration as Sustainable Strategy: ESG Transparency and Firm Valuation in the Palm Oil Sector. *Sustainability, vol. 15, no. 22,* p. 15943. Retrieved from: https://www.mdpi.com/2071-1050/15/22/15943
10. Crowe & Envirly (2023). *Polish companies not prepared for ESG reporting obligations.* Retrieved from: https://www.crowe.com/global/insights/polish-companies-not-prepared-for-esg-reporting-obligations
11. Diego, J., Montes-Sancho, M.J. (2025). Nexus supplier transparency and supply network accessibility: Effects on buyer ESG risk exposure. *International Journal of Operations & Production Management*, *vol. 45, no. 4,* pp. 895-924. Retrieved from: https://www.emerald.com/insight/content/doi/10.1108/ijopm-12-2023-0972/full/html
12. Dmuchowski, P., Dmuchowski, W., Baczewska-Dąbrowska, A.H., Gworek, B. (2023). Environmental, social, and governance (ESG) model; impacts and sustainable investment – Global trends and Poland's perspective. *Journal of Environmental Management, vol. 329,* p. 117023.

13. European Commission (2022). *Corporate Sustainability Reporting Directive (CSRD).* Brussels: Official Journal of the European Union. Retrieved from: https://finance.ec.europa.eu/sustainable-finance/corporate-sustainability-reporting_en
14. Faccia, A., Manni, F., Capitanio, F. (2021). Mandatory ESG Reporting and XBRL Taxonomies Combination: ESG Ratings and Income Statement, a Sustainable Value-Added Disclosure. *Sustainability, vol. 13, no. 16,* p. 8876. Retrieved from: https://www.mdpi.com/2071-1050/13/16/8876
15. Gidage, M., Bhide, S. (2025). ESG and economic growth: Catalysts for achieving sustainable development goals in developing economies. *Sustainable Development, vol. 33, no. 2,* pp. 2060-2077.
16. Ingaldi, M., Ulewicz, R. (2025). Sustainable development and technological advancements in Industry 4.0: Overcoming barriers in SME sector integration. *Management Systems in Production Engineering,* pp. 144-162.
17. Kandpal, V., Jaswal, A., Santibanez Gonzalez, E.D.R., Agarwal, N. (2024). Corporate Social Responsibility (C.S.R.) and E.S.G. Reporting: Redefining Business in the Twenty-First Century. In: *Sustainable Energy Transition* (pp. 239-272). Retrieved from: https://link.springer.com/chapter/10.1007/978-3-031-52943-6_8
18. Koralun-Bereźnicka, J., Orcholski, T. (2025). The role of ESG factors in creating corporate value: Evidence from Polish public companies. *Optimum. Economic Studies, 2(120),* pp. 399-416. Retrieved from: https://repozytorium.uwb.edu.pl/jspui/handle/11320/18359
19. KPMG Poland (2023). *The ESG revolution: How Polish companies are responding to sustainability reporting challenges.* Retrieved from: https://kpmg.com/pl/en/home/services/esg.html
20. Kulej-Dudek, E., Dudek, D. (2024). Good practices of corporate social responsibility of Polish enterprises in the aspect of ESG. *Procedia Computer Science, vol. 246,* pp. 5234-5243.
21. Li, X., Saat, M.M., Khatib, S.F.A., Liu, Y. (2024). Sustainable development and firm value: How ESG performance shapes corporate success – A systematic literature review. *Business Strategy & Development, vol. 7, no. 4,* e70026.
22. McDonald's Poland (2023). *Sustainability Report 2022-2023.* Retrieved from: https://mcdonalds.pl/fileadmin/user_upload/PDF/Raport_Zrownowazonego_Rozwoju_McDonald_s_Polska_2022-2023.pdf
23. ML System S.A. (2023). *Sustainability and CSR Report 2022.* Retrieved from: https://mlsystem.pl
24. Oluwakemi, A.A., Mishelle, D. (2025). Effect of ESG financial materiality on financial performance of firms: Does ESG transparency matter? *Journal of Risk and Financial Management, vol. 18, no. 6,* p. 315. Retrieved from: https://www.mdpi.com/1911-8074/18/6/315

25. Oncioiu, I., Popescu, D.-M., Aviana, A.E., Șerban, A., Rotaru, F., Petrescu, M., Marin-Pantelescu, A. (2020). The role of environmental, social, and governance disclosure in financial transparency. *Sustainability, vol. 12, no. 17,* p. 6757. Retrieved from: https://www.mdpi.com/2071-1050/12/17/6757
26. PARP (Polish Agency for Enterprise Development) (2024). *Raport o stanie wdrażania zasad ESG w sektorze MŚP w Polsce* [Report on the state of ESG implementation in the SME sector in Poland]. Warsaw: PARP. Retrieved from: https://www.parp.gov.pl
27. Petelczyc, J. (2022). The readiness for ESG among retail investors in Central and Eastern Europe. The example of Poland. *Global Business Review, vol. 23, no. 6,* pp. 1299-1315.
28. Prasek, D. (2024). Practical ESG aspects for Poland. *Gaz, Woda i Technika Sanitarna, vol. 1, no. 5,* pp. 22-24. Retrieved from: https://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-3966b324-fbb7-4a0f-98da-822a2c2b7090
29. PwC Poland (2024). *ESG in consumer goods and retail: Polish market insights.* Retrieved from: https://www.pwc.pl/en/publikacje/esg-in-consumer-goods-and-retail.html
30. Rosak-Szyrocka, J., Knop, K. (2024). Sustainable development universities – Opportunities & challenges on the road to Society 5.0 from the key stakeholder perspective. *PLOS ONE, vol. 19, no. 8,* e0308929. Retrieved from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0308929
31. Rosak-Szyrocka, J., Żywiołek, J., Shahbaz, M. (2023). *Quality Management, Value Creation, and the Digital Economy.* London: Routledge.
32. Saam, J.-S., Rosenstein, A. (2024). *Reshaped ESG Reporting Challenges of Scandinavian Organizations: The Transformation from the NFRD to the CSRD.* Retrieved from: https://www.diva-portal.org/smash/record.jsf?pid=diva2:1860293
33. Sahu, M., Mishra, A., Alahdal, W.M., Sami, M. (2025). ESG performance and audit committee expertise: Advancing sustainable development goals in leading nations. *International Review of Economics & Finance, vol. 103,* p. 104445.
34. Santander Bank Poland (2023). *Report ESG 2022.*
35. Seele, P. (2016). Digitally unified reporting: How XBRL-based real-time transparency helps in combining integrated sustainability reporting and performance control. *Journal of Cleaner Production, vol. 136,* pp. 65-77.
36. Sustainalytics & SEC Newgate (2023). *Poland ESG Monitor 2023.* Retrieved from: https://fdcesg.com/wp-content/uploads/2024/01/poland_sec_newgate_esg_monitor-2023_poland-final.pdf
37. Tylec, A. (2022). ESG reporting framework in Poland – The current state of affairs and perspectives. *Scientific Papers of Silesian University of Technology. Organization and Management Series, no. 157,* pp. 609-622. Retrieved from: https://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-fe9093dd-0634-47cb-bb38-76257e56d8c0

38. Waldau, R. (2024). A systematic literature review on determinants and outcomes of ESG performance in family firms. *Management Review Quarterly,* pp. 1-59. Retrieved from: https://link.springer.com/article/10.1007/s11301-024-00462-9
39. Wang, K., Yu, S., Mei, M., Yang, X., Peng, G., Lv, B. (2023). ESG performance and corporate resilience: An empirical analysis based on the capital allocation efficiency perspective. *Sustainability, vol. 15, no. 23,* p. 16145.
40. Warsaw Stock Exchange (GPW) (2023). *ESG reporting guidelines*. Retrieved from: https://www.gpw.pl/pub/GPW/ESG/ESG_Reporting_Guidelines.pdf
41. Wolf Theiss (2022). *ESG in Poland: Regulatory landscape and key trends.* Retrieved from: https://www.wolftheiss.com/app/uploads/ESG22_Poland.pdf
42. Xue, Y., Zhang, C., Mentel, G., Mohammed, K.S., Rosak-Szyrocka, J., Zhao, X. (2025). Impact of ESG rating divergence on corporate resilience: Insights from China's A-share market. *Environment, Development and Sustainability,* pp. 1-26. Retrieved from: https://link.springer.com/article/10.1007/s10668-025-06799-9

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THE IMPACT OF INDUSTRY 4.0 IMPLEMENTATION ON ENTERPRISE DEVELOPMENT IN SELECTED EU COUNTRIES: A COMPARATIVE ANALYSIS

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Purpose: This paper aims to assess the impact of Industry 4.0 implementation on enterprise development within the digital economy, with particular emphasis on small and medium-sized enterprises (SMEs). The study also compares the level of digitalization and Industry 4.0 adoption in selected European Union countries: Denmark, Germany, Hungary, and
Design/methodology/approach: The research is based on a survey conducted among 60 Polish enterprises of different sizes and a comparative analysis using secondary data from the Digital Economy and Society Index (DESI) and existing literature. The study examines the level of Industry 4.0 awareness, key technologies, investment readiness, and digital competencies.
Findings: The results indicate that medium and large enterprises demonstrate a higher level of Industry 4.0 adoption and investment capacity than small enterprises, which face financial and knowledge-related barriers. Cybersecurity, cloud computing, simulations, and system integration are identified as the most relevant technologies. The comparative analysis shows that Poland remains behind Denmark and Germany in terms of digital maturity and advanced digital skills, while its position is comparable to Hungary.
Practical implications: The findings highlight the importance of strategic planning, gradual implementation of Industry 4.0 solutions, and continuous employee training to enhance enterprise competitiveness, particularly in SMEs.
Originality/value: The paper provides a concise empirical and comparative perspective on Industry 4.0 implementation across enterprises of different sizes in selected EU countries, offering practical insights for managers and policymakers supporting digital transformation.
Keywords: Industry 4.0, Digital Economy, Strategic Management, SMEs; Digitalization; Enterprise development.
Category of the paper: Research paper.

1. Introduction

The strategic focus of the contemporary manufacturing industry integrates advanced digital information technology into various application fields of the manufacturing industry. With the advent of Industry 4.0, multiple aspects of manufacturing production, value creation processes, and business models have undergone tremendous changes. Manufacturing companies of all sizes worldwide continue to develop in the direction of intelligence, and formulating a reasonable and efficient digital strategy will steadily boost their competitive advantages (Li et al., 2022; Lasi et al., 2014; Olsen, Tomlin, 2020; Sharma et al., 2021). One of the key challenges of Industry 4.0 is to make the production systems more flexible and collaborative. To achieve this, the Industry 4.0 paradigm relies on the strategic use of enabling technologies. It offers a quick response to customer demand, improves productivity, and allows stakeholders to make quicker decisions in real-time (Alcácer, Cruz-Machado, 2019; Manavalan, Jayakrishna, 2019; Tortora et al., 2021). By merging the concepts of Industry 4.0 and the digital economy, it is possible to improve and automate processes at various levels of the economy as well as the processes within the enterprises.

Each of the four industrial revolutions was marked by the introduction and spread of inventions that caused significant and deep changes in every area of economic and social life. These revolutions enabled the transformations in production processes and work organization thereby improving efficiency (Grześ, 2020). Currently, the economy is developing and changing at a very fast pace, with an increasing emphasis on digital technologies and their implementation in enterprises across various industries. Digitalization is one of the numerous challenges facing industrial companies (Łobejko, 2018; Kuzmin, 2022; Pech, Vrchota, 2020; Castelo-Branco et al., 2023), and it is Industry 4.0 that offers a great opportunity to enhance the competitiveness of small- and mediumsized enterprises (Schumacher et al., 2019; Huang et al., 2019).

1.1. Digitization of processes in enterprises

Digitization, in its original meaning, referred to the conversion of analog information into digital formats Federal Ministry of Food and Agriculture of Germany (2022), distinct from digitalization, which considers a broader adoption of digital technologies (Vrana, Singh, 2021; Barmuta et al., 2023). Over time, this term expanded its meaning by including the use of data processed into digital form by computer applications (Rogalewski, 2020; Adamczak et al., 2023; Schniederjans et al., 2020; Egorov et al., 2020). Nowadays, digitization is seen as a process and involves the use of information or digital technologies to optimize an existing business for cost savings or improve customer service (Verhoef et al., 2021). Today, digitization and digitalization have blended their meanings, as the conversion of information form into a digital one seems obvious. Therefore, it now has a much more horizontal concept, including

the digital revolution (also referred to as the digital transformation) Federal Ministry of Food and Agriculture of Germany (2022). Digital transformation involves inevitable changes in the operation of enterprises, at all levels of enterprise structures, processes, models, strategic action systems, goals, and values, and it constitutes a key element of competitiveness. Inseparable elements of digital transformation are new digital technologies that influence the growth of enterprises, bring new values and quality, and define business future based upon digital technologies, products, services, and solutions (DeStefano et al., 2017; Yang et al., 2021; de Lucas Ancillo, Gavrila, 2023). New digital technologies such as Artificial Intelligence, AI-based services, Big Data, Cloud Computing, Internet of Things, or on-demand 3D print/prototyping, accelerate the digital transformation of enterprises, providing new opportunities for economic development (Baines, Lightfoot, 2013; Ricci et al., 2021; Rojek et al., 2022; Wang et al., 2023).

1.2. Digitalization in strategic management

The incorporation of digital technologies into strategic management increases productivity by automating numerous tasks, enabling companies to achieve more in less time, and by offering personalized products and services with a better quality and customer experience (Hahn, 2020; Wei et al., 2024). Enterprises are expected to continuously improve in the area of strategic management as it involves defining organizational goals, creating policies and strategies, and directing activities to achieve these goals (Wang et al., 2023; David, 2011; Radicic, Petković, 2023). The main goal of strategic management is to make decisions that will provide a long-term competitive advantage for the organization. It consists of several stages: setting business goals, developing policies and action plans, and creating strategies to achieve these goals (Troise et al., 2022; Kraus et al., 2023; May, Hui, 2023). As Ayitey has put it in the (Ayitey 2010), "Strategic management is the art and science of formulating, implementing, and evaluating cross-functional decisions that will enable an organization to achieve its goals. It is the process of determining the organization's goals, developing policies and plans to achieve those goals, and allocating resources to implement the policies and plans to achieve the organization's goals. Strategic management therefore integrates the activities of various functional areas of a company to achieve organizational goals. It is the highest level of managerial activity" (Ayitey. 2010).

In the era of digital transformation, new technologies significantly affect business processes and strategic management. The introduction of new digital technologies to all areas of a company's activity radically changes its functioning and the way it delivers value to customers. Digitalization is changing the traditional competitive landscape of companies. The right combination of digital technology, information, and physical assets can provide a digital advantage that can be a competitive advantage (Bozintan et al., 2023; Rêgo et al., 2021; Li et al., 2018). Digitalization triggers the use of specific new digital technologies (e.g. with AI – the analysis and decisions can be based on artificial intelligence methods, self-learning, self-

optimizing approaches and algorithms, etc.). Digitalization has a huge impact on business management strategy, providing opportunities for improving quality, efficiency, and innovation at the operational level, and opportunities for growth and gaining market advantage at the strategic level. This means integrating technology with every aspect of the organization from customer contacts to internal operations, completely changing the way a company creates and delivers value, streamlining business processes, reducing costs and increasing efficiency, while generating revenues (Schwertner, 2017; Bughin et al., 2021; Sestino et al., 2020).

Digitalization of companies is inevitable these days. Investing in increasingly modern IT systems is very expensive, but necessary. Companies investing in IT development develop their products and become more competitive in the market (Olbrys, Smoliński, 2020; Galanti et al., 2023; Varoglu et al., 2021). Digital transformation for business models requires the use of new methods that will be managed digitally. Digital transformation allows observing all business operations performed and remote monitoring with control and optimization in real-time.

The objective of this paper is to examine and summarize the impact of Industry 4.0 implementation on the development of small- and medium-sized enterprises (SMEs). This research includes a comparative analysis across selected European Union countries, specifically Denmark, Germany, Hungary, and Poland, to explore cross-country differences and similarities in how SMEs are leveraging Industry 4.0 for their growth and competitiveness.

2. Materials and Methods

The study aims to present the impact of Industry 4.0 implementation on enterprise development in selected EU countries through a comparative analysis. The implementation of this goal was focused on analyzing the impact of Industry 4.0 implementation on the development of small and mediumsized enterprises (SMEs). This study includes a comparative analysis of selected enterprises across selected European Union countries. As part of the conducted research, the results of the comparative analysis conducted in Poland were compared with selected EU countries, i.e. Germany, Denmark, and Hungary.

2.1. Analysis and evaluation of Industry 4.0 implementation in Polish SMEs

The research included a survey conducted among 60 companies from Poland. The companies were characterized by transport, production, and financial services. They provide their services in the country and abroad. In order to better present the impact of Industry 4.0 on Polish enterprises, they have been divided according to their size:

- small (employing less than 50 people),
- medium (employing from 50 to 250 people),
- large (employing more than 250 people).

The division by size of companies in the survey allows for a better illustration of the stage of implementation of Industry 4.0 that Polish companies are at. On this basis, it is also possible to compare which sizes of companies perform better in the survey.

2.2. Industry 4.0 in Small Enterprises

Small enterprises are those that employ fewer than 50 people and whose total annual balance sheet does not exceed EUR 10 million Agencja Rozwoju Pomorza (2022). The five-question survey was attended by 20 small businesses from across Poland, of which 60% were managed by men and the remaining 40% by women. Respondents had to answer five questions about Industry 4.0. The first question was related to the knowledge of the Fourth Industrial Revolution in enterprises. 65% of respondents are familiar with its concept, while 35% of respondents had no experience with the issue of Industry 4.0 (see Figure 1).

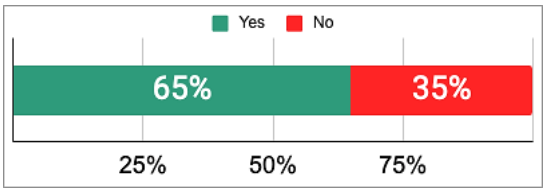


Figure 1. Small enterprises – Question 1 – Did you have anything to do with the term Industry 4.0?
Source: own research.

Next, respondents were asked about Industry 4.0 technology solutions that would be important or are important to the company. The participants said they have 9 Industry 4.0 technologies/contexts at their disposal and could select up to 3 answers about technologies they use in their companies or would be very useful in the functioning of the company. The most frequently chosen technology/context was Cybersecurity with a result of 27%. In the second place (ex-aequo), were two technologies: Augmented Reality (15%), which could be used in companies, e.g. for employee training purposes, and horizontal/vertical software integration. Not far behind AR and integration was Cloud Computing with a score of 13%, which would, for example, support mobile management and real-time performance. The rest of the technologies of the 4th revolution were chosen reluctantly, because only 8% of respondents chose Big Data, and with a score of 7%: Autonomous Robots and the Internet of Things. According to the respondents, in enterprises, additive manufacturing (3D printing) (5%) and simulations (3%) are less important (see Figure 2).

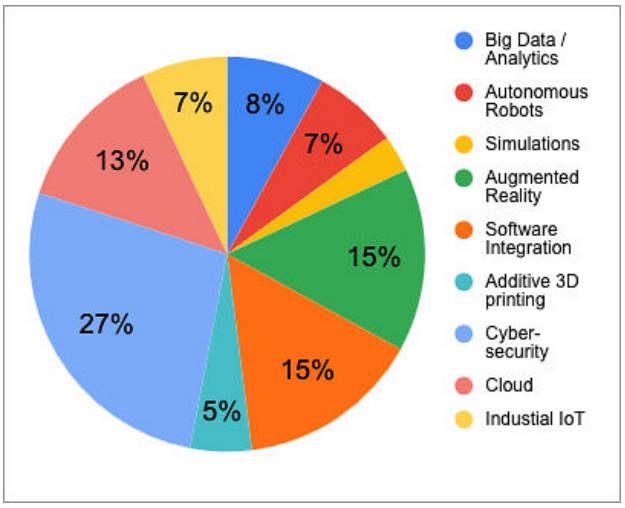


Figure 2. Small enterprises – Question 2 – Which digital technologies of Industry 4.0 do you consider important for your Enterprise? (choose max three most relevant).

Source: own research.

The research also examined the financial commitments small businesses were willing to make in Industry 4.0 to grow their operations. As for the small enterprises, the most frequently selected amount was between EUR 25,000 and EUR 75,000, accounting for 38% of the responses. The second most common choice was up to EUR 25,000, representing 24%. In third place, tied at 14%, were two ranges: EUR 75,000-125,000 and EUR 125,000-175,000. The least chosen option, at 10%, was an investment above EUR 175,000, as presented in Figure 3.

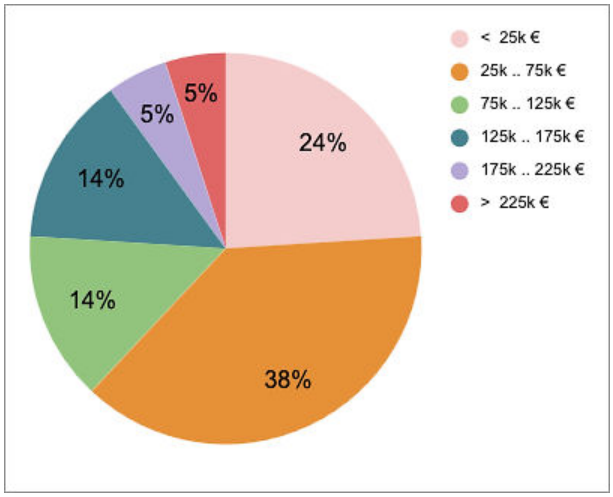


Figure 3. Small enterprises – Question 3 – How much are you willing to invest in the digital technologies of Industry 4.0 in order to advance your enterprise?

Source: own research.

The respondents were also asked to answer a question about the benefits resulting from the use of Industry 4.0 technologies (see Figure 4). The most popular answers were benefits such as increased productivity, competitiveness, and cost optimization (80%). For the remaining 20% of respondents, the benefits were not attractive, because at the very beginning, it involved

huge costs for the company, which, in their opinion, may not pay off in the future, and as a result, the company will go bankrupt.

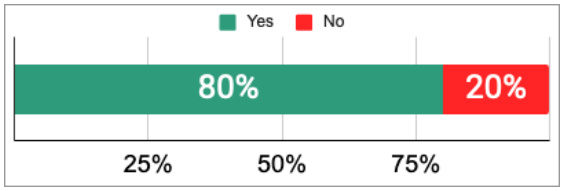


Figure 4. Small enterprises – Question 4 – Would the benefits of using Industry 4.0 technology (such as increasing productivity, competitiveness, cost optimization, etc.) be attractive to your enterprise?

Source: own research.

The last question, which was asked of respondents of smaller companies, aimed to check whether these companies will link their future with the development of Industry 4.0 technologies. As many as 75% of respondents declared that they will link their future with a given program due to the many benefits that they can achieve. On the other hand, 1/4 of respondents will not be associated with Industry 4.0 technologies. The most common reason they indicated was the lack of appropriate knowledge about Industry 4.0 and ambition to develop their company.

In summary, the survey shows that more than half of small businesses are familiar with the issue of Industry 4.0. For companies, technologies are very interesting and can have a positive impact on their overall functioning. A barrier that may be insurmountable for certain companies is the amount that must be invested at the very beginning to develop the technology. As much as 3/4 of companies declared that they would link their future with the Fourth Industrial Revolution to develop their company. The remaining companies that have not decided on Industry 4.0 will have a very hard time catching up with companies with technologies resulting from Industry 4.0.

2.3. Industry 4.0 in Medium Enterprises

Medium-sized enterprises are defined as those employing between 50 and 250 people and whose total annual balance sheet does not exceed EUR 50 million Biznes Rangers (2022). A five-question survey was conducted among 20 medium-sized enterprises across Poland, 75% of which were managed by men, and the remaining 25% by women. Respondents had to answer five questions about Industry 4.0. The first question (Figure 5) was related to the knowledge of the Fourth Industrial Revolution in enterprises. 80% of respondents are familiar with its concept, while 20% of respondents had no experience with the issue of Industry 4.0.

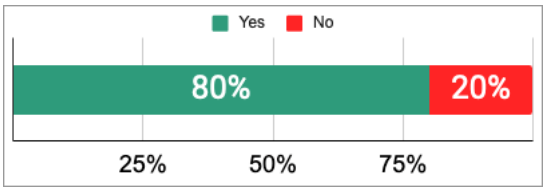


Figure 5. Medium enterprises – Question 1 – Did you have anything to do with the term Industry 4.0?

Source: own research.

Next, the respondents were asked about the Industry 4.0 technological solutions that would be important or are important to them in the company. The respondents who took part in the survey had 9 Industry 4.0 technologies at their disposal and could choose a maximum of 3 answers. According to the respondents, the most important technological solution in companies was Cybersecurity (28%), which would ensure data security. In second place, according to the respondents, with a result of 17% was Cloud Computing, thanks to which companies can manage performance, as well as simulations to, for example, supervise production. The third place was taken by horizontal/vertical software integration (15%), which can improve existing IT systems. The least frequently chosen Industry 4.0 technologies by respondents were Big Data (7%), while autonomous robots and AR were with a result of 5%. The respondents considered AR and additive manufacturing to be the least needed technological element in their companies (see Figure 6).

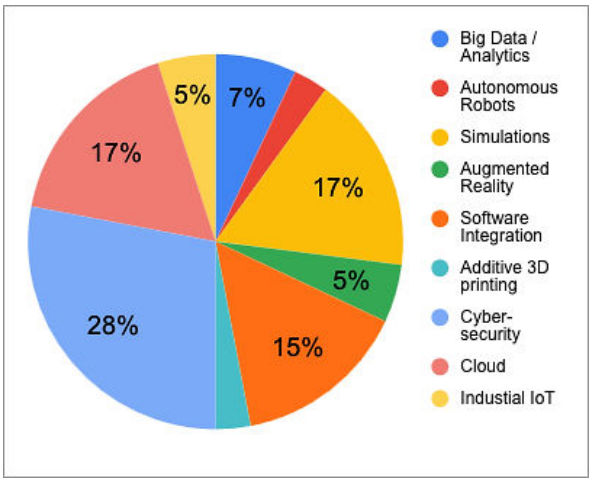


Figure 6. Medium enterprises – Question 2 – Which digital technologies of Industry 4.0 do you consider important for your Enterprise? (choose max three most relevant).

Source: own research.

The third question respondents were asked to answer concerned the amount of investment in Industry 4.0 technologies for their company's development, depicted in Figure 7. The most frequently chosen investment range was between EUR 25,000 and 75,000, representing 38% of all responses. In second place, with 24%, was the range of EUR 75,000 to 125,000, followed closely by EUR 125,000 to 175,000. The fewest respondents indicated they would invest not more than EUR 25,000 (9%) or above EUR 175,000 (10%).

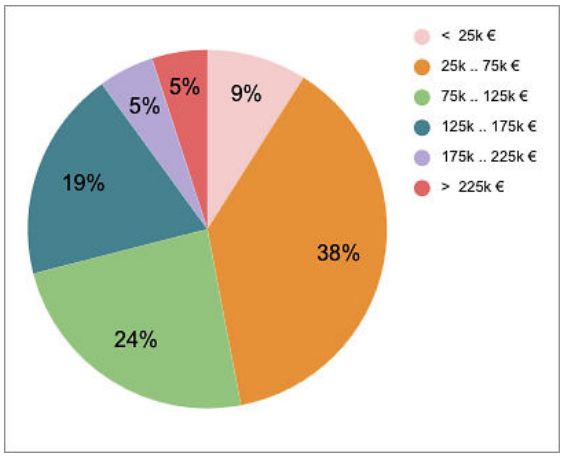


Figure 7. Medium enterprises – Question 3 – How much are you willing to invest in digital technologies of Industry 4.0 in order to advance your enterprise?

Source: own research.

Respondents were also asked whether benefits such as increased productivity, competitiveness, or cost optimization resulting from the use of Industry 4.0 technologies would be attractive to them (see Figure 8). As many as 90% of respondents answered YES to the benefits resulting from Industry 4.0, while 10% of respondents are still not convinced about the benefits resulting from the Industrial Revolution. The main fear that will once again appear is the possibility of bankruptcy of the company. Companies also have concerns about changes related to the industry, specifically the restructuring of the company. The fifth question, and the last one, that the respondents had to answer, concerned the future of connecting with Industry 4.0 in order to develop their company. As many as 85% of the respondents will connect their future with Industry 4.0 because the technologies are very attractive to them and future-proof for the further running of their company. Unfortunately, 15% of the respondents will not connect with Industry 4.0. The reason they indicated is the fact that the company operates on an internal application and there is no need to introduce Industry 4.0.

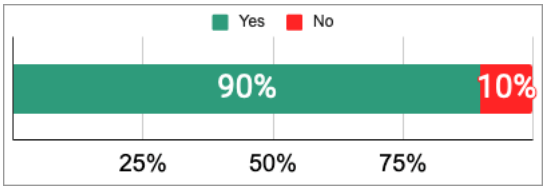


Figure 8. Medium enterprises – Question 4 – Would the benefits of using Industry 4.0 technology (such as increasing productivity, competitiveness, cost optimization, etc.) be attractive to your enterprise?

Source: own research.

In summary, the survey shows that more medium-sized enterprises are familiar with the issue of Industry 4.0 compared to small enterprises. The former would invest significantly more money to develop technology because their budgets are generally larger than those of small companies. Medium-sized enterprises, investing in Industry 4.0 technologies, see the possibility of developing themselves through technology and increasing their competitiveness on the market.

2.4. Industry 4.0 in Large Enterprises

Large enterprises are those that employ 250 or more employees and whose total annual balance sheet exceeds EUR 50 million Nawrocki (2022). The five-question survey was attended by 20 large enterprises from all over Poland, 90% of which were managed by men and the remaining 10% by women (see Figure 9).

The respondents answered five questions related to the Fourth Industrial Revolution. The first question concerned the respondents' familiarity with the issue of Industry 4.0. 95% of the respondents knew its concept, while the remaining 5% had no contact with this issue.

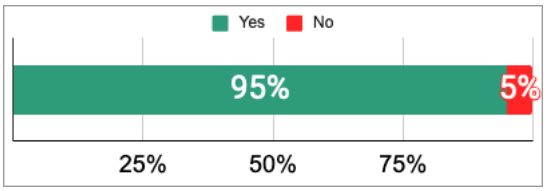


Figure 9. Large enterprises – Question 1 – Did you have anything to do with the term Industry 4.0?

Source: own research.

Then, respondents were asked to mark three technological solutions that are part of Industry 4.0 and would be or are useful in their companies. The respondents focused most on cybersecurity with a score of 25%, which will allow them to secure company data. In second place was simulation with a score of 18%, and in third, with a score of 15%, horizontal and vertical software integration, which will improve the functioning of the company. Respondents with the same score of 11% chose autonomous robots, which can support the system, and the cloud, thanks to which there is the possibility of mobile performance management in real-time. BD technology was in 6th place with a score of 10%. The respondents considered IoT, augmented reality, and additive manufacturing using 3D printers to be the least needed technological element in their companies (see Figure 10).

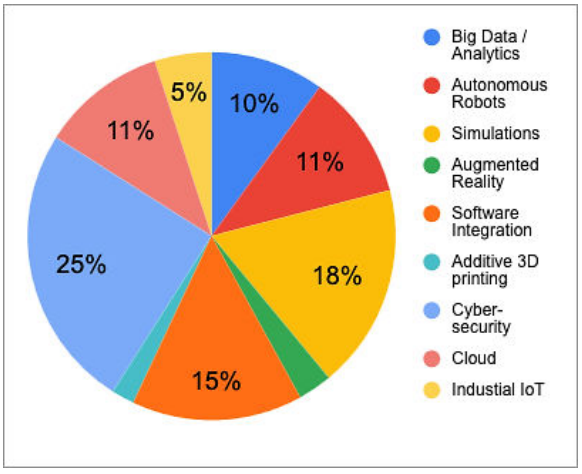


Figure 10. Large enterprises – Question 2 – Which digital technologies of Industry 4.0 do you consider important for your Enterprise? (choose max three most relevant).

Source: own research.

The next question the respondents faced was related to the previous one, as they were asked to determine how much they would invest in the selected Industry 4.0 technologies deemed useful for their company (see Figure 11). The most common investment range, chosen by 40% of respondents, was between EUR 125,000 and EUR 175,000. The second most selected range was EUR 75,000 to EUR 125,000, followed closely by the EUR 175,000 to EUR 225,000 range. Only 10% of respondents indicated they would invest between EUR 25,000 and EUR 75,000 or more than EUR 225,000. The least frequently selected option was an investment of up to EUR 25,000.

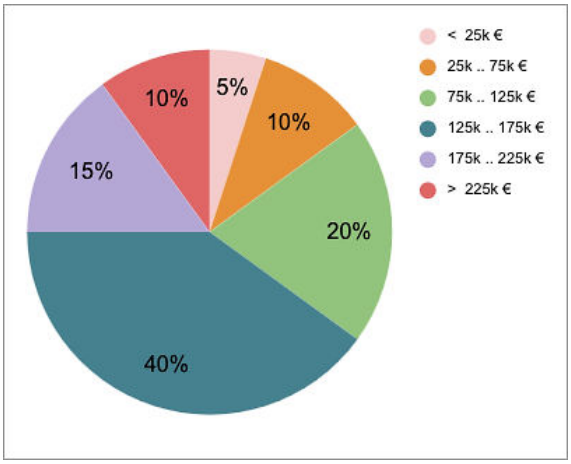


Figure 11. Large enterprises – Question 3 – How much are you willing to invest in digital technologies of Industry 4.0 in order to advance your enterprise?

Source: own research.

The next question concerned the benefits of Industry 4.0 technologies. The respondents had to answer the question of whether benefits such as cost optimization, increased productivity, better planning, and monitoring of manufacturing processes would be beneficial for their companies. As many as 95% of respondents answered that the above-mentioned benefits would be beneficial for their company. Only 5% of all answers were negative. The only company for which the benefits would not be attractive answered that the company does not need Industry 4.0 technologies because it functions perfectly without them (see Figure 12).

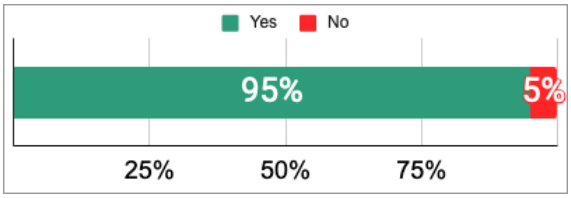


Figure 12. Large enterprises – Question 3 – How much are you willing to invest in digital technologies of Industry 4.0 in order to advance your enterprise?

Source: own research.

The last question that the respondents had to answer was aimed at obtaining a final answer regarding the future of Industry 4.0 in their companies. 90% of the respondents answered yes, and the benefits offered by the Fourth Revolution are very attractive and beneficial for them, which is why in the future they are associated with the development of Industry 4.0 technologies. Only 10% of companies will not be associated with Industry 4.0. Companies will not be associated with their future because it is associated with necessary procedures that need time, and for the company it is too long to wait for any effects. In addition, they are not convinced about Industry 4.0 technologies. In summary, the survey shows that the vast majority of large enterprises are familiar with the issue of Industry 4.0. Enterprises with a significantly large budget would be much more willing to invest money in Industry 4.0 technologies, because they are aware that the money invested will prove to be an ideal investment in the future, which will then be associated with financial benefits, as well as in building a strong enterprise on a very competitive market.

2.5. Comparison between Polish and selected EU countries' SMEs in terms of digital economies

This chapter contains the comparative research performed by confronting the literature-based data on selected EU countries' digital economies, with the survey-based information acquired from the decision-makers of 60 Polish enterprises.

2.5.1. Comparison of the Polish and Danish digital economies

The comparative analysis of the Polish and Danish digital economy aims to show the differences and the reasons that divide these two countries in the subject of the digital economy. In 2021, in the Digital Economy and Society Index (DESI) ranking, the Polish digital economy was ranked 24th, while Denmark was ranked 2nd among the 27 EU member states. 60 respondents took part in the analysis.

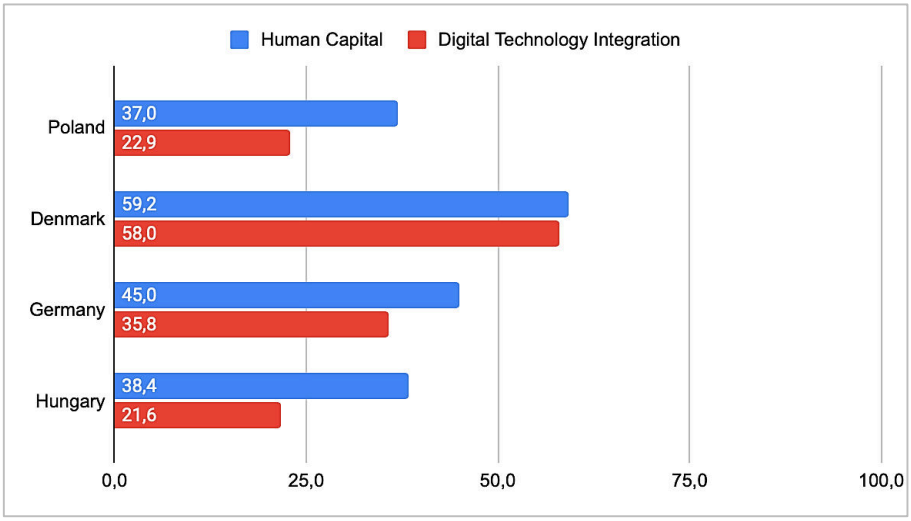


Figure 13. Comparison of the Polish and other selected European countries' digital economies in the use of digital technologies and the human capital regarding digital skills.

Source: own work, based on European Commision (2022b, e, a, d, c).

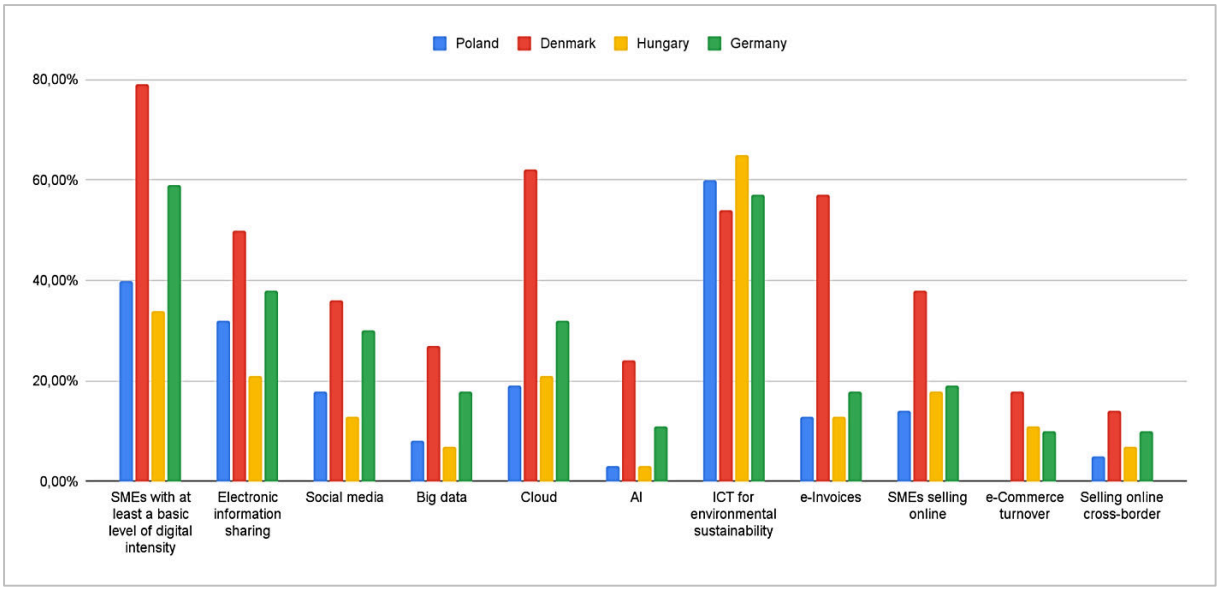


Figure 14. Comparison of the Polish and other selected European countries' digital economies in the use of digital technologies.

Source: own work, based on European Commision (2022b, e, a, d, c).

At the beginning, respondents were asked about digital technologies and services used in companies. In Poland, 88% of them use digital technologies and services, while in Denmark, 94% use digital technologies and services. In Poland, 12% do not use any digital technologies and services, while in Denmark, only 6%.

The second question that the respondents had to face concerned digital technologies, or more precisely, which digital technologies are most commonly used. In Poland, the most commonly used digital technology is electronic information exchange, which obtained 25%. Right behind it with a result of 20% was e-invoice. In third place is social media, which obtained 18% of all answers. Next, respondents used IT systems (16%), and the least popular were the data cloud (12%) and online sales (9%). In Denmark, the most commonly used technology is the data cloud with a result of 62%. The second most commonly used technology is e-invoice, which obtained 57%. Another technology that is often used by Danes is electronic information exchange (50%) and social media (36%).

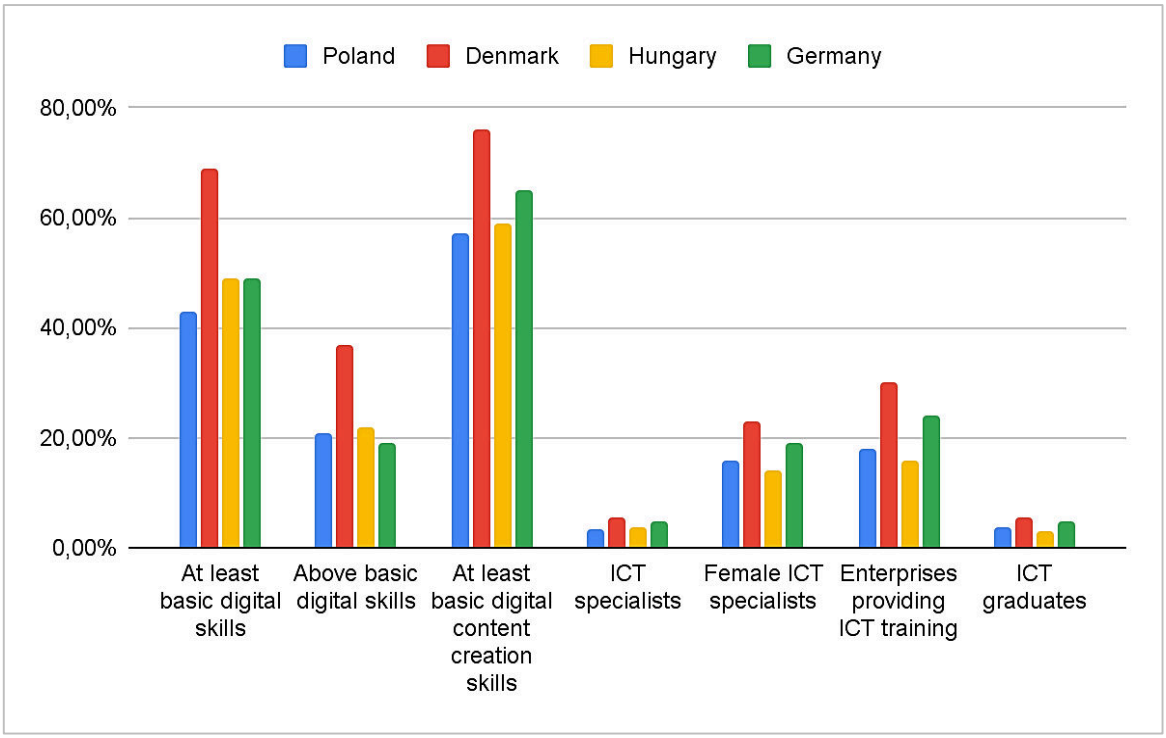


Figure 15. Comparison of the Polish and other selected European countries' human capital regarding digital skills.

Source: own work, based on European Commision (2022b, e, a, d, c).

The technologies chosen less often by Danes were IT systems (24%) as well as e-commerce (14%). It can be seen that Danes use digital technologies much more often and more willingly than Poles. The next question aimed to check the IT and digital skills of the respondents. In Poland, 60% of the people taking part in the survey have at least basic IT and digital skills, while in Denmark, as many as 76% have such skills. The intermediate level in Poland is possessed by 27% of the respondents, compared to Denmark, where intermediate skills are 69%. When it comes to high skills, in Poland, 13% of the respondents have such skills, while in Denmark 37%. A significant difference between these countries can be seen in the intermediate and high levels. This may be due to the fact that in Poland very few people take part in training that could improve the level of IT and digital skills. It is also worth mentioning that Poland is a country where the elderly population outnumbers the young, which is why there may be a reluctance to modern technologies, which affects the described results. To sum up, after the analysis, it can be stated that in Poland in terms of the use of digital technologies and services, it does not look bad, but the vast majority of digital technologies and services are still underused in order to develop the digital economy. Comparing digital technologies and services, Denmark is definitely better developed, as shown in Figure 14. It is encouraging that many people in Poland have at least basic skills. Unfortunately, in Denmark, a very large number of people, in addition to basic skills, also have intermediate skills. The Polish digital economy is still developing and in the near future should slowly climb up in the ranking of the Digital Economy and Society Index (DESI).

2.5.2. Comparison of the Polish and Hungarian digital economies

The comparative analysis of the Polish and Hungarian digital economy aims to show the difference and reasons that divide these two countries in the subject of the digital economy. In 2021, in the DESI ranking, the Polish digital economy was ranked 24th, while the Hungarian one 22nd, among the 27 EU Member States. The analysis took into account Hungary's data from the DESI ranking from 2021 and the responses of Polish respondents collected in 2022. 60 respondents from Poland took part in the analysis. The first question that respondents had to answer concerned the use of digital technologies and services. In Poland, services and technologies are used by as many as 88% of Poles, while in Hungary, the same figure is 83% of respondents. In Poland, 12% do not use any digital technologies or services, while in Hungary, it is 17%. The next question that the respondents had to face was to find out which digital technologies are used most often. In first place, the most frequently used digital technology in Poland is electronic information exchange with a score of 25%. In second place came e-invoice with a score of 20%. Right behind it is social media with a score of 18%. IT systems received 16% of all answers. The least frequently chosen digital technologies in Poland turned out to be the cloud (12%) and online sales (9%). In Hungary, on the other hand, the most frequently used digital technology turned out to be the cloud and electronic information exchange, which received 21% each. Ex-aequo with a score of 18% came technologies such as online sales and IT systems. The less frequently chosen technologies turned out to be social media and e-invoices, which received 13%. The respondents were then asked about their level of digital skills. In Poland, 60% of respondents declared a basic level, while 27% an intermediate level. Only 13% of respondents in Poland are advanced. Comparing the situation in Hungary: 64% of respondents have basic skills, and 33% have intermediate skills. 19% achieved an advanced level in Hungary. In summary, the collected information should be noted that when comparing Poland with the results of the 2022 survey and Hungary with the DESI ranking from 2021, it can be said that Poland has made a significant step towards improvement in terms of the use of digital technologies and services. It is worth noting that the technologies used by Hungary are at a very close level and there is no major fluctuation in the use of technologies, while in Poland one technology is used more often and the other very rarely. The IT skills of people in Hungary are comparable to those of Poles. When comparing the digital technologies and services of Poland and Hungary, it can be said that it will be a matter of time before Hungary overtakes Hungary in the DESI ranking.

2.5.3. Comparison of the Polish and German digital economies

The comparative analysis of the Polish and German digital economy aims to show the difference and the reasons that divide these two countries in the subject of the digital economy. In 2021, in the Digital Economy and Society Index (DESI) ranking, Poland ranked 24th, while Germany ranked 12th, among the 27 EU Member States. The analysis took into account German data from the DESI ranking from 2021 and the responses of Polish respondents collected in 2022. 60 respondents from Poland took part in the analysis. At the very beginning,

the respondents were asked whether they use digital technologies and services. In Poland, 88% use digital technologies and services, and in Germany 83%. In Poland, 12% of the people taking part in the survey do not use digital technologies and services, and in Germany 17%. The second question concerned the most frequently used digital technologies. In Poland and Germany, the most frequently used technology is electronic information exchange, which was obtained in Poland by 25% of all respondents and in Germany by 38%. The second most frequently used digital technology in Poland is e-invoice with a result of 20%, and social media are right behind it with a result of 20%. IT system are right behind the podium with a result of 16%. Less frequently chosen technologies in Poland were the data cloud (12%) and e-commerce (9%). In Germany, the second most frequently used digital technology is the data cloud with a result of 32%, and right behind it in third place with a result of 30% are social media. Right behind the podium with a result of 18% are e-invoices. The least frequently chosen technologies in Germany are IT systems (11%) and online sales (10%). The next question aimed to check the level of IT and digital skills in both countries. In Poland, 60% of respondents had a basic level, while in Germany it was 65%. As for the intermediate level, it was obtained in Poland, 27% of all answers, while in Germany it was 36%. High skills were obtained in Poland by 13%, and in Germany by 19%. In summary, there are very large differences between the Polish and German digital economies in terms of the level of use of individual digital technologies. It is also worth noting the level of IT and digital skills, where Poland even has an advantage in terms of the basic level, but at the intermediate and high level, it lags behind Germany. Comparing the Polish digital economy with the DESI ranking for Germany from 2021, it can be said that Poland is increasingly involved in digital technologies, and over the course of a few years it may become a very serious country in terms of the digital economy.

3. Discussion

3.1. Identification of problems with the implementation of Industry 4.0 in the surveyed enterprises

The survey and the answers provided by the respondents show that various problems can be identified in companies. The main cause of problems that hinder the implementation of Industry 4.0 is the size of companies, because it affects the income and development of companies. Finances play a key role here due to the fact that not every company can afford to introduce Industry 4.0 technologies. In small companies, the issue of Industry 4.0 is quite averagely known, which may be related to the lack of knowledge about the Fourth Industrial Revolution and the technological progress that goes with it. They do not have a large budget, so any expense that would be associated with investing in this technology would have to be thought through twice before the company decides to make a given investment.

Some companies do not associate themselves with the development of Industry 4.0, because the way they operate on a daily basis is sufficient for them. It is also worth mentioning here that it will be more profitable for small companies to hire new employees instead of investing in new technologies. In medium and large enterprises, a large number of respondents were familiar with the issues of Industry 4.0, but there were still a few enterprises that had not dealt with the Fourth Industrial Revolution. Companies are quite willing to use, or would use, Industry 4.0 technologies. Some enterprises will not link their future with technologies, because they operate on an external application, and for some, it would involve a huge reorganization of the functioning of enterprises. For medium and large enterprises, it involves time and various procedures, which unfortunately cost them too much money to reorganize the given enterprises. Based on the identification of problems that have arisen in companies of various sizes, it would be worth proposing training for employees in order to expand their knowledge of the issue of Industry 4.0 and to present the benefits of implementing the Fourth Industrial Revolution technologies for companies. The training proposal will make employees aware of the wide possibilities of Industry 4.0 and the significant benefits that improve the implementation of activities that can be obtained from the implementation of Industry 4.0, in addition, it will present interesting benefits for companies that will be able to benefit from it in the future. Along with training on Industry 4.0, which is the basis for Industry 5.0, companies should also learn what other benefits they can achieve in the near future, having already introduced Industry 4.0 in their company, in order to later move to Industry 5.0 and thus continue to develop. A change that would be worth proposing is the gradual introduction of Industry 4.0 for their companies. All companies have the false impression that implementing Industry 4.0 involves a radical change in the way a company functions, and that it would be enough to divide it into several stages so that time is not wasted, and the company can continue to work for itself and earn money. It is said that companies lack the right approach to planning and optimizing processes, so gradual changes that would be divided into stages would significantly affect the way a company functions.

Enterprises, unfortunately, do not want to implement Industry 4.0 technologies due to the costs and the way their organization functions, which in their opinion is doing well without the Fourth Industrial Revolution. Generally speaking, enterprises that want to stand out on the labor market should invest in Industry 4.0 technologies, e.g. by taking out a loan and in this way try to implement the technology that would be most needed for their company at a given moment and see if it works over a few months, and then draw conclusions whether the investment was worth it. Enterprises should remember that other companies from the same industry that will introduce modern technologies will constitute greater competition on the labor market than their industry opponents that do not invest in any technologies, because in their opinion the company is functioning well and no company threatens them. Enterprises should strive to develop their companies and be as attractive as possible in their industry, overtaking their competition thanks to modern technologies.

3.2. Identifying the problems of the Polish digital economy

Comparing the Polish digital economy to countries such as Denmark, Germany and Hungary, one can see differences that distinguish Poland from the above-mentioned countries. The biggest differences can be seen in the use of digital technologies and IT and digital skills. Taking into account the digital technologies of all countries, it can be concluded that Poland uses only some of them to a significant extent, and some are used very little or in a negligible way. The role model in the use of technologies, which were presented in Figure EQ2, are very often used. Poland should follow the example of countries such as Denmark and pay more attention to the use of all digital technologies year by year and develop them step by step. It can be said that thanks to the development of digital technologies, Poland should develop very quickly, thus catching up with countries in the DESI ranking, thanks to which it will improve its place and the quality of functioning of the Polish digital economy. Another problem that the Polish digital economy is struggling with is the knowledge of IT and digital skills. The Polish digital economy should pay attention to the skills of society, because when compared to countries that are higher than Poland in the DESI ranking, it does not lag behind these countries only at a basic level. Taking into account the intermediate and high level, countries that are ahead of Polish society have a greater or lesser advantage. The problem with IT or digital skills can appear from the earliest years, where society is only taught basic skills. In later professional life, society is very rarely sent for training that would significantly improve the qualifications of employees and increase the number of people who would have intermediate or high skills.

4. Conclusions

The aim of the study was to analyze and assess the intensity of implementation of Industry 4.0 technologies in the digital economy of European Union enterprises, taking into account the identification of problems with the implementation of Industry 4.0 and the presentation of significant benefits resulting from the implementation of Industry 4.0 technologies in the surveyed organizations. The survey conducted among enterprises aimed to examine enterprises in terms of the intensity of Industry 4.0 implementations and to compare the development of the Polish digital economy with the European Union countries, which consequently allowed for the presentation of important conclusions:

1. Small enterprises have a rather average understanding of the issue of Industry 4.0, which is caused by a "shortage" of knowledge about the Fourth Industrial Revolution; additionally, small enterprises have a limited budget when it comes to implementing Industry 4.0 technologies.
2. It is more profitable to hire a new employee in small businesses than to introduce any Fourth Industrial Revolution.
3. Medium and large enterprises are much more familiar with the issue of Industry 4.0 and are more willing to use and apply Industry 4.0 technologies to increase productivity and market competitiveness.
4. The vast majority of small, medium and large enterprises will link their future with Industry 4.0 in order to modernize the functioning of their enterprise.
5. The lack of knowledge among employees of small, medium and large enterprises about Industry 4.0 issues and the benefits resulting from them affects the way a given enterprise functions and develops.
6. Polish companies are making decisive use of digital technologies and services at a level of 88%. In the future, this will influence the development of enterprises and the digital economy in Poland, which will affect the position in the DESI ranking.
7. Poland uses some digital technologies to a large extent, and some technologies quite rarely. These include additive manufacturing using 3D printers, IIoT, autonomous robots. This is due to the high costs that must be faced at the beginning.
8. The knowledge of IT and digital skills of employees is insufficient, taking into account the surveyed countries from the European Union, which is confirmed by the results of the conducted research.
9. Polish enterprises are increasingly using fixed broadband connections at a level of 85%, which was confirmed by the results of the survey.

To sum up, it should be pointed out that the conducted research has shown that Polish enterprises should follow the development of technology, and in particular the Fourth Industrial Revolution, because the development of the digital economy and Industry 4.0 itself are interconnected. The development of employees and the entire Polish society in digital and IT skills will bring a number of benefits that will later have an impact on the functioning of the companies they employ. Enterprises should pay attention to the development of Industry 4.0 technologies in their area, because in the future it will be associated with significant benefits. Additionally, the introduction of Industry 4.0 will be another facilitation for entering the era of the Fifth Industrial Revolution, the presence of which is certain in the near future. The digital economy and Industry 4.0 itself go hand in hand and it is only a matter of time and it depends on enterprises how they combine these two things so that their companies function properly.

5. Summary

The presented work describes the possibilities of implementing Industry 4.0 in small, medium and large enterprises, and also compares the digital economy of Poland to the countries of the European Union. Thanks to the analysis of the possibilities of implementing the Fourth Industrial Revolution, it was concluded that some enterprises are ready to implement Industry 4.0, but for some sizes of companies, the key factor that may limit the introduction of modern technologies is the initial costs, which for some companies are very high. For the vast majority of enterprises, modern technologies are very attractive and even the initially high cost is not a problem for them, due to the significant benefits that "come" with these technologies and the possibility of developing the enterprise, because in this way organizations strengthen their position and competitiveness on the market. Taking into account the comparative analysis of the Polish digital economy with EU countries, it can be concluded that Poland is increasingly developing in terms of IT and digital skills, although Polish enterprises use some digital technologies much less often, thus focusing only on some of them instead of using them much more often and developing digital technologies in this way. Industry 4.0 is a huge step for companies and logistics, which leads to the modernization of production in various companies, using modern information and communication technologies. Nowadays, the digitalization of companies and logistics processes is inevitable and it is necessary and should be more and more invested in modern technologies. At first, it can be very expensive, but in the end, it is very profitable in its resources, it has many modern technologies that can help companies develop their functionality and development and be more competitive on the market.

To sum up, Industry 4.0 will be eagerly implemented by Polish companies, thanks to the benefits resulting from the technologies introduced or being introduced, and the initially high cost will pay off very quickly. Additionally, it will make it much easier for companies to introduce Industry 5.0 to their operations. The digital economy is developing very dynamically and it is only a matter of time before it takes a higher place in the DESI ranking.

References

1. Adamczak, M., Kolinski, A., Trojanowska, J., Husár, J. (2023). Digitalization trend and its influence on the development of the operational process in production companies. *Applied Sciences, 13(3),* 1393.
2. Agencja Rozwoju Pomorza (2022). *The definition of micro, small and medium-sized enterprises adopted by the commission [Definicja mikroprzedsiębiorstw oraz małych*

i średnich przedsiębiorstw przyjęta przez komisję], https://www.arp.gda.pl/plik,165,1-definicja-mikro-malych-i-srednich-przedsiebiorstw.pdf, 24.08.2022.

3. Alcácer, V., Cruz-Machado, V. (2019). Scanning the industry 4.0: A literature review on technologies for manufacturing systems. *Engineering Science and Technology, an International Journal, 22(3),* 899-919.
4. Ayitey, W. (2010). *A simple approach to strategic management*. Ghana: Methodist Book Depot Ltd.
5. Baines, T.W., Lightfoot, H. (2013). Servitization of the manufacturing firm: Exploring the operations practices and technologies that deliver advanced services. *International Journal of Operations & Production Management, 34(1),* 2-35.
6. Barmuta, K., Fateeva, O., Dymchenko, O. (2023). *Digitalization of the economy and its impact on the transformation of business.* International Scientific Conference Fundamental and Applied Scientific Research in the Development of Agriculture in the Far East. Springer, 538-547.
7. Biznes Rangers (2022). *Definition of sme, or what are micro, small and medium-sized enterprises [Definicja mśp, czyli czym są mikro, małe i średnie przedsiębiorstwa]*. https://biznesrangers.pl/definicja-msp-czyli-czym-sa-mikro-male-i-srednie-przedsiebiorstwa/, 15.09.2022.
8. Bozintan, A., Cris, an E., Pinco, O. (2023). The impact of digital transformation on strategic management. *The Annals Of The University Of Oradea, 32(1st),* 647.
9. Bughin, J., Kretschmer, T., van Zeebroeck, N. (2021). Digital technology adoption drives strategic renewal for successful digital transformation. *IEEE Engineering Management Review, 49(3)*, 103-108.
10. Castelo-Branco, I., Amaro-Henriques, M., Cruz-Jesus, F., Oliveira, T. (2023). Assessing the industry 4.0 european divide through the country/industry dichotomy. *Computers & Industrial Engineering, 176*, 108925.
11. David, F.R. (2011). *Strategic management concepts and cases*. Prentice Hall.
12. de Lucas Ancillo, A., Gavrila, S.G. (2023). The impact of research and development on entrepreneurship, innovation, digitization and digital transformation. *Journal of Business Research, 157,* 113566.
13. DeStefano, T., De Backer, K., Moussiegt, L. (2017). *Determinants of digital technology use by companies.* Technical report.
14. Egorov, D., Levina, A., Kalyazina, S., Schuur, P., Gerrits, B. (2020). *The challenges of the logistics industry in the era of digital transformation.* International conference on technological transformation: A new role for human, machines and management. Springer, 201-209.
15. European Commision (2022a). *Denmark in the digital economy and society index - 2022 desi country profile.* https://digital-strategy.ec.europa.eu/en/policies/desi-denmark

16. European Commision (2022b). *The digital economy and society index - countries' performance in digitisation - shaping europe's digital future*. https://digital-strategy.ec.europa.eu/en/policies/desi
17. European Commision (2022c). *Germany in the digital economy and society index - 2022 desi country profile*. https://digital-strategy.ec.europa.eu/en/policies/desi-germany
18. European Commision (2022d). *Hungary in the digital economy and society index -2022 desi country profile*. https://digital-strategy.ec.europa.eu/en/policies/desi-hungary
19. European Commision (2022e). *Poland in the digital economy and society index - 2022 desi country profile*. https://digital-strategy.ec.europa.eu/en/policies/desi-poland
20. Federal Ministry of Food and Agriculture of Germany (2022). *Glossary explaining key terms of digitization [Glossar zur erklärung wesentlicher begriffe der digitalisierung]*. https://www.bmel.de, 26.06.2022.
21. Galanti, T., De Vincenzi, C., Buonomo, I., Benevene, P. (2023). Digital transformation: Inevitable change or sizable opportunity? the strategic role of hr management in industry 4.0. *Administrative Sciences 13(2),* ISSN 2076-3387, http://dx.doi.org/10.3390/admsci13020030
22. Grześ, A. (2020). *Changes in the demand for labor in selected PKD sections in Poland in the conditions of the Fourth Industrial Revolution [Zmiany w popycie na pracę w wybranych sekcjach PKD w Polsce w warunkach Czwartej Rewolucji Przemysłowej]*. Toruń: Adam Marszałek.
23. Hahn, G.J. (2020). Industry 4.0: a supply chain innovation perspective. *International Journal of Production Research, 58(5),* 1425-1441, http://dx.doi.org/10.1080/00207543.2019.1641642
24. Huang, C.J., Talla Chicoma, E.D., Huang, Y.H. (2019). Evaluating the factors that are affecting the implementation of industry 4.0 technologies in manufacturing msmes, the case of Peru. *Processes, 7(3),* 161.
25. Kraus, S., Vonmetz, K., Bullini Orlandi, L., Zardini, A., Rossignoli, C. (2023). Digital entrepreneurship: The role of entrepreneurial orientation and digitalization for disruptive innovation. *Technological Forecasting and Social Change, 193,* 122638, ISSN 0040-1625, http://dx.doi.org/https://doi.org/10.1016/j.techfore.2023.122638
26. Kuzmin, P. (2022). Industrial digitalization: an empirical assessment of the digital maturity of enterprises. *Strategic decisions and risk management, 12(3),* 220-235.
27. Lasi, H., Fettke, P., Kemper, H.G., Feld, T., Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering, 6,* 239-242.
28. Li, C., Chen, Y., Shang, Y. (2022). A review of industrial big data for decision making in intelligent manufacturing. *Engineering Science and Technology, an International Journal, 29,* 101021.
29. Li, L., Su, F., Zhang, W., Mao, J.Y. (2018) Digital transformation by sme entrepreneurs: A capability perspective. *Information Systems Journal, 28(6),* 1129-1157.

30. Łobejko, S. (2018). *Enterprise digitization strategies [Strategie cyfryzacji przedsiębiorstw]*. Konferencja Innowacje w Zarządzaniu i Inżynierii Produkcji [Enterprise digitization strategies. The Innovation in Management and Production Engineering Conference]. Opole: Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją.
31. Manavalan, E., Jayakrishna, K. (2019). A review of internet of things (iot) embedded sustainable supply chain for industry 4.0 requirements. *Computers & Industrial Engineering, 127*, 925-953.
32. May, A.Y.C., Hui, E.L.K. (2023). The prospect of business undergraduates' intention to engage in digital entrepreneurship: Do the government initiative matters? *Studia z Polityki Publicznej, 10(1(37)),* 9-40.
33. Nawrocki, A. (2022). Duże przedsiębiorstwo – wszystko, co powinieneś o nim wiedzieć. https://magazynprzedsiebiorcy.pl/duze-przedsiebiorstwo, 19.09.2022.
34. Olbrys, P., Smoliński, M. (2020). *The impact of digitalization on business revenues [Wpływ cyfryzacji na przychody przedsiębiorstw],* https://www.ican.pl/b/wplyw-cyfryzacji-na-przychody-przedsiebiorstw/P2dqT4G8M, 27.05.2022.
35. Olsen, T.L., Tomlin, B. (2020). Industry 4.0: Opportunities and challenges for operations management. *Manufacturing & Service Operations Management, 22(1),* 113-122.
36. Pech, M., Vrchota, J. (2020). Classification of small-and medium-sized enterprises based on the level of industry 4.0 implementation. *Applied Sciences, 10(15),* 5150.
37. Radicic, D., Petković, S. (2023). Impact of digitalization on technological innovations in small and medium-sized enterprises (smes). *Technological Forecasting and Social Change, 191,* 122474, ISSN 0040-1625, https://doi.org/10.1016/j.techfore.2023.122474
38. Rêgo, B.S., Jayantilal, S., Ferreira, J.J., Carayannis, E.G. (2021). Digital transformation and strategic management: A systematic review of the literature. *Journal of the Knowledge Economy*, 1-28.
39. Ricci, R., Battaglia, D., Neirotti, P. (2021). External knowledge search, opportunity recognition and industry 4.0 adoption in smes. *International Journal of Production Economics, 240,* 108234.
40. Rogalewski, A. (2020). *Digitalization and platform work. Information for employees [Cyfryzacja i praca platformowa. Informator dla pracowników]*. Warszawa: Friedrich-Ebert-Stiftung, Przedstawicielstwo w Polsce.
41. Rojek, I., Dostatni, E., Mikołajewski, D., Pawłowski, L., Węgrzyn-Wolska, K. (2022). Modern approach to sustainable production in the context of industry 4.0. Bulletin of the Polish Academy of Sciences. *Czasopisma i Monografie PAN*, *Technical Sciences, 70(6).*
42. Schniederjans, D.G., Curado, C., Khalajhedayati, M. (2020). Supply chain digitisation trends: An integration of knowledge management. *International Journal of Production Economics, 220*, 107439.

43. Schumacher, A., Nemeth, T., Sihn, W. (2019). Roadmapping towards industrial digitalization based on an industry 4.0 maturity model for manufacturing enterprises. *Procedia Cirp., 79,* 409-414.
44. Schwertner, K. (2017). Digital transformation of business. *Trakia Journal of Sciences, 15(1),* 388-393.
45. Sestino, A., Prete, M.I., Piper, L., Guido, G. (2020). Internet of things and big data as enablers for business digitalization strategies. *Technovation, 98*, 102173.
46. Sharma, A.K., Bhandari, R., Pinca-Bretotean, C., Sharma, C., Dhakad, S.K., Mathur, A. (2021). A study of trends and industrial prospects of industry 4.0. *Materials Today: Proceedings, 47,* 2364-2369.
47. Tortora, A.M., Maria, A., Iannone, R., Pianese, C. et al. (2021). A survey study on industry 4.0 readiness level of italian small and medium enterprises. *Procedia Computer Science 180,* 744-753.
48. Troise, C., Tani, M., Matricano, D., Ferrara, E. (2022). *Digital Transformation, Strategic Management and Entrepreneurial Process: Dynamics, Challenges and Opportunities*. Emerald.
49. Varoglu, A., Gokten, S., Ozdogan, B. (2021). *Digital Corporate Governance: Inevitable Transformation.* Cham: Springer International Publishing, 219-236. ISBN 978-3-030-72624-9
50. Verhoef, P.C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J.Q., Fabian, N., Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research, 122,* 889-901.
51. Vrana, J., Singh, R. (2021). *Digitization, digitalization, and digital transformation. Handbook of Nondestructive Evaluation 4.0,* 1-17.
52. Wang, Z., Lin, S., Chen, Y., Lyulyov, O., Pimonenko, T. (2023). Digitalization effect on business performance: Role of business model innovation. *Sustainability, 15,* 9020.
53. Wei, S., Liu, W., Choi, T.M., xin Dong, J., Long, S. (2024). The influence of key components and digital technologies on manufacturer's choice of innovation strategy. *European Journal of Operational Research, 315(3),* 1210-1220, ISSN 0377-2217, https://doi.org/10.1016/j.ejor.2024. 01.008
54. Yang, M., Fu, M., Zhang, Z. (2021). The adoption of digital technologies in supply chains: Drivers, process and impact. *Technological Forecasting and Social Change, 169*, 120795.

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METROPOLIS GZM RESIDENTS' ACCEPTANCE OF SUSTAINABILITY MESSAGING FROM ACCOMMODATION PROVIDERS

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Purpose: The article aims to explain the mechanisms behind the reception and acceptance of sustainability messages formulated by companies within the accommodation sector among GZM residents, with particular focus on the key determinants of this process.
Design/methodology/approach: The study employed a structured questionnaire comprising 25 questions, administered to a sample of 800 adult residents of the Upper Silesian-Zagłębie Metropolis to collect data. To verify the hypotheses and investigate the proposed relationships, the Partial Least Squares Structural Equation Modeling (PLS-SEM) method was employed. The research model consisted of six constructs.
Findings: The analysis results confirmed all hypotheses, indicating that consumers positively accept sustainable development communication from accommodation providers and do not perceive a decrease in service quality, contrary to widely cited industry fears.
Research limitations/implications: Future research should incorporate a nationwide representative sample and consumer segmentation (e.g., using cluster analysis) to provide more specific guidance for accommodation providers.
Practical implications: The findings of the study have significant implications for tourism sector representatives, local authorities, and marketing specialists in creating more effective and targeted sustainability communications. Understanding what influences acceptance will allow entrepreneurs to build a deeper relationship with the local community, which is key to their image and development.
Social implications: The study identified factors influencing the acceptance of sustainability communication, which can be a significant suggestion for local authorities in developing campaigns concerning ecological awareness and fostering pro-social attitudes.
Originality/value: The study proposes an original model of sustainability communication acceptance factors.
Keywords: sustainable development, tourism enterprises, sustainable communication, acceptance model.
Category of the paper: Research paper.

1. Introduction

Communication by organizations about activities implementing the assumptions of sustainable development or Corporate Social Responsibility (CSR) concepts is gaining popularity. This trend is largely driven by the introduction of legal regulations mandating reporting, such as the Corporate Sustainability Reporting Directive (CSRD), according to which the obligation to report on ESG will cover further groups of enterprises in the coming years (Bujalski, 2024) and the Corporate Sustainability Due Diligence Directive (CSDDD or CS3D), announced in July 2024 (Ministerstwo Funduszy i Polityki Regionalnej, 2024). However, the reporting obligation is not the sole motivation for introducing communication regarding sustainable development and CSR activities. Many enterprises choose to inform consumers about their initiatives to improve their image or to emphasize the fact that sustainable development has become an essential element of their business strategy. Thus, communicating about these activities becomes a fundamental element of corporate communication strategy, shaping the company's reputation and brand perception (Deni Saputra, Hanutama, 2025).

Although the Silesian Voivodeship is often stereotypically perceived as a touristically unattractive region due to historical pollution resulting from heavy industry (Gawroński et al., 2010), it possesses potential that needs to be unlocked. Consequently, promoting sustainable tourism initiatives should become one of the priorities within both regional policy and the operations of individual tourist facilities. Unfortunately, many tourist facilities deliberately refrain from communicating their commitment to sustainable development, fearing negative consumer reactions (Carlos, Lewis, 2018; Ettinger et al., 2021; Font, McCabe, 2017; Ginder et al., 2021; Tiago et al., 2021). To encourage tourist facilities to intensify the communication of their sustainable development activities, it is essential to establish what determines the positive acceptance of this message by consumers. This analysis is also particularly relevant in the context of the upcoming regulatory reporting obligation in the area of sustainable development (resulting from the CSRD and CS3D directives).

To address this issue, the present article investigates the determinants of positive acceptance of messages about sustainable development actions communicated by accommodation providers to consumers from the Upper Silesian-Zagłębie Metropolis (Górnośląsko-Zagłębiowska Metropolia - GZM). A literature review was initially conducted, highlighting the key determinants of tourism in the GZM and the theoretical context related to corporate communication in the area of CSR and sustainable development, with particular emphasis on aspects identified in the literature as reasons why the topic of sustainable development is not widely employed in the communication strategies of tourism enterprises. Subsequently, a conceptual model was developed, and the research methodology and study results were discussed. The work concludes with a discussion comparing the findings to previous research and presenting the conclusions.

2. Literature Review

2.1. Determinants of Tourism in the Upper Silesian-Zagłębie Metropolis (GZM)

Tourism constitutes one of the key sectors of the global economy (Cembruch-Nowakowski, 2019; Rabadán-Martín et al., 2019). In 2023, this sector accounted for approximately 9.1% of the world's GDP, and forecasts predict an increase in this share to 11.4% by 2034 (World Economic Forum & University of Surrey, 2024).

Tourism plays a significant role in the economy of the Silesian Voivodeship. In the first half of 2025, accommodation facilities in Silesia hosted 1.4 million tourists (Główny Urząd Statystyczny, 2025). This figure places the region sixth in Poland, behind the Mazowieckie (3.4 million), Małopolskie (3.1 million), Dolnośląskie (2.3 million), Pomorskie (1.7 million), and Zachodniopomorskie (1.7 million) voivodeships (Główny Urząd Statystyczny, 2025). The Silesian region is also distinguished by one of the highest densities of tourist facilities per unit of area (Główny Urząd Statystyczny, 2025). According to the Central Statistical Office report, there are 610 tourist establishments in the region, out of a total of 10,354 such facilities in Poland. It should be noted, however, that this report includes only establishments offering more than ten rooms, thereby excluding apartments, smaller guesthouses, and agritourism farms. To obtain a more comprehensive picture, data from the Booking.com reservation platform (accessed on August 20, 2025) were analyzed, indicating the existence of at least 2520 facilities in the Silesian Voivodeship. Nevertheless, one must bear in mind the limitations inherent in using such a platform, as not all Polish facilities are registered there, and their availability may have varied during the study period.

Tourism constitutes one of the fifteen priority domains of inter-municipal cooperation within the Metropolia GZM framework. In this context, local governments are expected to undertake joint actions in the areas of promotion, spatial development, and tourism development programs (Czakon, Jarczewski, 2023). The attractiveness of the GZM region stems primarily from its industrial heritage, including numerous post-industrial and mining monuments as well as the Industrial Monuments Route. Nevertheless, a survey conducted by Gawroński et al. (2010) also indicated other elements attractive for the region, such as cultural and sports offerings, as well as landscape values. An interesting and promising direction for the development of the tourism sector is also the concept of converting former factories and mining facilities into hotel properties and tourist attractions (Drzewiecki, Kazimierczak, 2014).

2.2. Corporate Communication in the Area of CSR and Sustainable Development

The way enterprises communicate their activities in the area of CSR and sustainable development plays a crucial role both in achieving organizational success and in building their credibility, especially in the context of using new media for communication (Adanlawo, Chaka, 2021). As an element of marketing strategy, communicating about CSR and sustainable

development activities can influence the perception of the organization by both business partners (Lin et al., 2024) and customers, particularly in controversial industries (Jansen et al., 2024). Communication regarding CSR and sustainable development conducted via new media (including websites and social media) is highly susceptible to manipulation (Jansen et al., 2024) while simultaneously competing with widespread disinformation about climate change, climate denialism (Treen et al., 2020), and suspicions of greenwashing. Adanlawo & Chaka (2025) note that strong stakeholder reactions often occur in response to communications regarding CSR and sustainable development, especially those that initiate a discussion on whether enterprises are truly meeting expectations with their actions or if they are overstating their merits in these areas.

Research indicates that tourism enterprises communicate their sustainability efforts less frequently than firms in other sectors, which may suggest a lack of commitment (Buckley, 2012; Moyle et al., 2018; Sharpley, 2009). Nevertheless, Moyle et al. (2018) proved that tourism companies show greater actual engagement in environmentally friendly practices. Despite this real commitment and the growing awareness of the concept, the communication of these actions within the tourism industry remains low (Ghanem, Elgammal, 2017; Santos et al., 2019). Studies in Portugal (Santos et al., 2019) found that only about 10% of hotels published sustainability information on their websites. Similarly, analysis of active tourism companies in Andalusia (Pérez-Villalba et al., 2017) and hotels in Spain (Pérez, Del Bosque, 2015) confirmed the rare presence or dispersion of these communications. In Poland (Rutecka, 2023), in turn, agritourism businesses communicate their activities, but the level of communication does not reflect their actual engagement. Furthermore, research in Croatia points to a low level of experience and readiness in the hotel sector for sustainability reporting (Bedenik et al., 2020).

A variety of explanations have been proposed as to why the topic of sustainable development is not widely used in the communication of tourism enterprises. Among the most frequently cited reasons are: the perceived conflict of the concept with the nature of tourism services (Font et al., 2018), low consumer awareness (Santos et al., 2019), lack of brand trust resulting from information asymmetry (Sun et al., 2021), and difficulties in designing effective communications (Tölkes, 2018).

2.3. The perceived conflict of the concept with the nature of tourism services

Tourism, as an industry sector whose aim is largely to provide entertainment, can to some extent be considered controversial. Tourism services primarily meet self-interested and hedonistic leisure needs, and as a result, tourists may focus solely on satisfying individual needs, disregarding global social and environmental problems (Higgins-Desbiolles, 2018). Therefore, sustainable development in tourism is sometimes described as a paradox (Tiago et al., 2021). On the one hand, the role of tourism includes providing maximum comfort, unique experiences, and entertainment (Font, McCabe, 2017; Malone et al., 2014; Scott, 2011; Tiago et al., 2021), while on the other hand, tourism enterprises are increasingly obliged to implement sustainable measures, including limiting the freedom offered to tourists. These restrictions may

be perceived negatively by consumers and result in reluctance to take up the offer (Kachniewska, 2018; Tiago et al., 2021), yet they are necessary to reduce resource consumption and to mitigate the negative impact of tourism on the environment and local communities.

Sustainable development practices, however, may be perceived by consumers as a form of lowering service quality or as attempts to reduce hotels' costs under the guise of environmental actions (Choudhary, Gokarn, 2013; Clark et al., 2021). Amatulli et al. (2021) cite numerous pieces of evidence indicating that luxury hotels' engagement in sustainability can negatively affect their image and diminish consumers' perceptions of the attractiveness of those hotels' offerings. On the other hand, the results of their experiment (Amatulli et al., 2021) showed that a sustainability-oriented communication strategy by a luxury hotel leads consumers to a higher perception of brand integrity, which in turn results in an intention to book a room in such a luxury hotel.

H1. Service Quality has a significant impact on Satisfaction

The group of tourists who want to relax in a clean, natural environment and are willing to pay more to stay at properties whose owners demonstrate environmental care is steadily growing (Clark et al., 2021; Fernández Robin et al., 2016). According to research conducted by Booking Holdings, as many as 82% of surveyed travelers believe that sustainable travel is important, and 72% of travelers say they are more likely to book at a property that adheres to sustainable practices (Booking Holdings, 2020). Other studies show that over 30% of guests are willing to pay more for a stay in environmentally friendly hotels, and that nearly 40% of tourists take sustainability into account when choosing a destination (Clark et al., 2021; Fernández Robin et al., 2016).

If a person values a specific feature of a product or service (e.g., concern for sustainability issues), they may be more satisfied if that feature is present. In Expectancy-Disconfirmation Theory (EDT), described by Oliver (Oliver, 1977, 1980), satisfaction is defined as the emotional response a person feels after using a product or service. Kotler (2003) defined customer satisfaction as "the feeling of pleasure or disappointment resulting from comparing a product's perceived performance (or outcome) with the customer's expectations" (Kotler, 2005; Zeqiraj, Nimani, 2022). It is thus the degree to which a good or service meets the consumer's expectations prior to consumption and the satisfaction resulting from obtaining what one counted on and expected from the product or service (Zeqiraj, Nimani, 2022). Satisfaction may also be influenced by the weight a person attaches to different aspects of a product or service. Consumer satisfaction is also influenced, among other things, by service quality, information quality, and trust (Geebren et al., 2021; Sharma, Sharma, 2019).

H2. Satisfaction has a significant impact on Intention to use

2.4. Low consumer awareness

Despite the growing number of people declaring sustainable attitudes (Font, McCabe, 2017; Santos et al., 2019), many tourists still do not understand the meaning of sustainable development or cannot recognize its manifestations in service offerings (Fernández Robin et al., 2016). A lack of environmental knowledge limits consumers' ability to appreciate responsible practices (Bordian, Gil-Saura, 2021; Tölkes, 2018). Consumers often do not understand what sustainability is and are unaware of its significance, and consequently do not seek information about sustainable development practices implemented by hotels (Fernández Robin et al., 2016). They also do not understand the value they may receive by choosing sustainable tourism products, or how to recognize them (Tölkes, 2018). Consumers who lack sufficient environmental knowledge are unable to appreciate responsible practices in tourism establishments (Bordian, Gil-Saura, 2021). Environmental awareness has been used as an additional construct in the Technology Acceptance Model (Davis, 1989) in a study of consumers' intention to use ride-sharing services (Wang et al., 2020) and is defined as knowledge of and concern about the consequences and impact of human behavior on the climate and environment (Schuitema et al., 2013) and is an important factor determining a change in current behavior towards more environmentally friendly actions (Schuitema et al., 2013; Wang et al., 2020). In the study by Wang et al. (2020), it was found that environmental awareness has a positive and direct effect on the intention to use pro-environmental services, in this case, ride sharing.

H3. Ecological Awareness has a significant impact on Intention to use

H4. Ecological Awareness has a significant impact on Service Quality

2.5. Lack of brand trust resulting from information asymmetry

Trust means the degree to which stakeholders are willing to accept vulnerability to the actions of others (Curşeu, Schruijer, 2010), and it can be directed both toward a group and toward a specific decision, in this case, a company's adopted sustainability strategy and the integrity associated with its communication strategy in this area. Trust is also perceived as a psychological state in which consumers and entrepreneurs have mutual trust and positive expectations toward each other (Asante Boadi et al., 2019). Perceived risk, in turn, refers to the financial, social, physical, time, or psychological risk associated with using a product or service (Featherman, Pavlou, 2003). In the case of tourism services, it is linked to the concern discussed above that implementing sustainability actions may undermine service quality or conflict with the nature of tourism, as well as to information asymmetry and the veracity of messages. There are situations in which business owners undertake low-cost and low-impact actions, such as labeling a property with "green" tags, including information on water saving, towel washing, and the like. These actions are appropriate, provided they are not used solely to gain a competitive advantage (Moyle et al., 2018) and are not equated with the company's holistic

approach to sustainability. Since the tourism offering is intangible and it is not possible to test the product or return it, trust in the brand and in the information it provides is crucial (Bilgihan, 2016; Cheunkamon et al., 2022). Nowadays, with the widespread use of the Internet as a communication channel, it is possible to verify the authenticity of a property's messages by reviewing the opinions of other guests of a given property who review their experiences related to their stay (Miranda, Briley, 2021; Prendergast et al., 2015), although there is also a risk here, both related to the possibility of generating false reviews and to their bias linked to the reviewer's personal perception. As Cheunkamon (2022) points out, a company can earn consumer trust through honesty and keeping its promises. Trust can be used to predict tourists' behaviors, including their intention to choose an offer and their engagement (Han et al., 2021).

H5. Trust has a significant impact on Ecological Awareness

H6. Trust has a significant impact on Service Quality

2.6. Difficulties in designing effective communications

Communication plays a significant role in business management, including sustainability management, enabling an organization to engage in dialogue with its stakeholders. Based on this dialogue, a new, more sustainable product may emerge, which in turn can reduce the company's negative impact on the environment and society. For a company to build its market position and increase competitiveness through sustainable actions, communication should include informing stakeholders about the values of new products and the company's values (Kowalska, 2020). Without effective communication, transformation toward sustainability in both the company and society becomes impossible (Hartmann, Apaolaza Ibáñez, 2006; Kowalska, 2020; Martin, Schouten, 2014). Communication is described as a strategic management function that helps build relationships with key audiences, thereby influencing an organization's mission, goals, and tasks (Dozier et al., 2013; Etter, 2014). If a company does not share information about its values with stakeholders, they will not be aware of their existence or of their incorporation into products. The manner of conducting communication, in turn, signals how the company wants to present itself (Font et al., 2017) and how it wishes to be perceived by its stakeholders.

As observed by Kronrod et al. (2012), a significant number of sustainability messages use aggressive, imperative slogans that leave recipients with no possibility of refusal. However, as Zhang et al. (2011) demonstrate, consumers are more willing to engage when it results from an autonomous choice, and they most readily participate in actions that are linked to their own goals (Goldstein et al., 2008). Cornelissen et al. (2006), in turn, indicate that audiences may respond better to messages when they are shown behaviors considered responsible that they could emulate. The form of the message can thus have a significant impact on the intention to use the offer, and inappropriate communication can negatively influence it, even if other components of the offer suit the customer. Moreover, as indicated by studies by Cerri (2018)

and Taufique (2017), communicating about sustainable actions can strengthen consumers' pro-environmental attitudes and their environmental awareness (Gaspar Ferreira, Fernandes, 2022).

H7. Service Quality mediated by the Form of Message has a significant impact on Intention to use

H8. Ecological Awareness mediated by the Form of Message has a significant impact on Satisfaction

3. Research Method

In structural equation modelling using the partial least squares method (PLS-SEM), the appropriate determination of the sample size is of fundamental importance for maintaining the credibility and robustness of the obtained results. In research projects employing PLS-SEM, the required number of observations is dependent on diverse factors. These include, among others, the level of model complexity, the sum of latent variables and their associated indicators, as well as the predicted effect size and the expected statistical power (Hair et al., 2013). The existing literature presents various standpoints regarding sample requirements: some experts postulate that a minimum respondent-to-indicator ratio of 5:1 or 10:1 is necessary, while other researchers recommend that the sample should include at least 100 to 200 observations (Kock, 2018; Strzelecki, 2023). Within the scope of the present analysis, a 10:1 sample-to-indicator ratio was adopted. Given that the research model comprises 25 indicators, the minimum required sample size was determined to be 250 observations. The conceptual model was based on six constructs, which were presented in detail in the earlier part of the study.

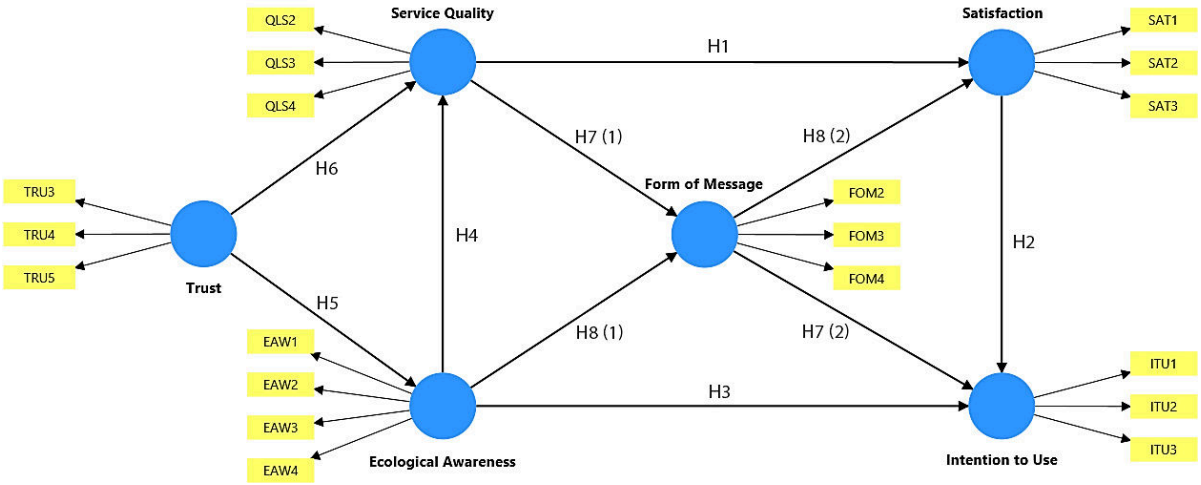


Figure 1. A conceptual acceptance model for sustainability communication.

The survey was conducted between July and August 2025 (with a data collection period of 30 days) among users registered in the National Research Panel. A 7-point Likert scale was used. The survey was conducted by the Fieldstat research agency and funded by the Metropolis GZM (Górnośląsko-Zagłębiowska Metropolia) under the "Metropolitan Science Support Fund" program for the period 2022-2024. The survey was closed after 800 responses from residents of the GZM Metropolis had been collected.

Table 1.
Expected and obtained number of interviews by age in GZM

	Residents 18+	% in total	Target interviews	Interviews completed
Female	935287	52,9%	423	423
Male	832107	47,1%	377	377
Total	**1767394**	**100,0%**	**800**	**800**

Source: developed by the author based on data from GUS, contained in the Local Data Bank.

Table 2.
Expected and obtained number of interviews by gender in GZM

	Residents 18+	% in total	Target interviews	Interviews completed
18-29	227372	12,9%	103	103
30-39	295648	16,7%	134	134
40-49	359278	20,3%	162	162
50-59	271349	15,4%	123	123
60-69	289635	16,4%	131	131
70 <	324112	18,3%	147	147
Total	**1767394**	**100,0%**	**800**	**800**

Source: developed by the author based on data from GUS, contained in the Local Data Bank.

The majority of respondents were women (52.9%, n = 423). Men made up 47.1% (n = 377) of respondents. The largest group of GZM residents consists of people aged 40-49 (20.3%), while the smallest group is people aged 18-29 (12.9%). The sample size was determined based on data from the Statistics Poland (GUS), contained in the Local Data Bank, which were current as of the last day of the previous year, i.e., 31.12.2024.

4. Results

The PLS-SEM model was constructed and analyzed using SmartPLS4 (version 4.1.0.9), with default settings applied throughout the process (Sarstedt et al., 2017). The initial step in assessing the reflective measurement model involved analyzing indicator loadings to determine indicator reliability. Reliability is calculated as the square of the loading, which represents the bivariate correlation between the indicator and its construct (Hair et al., 2022). A loading of 0.70 or higher is generally accepted as confirming satisfactory reliability, as it indicates the construct explains over half of the indicator's variance (Sarstedt et al., 2017).

Initially, the indicators FOM5, FOM6, and TRU2 were removed because their loadings were 0.135, 0.330, and 0.161, respectively. As these indicators did not meet the minimum threshold of 0.40, they contributed insufficiently to the construct's explained variance. Additionally, the indicator FOM1 (loading 0.413) was also eliminated due to its low Cronbach's alpha value. For the construct Trust, the AVE value remained below 0.50, which necessitated the removal of an additional indicator with the lowest loading: TRU1 (loading 0.505). To enhance the model's Composite Reliability, the indicator QLS1 (loading 0.457) was also removed. By sequentially discarding items, the measurement model's internal consistency and convergent validity were strengthened.

After confirming the reliability of individual indicators, the internal consistency of the constructs was assessed using three metrics: Composite Reliability (ρ_c), Cronbach's Alpha (α), and the reliability coefficient (ρ_A). In PLS-SEM analysis, Composite Reliability is a key and widely accepted metric; the higher its value, the greater the construct's reliability. It is accepted that in exploratory research, ρ_c values between 0.60 and 0.70 are permissible, while those from 0.70 to 0.95 are considered indicative of a high-quality model. Indicator Reliability values were derived from the squared indicator loadings. The loadings for the indicators, Indicator Reliability, as well as Cronbach's alpha, ρ_A (rho_A), Composite reliability ρ_c, and AVE for the variables are presented in Table 3.

Table 3.
Assessment of measurement models using PLS-SEM

Variable	Indicators	Convergent validity			Internal consistency reliability		
		Loading	Indicator reliability	Cronbach's alpha	ρA (rho_A)	Composite reliability ρc	AVE
		>.70	>.50	.70–.95	>.70	>.70	>.50
Environmental awareness	EAW1	.801	.641	.852	.852	0.900	.693
	EAW2	.856	.732				
	EAW3	.845	.714				
	EAW4	.826	.683				
Form of Message	FOM2	.770	.592	.787	.804	0.875	.702
	FOM3	.870	.756				
	FOM4	.870	.756				
Intention to use	ITU1	.930	.865	.917	.917	0.948	.858
	ITU2	.925	.856				
	ITU3	.924	.853				
Satisfaction	SAT1	.795	.632	.883	.884	0.928	.811
	SAT2	.885	.783				
	SAT3	.827	.684				
Service quality	QLS2	.903	.815	.785	.796	0.874	.699
	QLS3	.900	.810				
	QLS4	.899	.808				
Trust	TRU3	.609	.371	.577	.715	0.749	.506
	TRU4	.619	.384				
	TRU5	.874	.765				

To properly assess discriminant validity in the PLS-SEM framework, the Heterotrait–Monotrait Ratio of Correlations (HTMT) is the preferred criterion (Henseler et al., 2015). The recommended threshold to confirm discriminant validity is 0.90 (particularly for conceptually similar constructs), though a stricter 0.85 is advised when constructs are distinctly different. The results, displayed in Table 4, show that all construct pairings, with the exception of the Service Quality - Satisfaction pair, exhibit HTMT values below 0.90. This collectively indicates that the model achieves an acceptable level of discriminant validity.

Table 4.
Heterotrait–monotrait ratio (HTMT) values

	EAW	FOM	ITU	SAT	QLS	TRU
Environmental awareness (EAW)						
Form of message (FOM)	0,620					
Intention to use (ITU)	0,876	0,626				
Satisfaction (SAT)	0,802	0,637	0,859			
Service Quality (QLS)	0,756	0,634	0,855	0,965		
Trust (TRU)	0,654	0,783	0,685	0,695	0,724	

Table 5.
Results of the significance tests and the path coefficient of the structural model

Hypothesis	Path	Coefficient	Effect size (f2)	Significant (p <0.05)?
H1	Service Quality (QLS) → Satisfaction (SAT)	.721	1.194	Yes (0.00)
H2	Satisfaction (SAT) → Intention to use (ITU)	.426	.297	Yes (0.00)
H3	Ecological Awareness (EAW) → Intention to use (ITU)	.434	.319	Yes (0.00)
H4	Ecological Awareness (EAW) → Service Quality (QLS)	.436	.236	Yes (0.00)
H5	Trust (TRU) → Ecological Awareness (EAW)	.523	.377	Yes (0.00)
H6	Trust (TRU) → Service quality (QLS)	.352	.172	Yes (0.00)
H7(1)	Service quality (QLS) → Form of Message (FOM)	.301	.082	Yes (0.00)
H7(2)	Form of Message (FOM) → Intention to use (ITU)	.085	.017	Yes (0.00)
H8(1)	Ecological Awareness (EAW) → Form of Message (FOM)	.327	.097	Yes (0.00)
H8(2)	Form of Message (FOM) → Satisfaction (SAT)	.172	.068	Yes (0.00)

As indicated in Table 5, the findings for the path coefficients demonstrate that all hypotheses tested reached statistical significance at the 5% error margin. However, the f^2 values for H7 (1&2) and H8 (1&2) do not exceed the 0.15 threshold, suggesting a relatively low effect size. Among the tested relationships, the paths corresponding to H1 and H5 exhibit the highest significance, with path coefficient values exceeding 0.5.

Figure 2 presents the results of the PLS-SEM analysis, illustrating the standardized regression coefficients that define the relationships between the variables, while R^2 values are displayed within the circles.

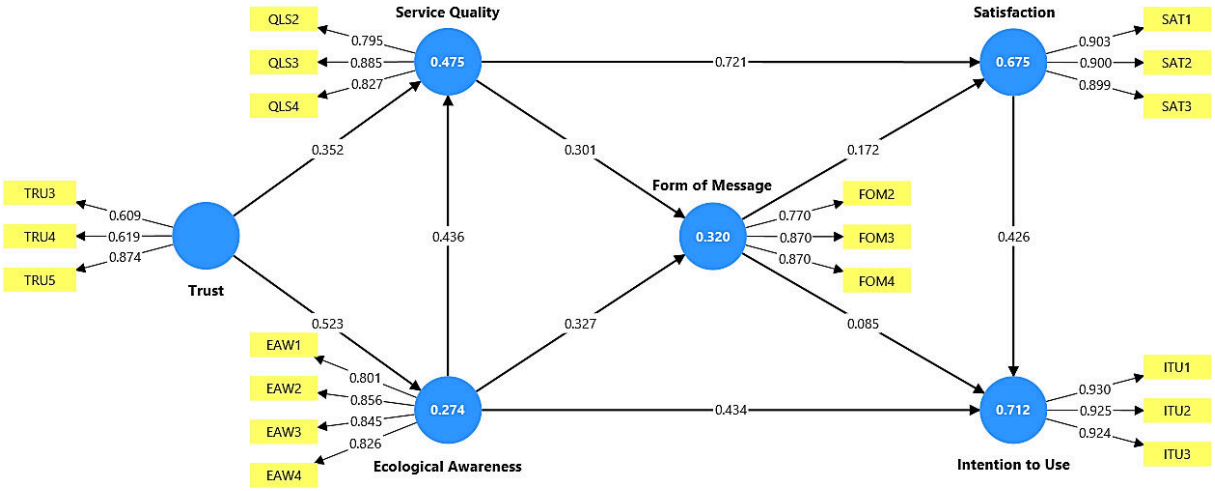


Figure 2. A conceptual acceptance model for sustainability communication – final results.

Mediation of the Form of Message (FOM) construct was intentionally tested within hypotheses H7 and H8, necessitating the use of the bootstrapping method to assess the statistical significance of the indirect effects. Bootstrapping is the dominant and recommended approach for testing mediation in PLS-SEM analysis. This method allows for the estimation of the statistical significance of the indirect effect without requiring the fulfillment of strict assumptions regarding data normality (Henseler et al., 2015).

The Indirect Effect for Hypothesis H7 is the product of the path coefficients of H7(1) and H7(2), while the Indirect Effect for Hypothesis H8 is the product of the path coefficients of H8(1) and H8(2):

$$H7 = QLS \rightarrow FOM * FOM \rightarrow ITU = 0.301 * 0.085 = 0.0256$$

$$H8 = EAW \rightarrow FOM * FOM \rightarrow SAT = 0.327 * 0.172 = 0.0562$$

For Hypothesis H7, the indirect effect is positive (0.0256), indicating that Service Quality (QLS) positively influences Intention to Use (ITU), and this influence is partially transmitted through the Form of Message (FOM). Since both the indirect effect and the direct effects are statistically significant, FOM acts as a partial mediator. However, the magnitude of the indirect effect is very small, suggesting that FOM's role as a mediator in this relationship is marginal. An increase in Service Quality (QLS) leads to a better Form of Message (FOM), which, in turn, only slightly increases Intention to Use (ITU).

For Hypothesis H8, the indirect effect is positive (0.0562), meaning that Ecological Awareness (EAW) positively influences Satisfaction (SAT), and this relationship is partially transmitted through the Form of Message (FOM). As both the indirect effect and the direct effect are statistically significant, it can be concluded that the Form of Message (FOM) construct acts as a positive mediator in the relationship between EAW and SAT. Higher Ecological Awareness leads to a better-perceived Form of Message, which results in higher consumer Satisfaction. Although the magnitude of this effect is also small, the Form of Message (FOM) exhibits a stronger mediating role in the context of Ecological Awareness than in that of Service Quality (QLS).

5. Discussion

This article proposes and verifies a model determining the factors that influence the acceptance of sustainable development communication disseminated by tourism accommodation providers among GZM residents. The literature has identified many reasons why communicating activities related to sustainable development and CSR is not a common phenomenon in the hospitality industry. The most frequently indicated factors include low consumer awareness (Santos et al., 2019), difficulty in formulating messages (Tölkes, 2018), the conflict of the sustainable development concept with the nature of tourism services (Font et al., 2018), and a low level of trust (Sun et al., 2021). Therefore, these most frequently cited reasons were incorporated into the model in this paper.

As a result of the model analysis, all formulated hypotheses were confirmed, although the best results were achieved for H1 (path coefficient 0.721) and H5 (0.523). The high result obtained for H1 is not surprising. The fact that Service Quality, both within and outside the tourism industry, positively influences satisfaction levels has been repeatedly proven (Geebren et al., 2021; Sharma, Sharma, 2019). In this study, however, respondents were asked, among other things, whether they had ever felt limitations when choosing an accommodation that implemented and communicated its sustainability initiatives, whether lodging facilities that communicate their sustainability initiatives meet their needs, and whether, in their opinion, lodging facilities that communicate their sustainability initiatives offer more services. In the context of Satisfaction, respondents were asked, among others, whether they are satisfied with the services of lodging facilities that communicate their sustainability initiatives, whether lodging facilities that communicate their commitment to sustainability meet their expectations, and whether they feel that choosing lodging facilities that implement sustainability initiatives is a good decision, and they would recommend them to others. This study confirmed that Service Quality positively influences Satisfaction in the context of communicating about sustainable development in the offer. It can be inferred that consumers do not perceive a deterioration in the quality of services provided by facilities that implement sustainable development and CSR principles, which is often suggested by researchers as a potential concern (Choudhary, Gokarn, 2013; Clark et al., 2021). Instead of negatively impacting their satisfaction, the effect is quite the opposite.

It was also confirmed that Trust has a significant, positive influence on Ecological Awareness. In the context of Trust, respondents were asked whether, when choosing tourist facilities, they rely on opinions about them, whether they pay attention to whether the facility responds to negative reviews, and whether they trust that facilities communicating about sustainable initiatives have sincere pro-environmental intentions. In the context of ecological awareness, they were asked whether they consider the consequences of their actions, whether they worry about the waste of the planet’s resources, whether they would describe themselves

as environmentally responsible individuals, and whether they are willing to endure inconveniences to take more environmentally friendly actions. Trust also has a positive influence on perceptions of service quality. Ecological Awareness likewise has a positive impact on perceptions of Service Quality, as consumers understand the reasons behind the actions taken by the facilities. Furthermore, it positively affects Intention to Use the services of a facility that communicates about its sustainable activities.

Based on the analysis results, it can be stated that trust in a tourist facility and its environmental intentions may lead to an increase in ecological awareness and a willingness to engage in sustainable initiatives proposed by the facility. This confirms the importance of transparency and sincerity in facility communication (Cheunkamon et al., 2022). Consistent with prior studies in fields ranging from fashion (Chen et al., 2022; Liu, He, 2025) to HoReCa (Kapoor et al., 2021; Xu, Jeong, 2019), this research demonstrates that communication acts as a positive mediator for service acceptance. Although the observed mediation effect is small, it reaffirms that sustainability-related messaging remains a valid tool for shaping consumer intentions. However, the form of the message is of paramount importance. The impact of communication varies significantly depending on whether it emphasizes gains or losses (Chen et al., 2022), highlights specific benefits (Xu, Jeong, 2019), or is perceived as generally attractive in its presentation (Kapoor et al., 2021). However, this study did not analyze whether different messages produce different mediating effects.

6. Conclusions

This study, conducted on a representative sample of GZM residents, yields interesting results that indicate no justification for the fears of tourism facilities regarding communicating their sustainable actions. It should be noted here that the Silesian Voivodeship has been the industrial center of Poland for many years, owing its development primarily to coal mines. Therefore, residents of this voivodeship, who are strongly linked to heavy industry and mining, might be potentially negatively disposed toward the concept of sustainable development. Due to the introduction of regulations aimed at achieving sustainable development goals, mines and steel mills are being closed. This means residents of this region must undergo professional reorientation. Mines in GZM are not only workplaces but also a major factor shaping the regional culture, which is largely drawn from mining traditions. It is important to highlight that while the regional context of mining and industrial identity was discussed to provide a broader perspective for interpreting the findings, these aspects were not included as empirical variables in the current model.

Nevertheless, the positive attitude of the region's residents toward such initiatives undertaken by tourism facilities indicates that they are increasingly understanding the need for these actions. However, it is important to them that the actions undertaken have sincere intentions, and they are even willing to endure inconveniences associated with the facilities' sustainable activities. The greater their ecological awareness, the greater their satisfaction, and they do not believe that sustainable actions negatively impact service quality.

This study confirms that communication acts as a small but positive mediator between ecological awareness, satisfaction, service quality, and the intention to use the service. While the small effect sizes of the message form suggest that its influence is secondary to more dominant factors—specifically service quality and trust—it remains a relevant consideration. To achieve the most substantial gains in user acceptance, tourism facilities should prioritize enhancing service quality while communicating their actions in a non-aggressive way that raises awareness and offers opportunities for value co-creation. These insights are valuable for both regional authorities, highlighting the need for further resident education, and tourism facility owners, who should not hesitate to showcase their commitment.

6.1. Limitations and Future Research

A deliberate limitation of this study was the examination of residents exclusively from the Silesian Voivodeship. Analyzing the profiles of individuals with varying attitudes could also provide interesting results. Furthermore, the current research did not include empirical indicators for individual ties to the mining industry, which represents a limitation; future studies could address this by using these factors as potential moderators or predictors in the model. The application of the PLS-SEM method allows for trend prediction but does not provide specific answers that could be delivered by, for instance, cluster analysis of respondents or regression analysis (or moderated regression analysis). Future research plans include both analyzing a representative sample from across the country and consumer segmentation to obtain more concrete guidance on factors influencing the acceptance of communication about sustainable development activities conducted by tourism accommodation providers.

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References

1. Adanlawo, E.F., Chaka, M. (2021). CSR Reporting: A Tool For Organisational Image, Reputation And Financial Improvement. *Webology*, *18*(6), 1131-1142. https://www.researchgate.net/publication/359820784_Csr_Reporting_A_Tool_For_Organisational_Image_Reputation_And_Financial_Improvement
2. Adanlawo, E.F., Chaka, M. (2025). Does Going Digital Matter In Communicating Corporate Social Responsibility To The Public? A Systematic Review Approach. *Journal of Ecohumanism*, *4*(4). https://doi.org/10.62754/joe.v4i4.6835
3. Amatulli, C., De Angelis, M., Stoppani, A. (2021). The appeal of sustainability in luxury hospitality: An investigation on the role of perceived integrity. *Tourism Management*, *83*, 104228. https://doi.org/10.1016/j.tourman.2020.104228
4. Asante Boadi, E., He, Z., Bosompem, J., Say, J., Boadi, E.K. (2019). Let the Talk Count: Attributes of Stakeholder Engagement, Trust, Perceive Environmental Protection and CSR. *SAGE Open*, *9*(1). https://doi.org/10.1177/2158244019825920
5. Bedenik, N.O., Strugar, I., Prebežac, D., Kojić, V. (2020). Quantitative and Qualitative Aspects of Non-financial Reporting in Hotel Enterprises in Croatia. *Eurasian Studies in Business and Economics*, *13*(1), 359-385. https://doi.org/10.1007/978-3-030-40375-1_25
6. Bilgihan, A. (2016). Gen Y customer loyalty in online shopping: An integrated model of trust, user experience and branding. *Computers in Human Behavior*, *61*, 103-113. https://doi.org/10.1016/J.CHB.2016.03.014
7. Booking Holdings (2020). *Sustainability Report 2020*. https://www.bookingholdings.com/wp-content/uploads/2021/03/BKNG-Sustainability-Report-2020-.pdf
8. Bordian, M., Gil-Saura, I. (2021). Do IMC and Ecological Knowledge Drive Value Co-Creation? The New Way to Loyalty in Hospitality. *Sustainability, 13*(19), 10785. https://doi.org/10.3390/SU131910785
9. Buckley, R. (2012). Sustainable tourism: Research and reality. *Annals of Tourism Research*, *39*(2), 528-546. https://doi.org/10.1016/j.annals.2012.02.003
10. Bujalski, R. (2024). *Dyrektywa o sprawozdawczości w zakresie zrównoważonego rozwoju (CSRD), czyli nowe obowiązki przedsiębiorstw w zakresie ESG*. LEX Prawo Europejskie. https://www.lex.pl/raportowanie-esg-dyrektywa-csrd,21697.html
11. Carlos, W.C., Lewis, B.W. (2018). Strategic Silence: Withholding Certification Status as a Hypocrisy Avoidance Tactic. *Administrative Science Quarterly*, *63*(1), 130-169. https://doi.org/10.1177/0001839217695089

12. Cembruch-Nowakowski, M. (2019). Green Hotels – Exception or Norm? *Studies of the Industrial Geography Commission of the Polish Geographical Society*, *33*(3). https://doi.org/10.24917/20801653.333.11
13. Chen, L., He, L., Yan, X., Liu, C. (2022). Green Message Framing in Enhancing Sustainable Consumption Behavior of Fashion Based on the Cross-Theoretical Model. *Journal of Environmental and Public Health*, *1*. https://doi.org/10.1155/2022/4038992
14. Cheunkamon, E., Jomnonkwao, S., Ratanavaraha, V. (2022). Impacts of Tourist Loyalty on Service Providers: Examining the Role of the Service Quality of Tourism Supply Chains, Tourism Logistics, Commitment, Satisfaction, and Trust. *Journal of Quality Assurance in Hospitality and Tourism*, *23*(6), 1397-1429. https://doi.org/10.1080/1528008X.2021.1995564
15. Choudhary, A., Gokarn, S. (2013). Green Marketing: A means for sustainable development. *International Refereed Research Journal*, *IV*(3).
16. Clark, M., Kang, B., Calhoun, J.R. (2021). Green meets social media: young travelers' perceptions of hotel environmental sustainability. *Journal of Hospitality and Tourism Insights*, https://doi.org/10.1108/JHTI-03-2021-0062
17. Cornelissen, G., Pandelaere, M., Warlop, L., Dewitte, S. (2006). Positive Cueing: Promoting Sustainable Consumer Behavior By Cueing Common Environmental Behaviors as Environmental. *SSRN Electronic Journal*, *4*(4), 278-288. https://doi.org/10.2139/ssrn.944391
18. Curşeu, P.L., Schruijer, S.G.L. (2010). Does conflict shatter trust or does trust obliterate conflict? Revisiting the relationships between team diversity, conflict, and trust. *Group Dynamics*, *14*(1), 66-79. https://doi.org/10.1037/A0017104
19. Czakon, P., Jarczewski, W. (2023). Funkcjonowanie Górnośląsko-Zagłębiowskiej Metropolii (GZM) na tle rozwiązań europejskich. *Badania Obserwatorium Polityki Miejskiej, Instytut Rozwoju Miast i Regionów,* https://doi.org/10.51733/opm.2023.09
20. Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly: Management Information Systems*, *13*(3), 319-339. https://doi.org/10.2307/249008
21. Deni Saputra, M., Hanutama, P. (2025). CSR as a Corporate Communication Strategy: An Analysis of Public Perception. *Jurnal Sosial Dan Sains*, *5*(3), 365-386. https://doi.org/10.59188/jurnalsosains.v5i3.32079
22. Dozier, D.M., Grunig, L.A., Grunig, J.E. (2013). Manager's Guide to Excellence in Public Relations and Communication Management. In: *Manager's Guide to Excellence in Public Relations and Communication Management*. Routledge. https://doi.org/10.4324/9780203811818
23. Drzewiecki, P., Kazimierczak, J. (2014). Inwestycje hotelarskie na terenach poprzemysłowych jako element przekształceń przestrzeni publicznej miast. Studium przypadku: In: P. Aniśkiewicz, J. Smutek (Eds.), *Współczesne aspekty badań przestrzeni*

geograficznej. Studia przypadków. Tom 1 (pp. 111-122). Wydawnictwo Uniwersytetu Szczecińskiego. https://open.icm.edu.pl/handle/123456789/16894

24. Etter, M. (2014). Broadcasting, reacting, engaging – three strategies for CSR communication in Twitter. *Journal of Communication Management*, *18*(4), 322-342. https://doi.org/10.1108/JCOM-01-2013-0007
25. Ettinger, A., Grabner-Kräuter, S., Okazaki, S., Terlutter, R. (2021). The Desirability of CSR Communication versus Greenhushing in the Hospitality Industry: The Customers' Perspective. *Journal of Travel Research*, *60*(3), 618-638. https://doi.org/10.1177/0047287520930087
26. Featherman, M.S., Pavlou, P.A. (2003). Predicting e-services adoption: a perceived risk facets perspective. *International Journal of Human-Computer Studies*, *59*(4), 451-474. https://doi.org/10.1016/S1071-5819(03)00111-3
27. Fernández Robin, C., Cea Valencia, J., Jamett Muñoz, G., Santander Astorga, P., Yáñez Martínez, D. (2016). Attitude and Behavior on Hotel Choice in Function of the Perception of Sustainable Practices. *Tourism & Management Studies*, *12*(1), 60-66. https://doi.org/10.18089/tms.2016.12106
28. Font, X., Elgammal, I., Lamond, I. (2017). Greenhushing: the deliberate under communicating of sustainability practices by tourism businesses. *Journal of Sustainable Tourism*, *25*(7), 1007-1023. https://doi.org/10.1080/09669582.2016.1158829
29. Font, X., English, R., Gkritzali, A. (2018). Mainstreaming sustainable tourism with user-centred design. *Journal of Sustainable Tourism*, *26*(10), 1651-1667. https://doi.org/10.1080/09669582.2018.1491981
30. Font, X., McCabe, S. (2017). Sustainability and marketing in tourism: its contexts, paradoxes, approaches, challenges and potential. *Journal of Sustainable Tourism*, *25*(7), 869-883. https://doi.org/10.1080/09669582.2017.1301721
31. Gaspar Ferreira, A., Fernandes, M.E. (2022). Sustainable advertising or ecolabels: Which is the best for your brand and for consumers' environmental consciousness? *Journal of Marketing Theory and Practice*, *30*(1), 20-36. https://doi.org/10.1080/10696679.2021.1882864
32. Gawroński, G., Kłoskowicz, M., Stawowa, A., Wycisk, A., Zygmunt, A. (2010). Metropolia w świetle opinii mieszkańców Górnośląskiego Związku Metropolitalnego. In: R. Pyka (Ed.), *Sposób na Metropolię. Idee a społeczne oczekiwania wobec projektu utworzenia śląsko-zagłębiowskiej metropolii* (pp. 56-58). Urząd Miasta Katowice.
33. Geebren, A., Jabbar, A., Luo, M. (2021). Examining the role of consumer satisfaction within mobile eco-systems: Evidence from mobile banking services. *Computers in Human Behavior*, *114*, 106584. https://doi.org/10.1016/j.chb.2020.106584
34. Ghanem, M., Elgammal, I. (2017). Communicating sustainability through a destination's website: a checklist to inform, motivate, and engage stakeholders. *Journal of Travel & Tourism Marketing*, *34*(6), 793-805. https://doi.org/10.1080/10548408.2016.1233928

35. Ginder, W., Kwon, W.-S., Byun, S.-E. (2021). Effects of Internal–External Congruence-Based CSR Positioning: An Attribution Theory Approach. *Journal of Business Ethics*, *169*(2), 355-369. https://doi.org/10.1007/s10551-019-04282-w
36. Główny Urząd Statystyczny (2025). *Turystyczna baza noclegowa i jej wykorzystanie w 1 półroczu 2025 r.* https://stat.gov.pl/obszary-tematyczne/kultura-turystyka-sport/turystyka/turystyczna-baza-noclegowa-i-jej-wykorzystanie-w-1-polroczu-2025-r-,4,22.html
37. Goldstein, N.J., Cialdini, R.B., Griskevicius, V. (2008). A Room with a Viewpoint: Using Social Norms to Motivate Environmental Conservation in Hotels. *Journal of Consumer Research*, *35*(3), 472-482. https://doi.org/10.1086/586910
38. Hair, J.F., Hult, G.T.M., Ringle, C., Sarstedt, M. (2022). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)* (3rd ed.). Thousand Oaks: Sage.
39. Hair, J.F., Ringle, C.M., Sarstedt, M. (2013). Partial Least Squares Structural Equation Modeling: Rigorous Applications, Better Results and Higher Acceptance. *Long Range Planning*, *46*(1-2), 1-12. https://doi.org/10.1016/j.lrp.2013.01.001
40. Han, J., Zuo, Y., Law, R., Chen, S., Zhang, M. (2021). Service Quality in Tourism Public Health: Trust, Satisfaction, and Loyalty. *Frontiers in Psychology*, *12*, 731279. https://doi.org/10.3389/FPSYG.2021.731279/FULL-SUPPLEMENTARY-MATERIAL
41. Hartmann, P., Apaolaza Ibáñez, V. (2006). Green value added. *Marketing Intelligence & Planning*, *24*(7), 673-680. https://doi.org/10.1108/02634500610711842
42. 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. https://doi.org/10.1007/s11747-014-0403-8
43. Higgins-Desbiolles, F. (2018). Sustainable tourism: Sustaining tourism or something more? *Tourism Management Perspectives*, *25*, 157-160. https://doi.org/10.1016/j.tmp.2017.11.017
44. Jansen, L., Cunningham, P., Diehl, S., Terlutter, R. (2024). Corporate social responsibility in controversial industries: A literature review and research agenda. *Corporate Social Responsibility and Environmental Management*, *31*(5), 4398-4427. https://doi.org/10.1002/csr.2813
45. Kachniewska, M. (2018). Circular Economy in The Opinions of Small- and Medium-sized Hotel Enterprises. *Folia Turistica*, *48*, 185-208. https://doi.org/10.5604/01.3001.0012.7698
46. Kapoor, P.S., Balaji, M.S., Jiang, Y. (2021). Effectiveness of sustainability communication on social media: role of message appeal and message source. *International Journal of Contemporary Hospitality Management*, *33*(3), 949-972. https://doi.org/10.1108/IJCHM-09-2020-0974
47. Kock, N. (2018). Minimum sample size estimation in PLS-SEM: An application in tourism and hospitality research. *Applying Partial Least Squares in Tourism and Hospitality Research*, 1-16. https://doi.org/10.1108/978-1-78756-699-620181001/FULL/XML

48. Kotler, P. (2005). *Marketing* (I). Dom Wydawniczy Rebis.
49. Kowalska, M. (2020). SME Managers' Perceptions of Sustainable Marketing Mix in Different Socioeconomic Conditions—A Comparative Analysis of Sri Lanka and Poland. *Sustainability*, *12*(24), 10659. https://doi.org/10.3390/su122410659
50. Kronrod, A., Grinstein, A., Wathieu, L. (2012). Go Green! Should Environmental Messages be So Assertive? *Journal of Marketing*, *76*(1), 95-102. https://doi.org/10.1509/jm.10.0416
51. Lin, J., Zheng, Q., Benitez, J. (2024). Impact of digital orientation and corporate social responsibility activities on the alliance relationship stability in contract farming. *Information & Management*, *61*(4), 103958. https://doi.org/10.1016/j.im.2024.103958
52. Liu, C., He, L. (2025). Green messaging strategies: shaping green consumption behavior in fashion retail. *International Journal of Retail & Distribution Management*, 1-17. https://doi.org/10.1108/IJRDM-09-2024-0447
53. Malone, S., McCabe, S., Smith, A.P. (2014). The role of hedonism in ethical tourism. *Annals of Tourism Research*, *44*(1), 241-254. https://doi.org/10.1016/j.annals.2013.10.005
54. Martin, D.M., Schouten, J.W. (2014). Sustainable Marketing through the Natural Step. In: R. Varey, M. Pirson (Eds.), *Humanistic Marketing* (pp. 231-243). Palgrave Macmillan.
55. Ministerstwo Funduszy i Polityki Regionalnej (2024). *Dyrektywa w sprawie należytej staranności przedsiębiorstw w zakresie zrównoważonego rozwoju - Ministerstwo Funduszy i Polityki Regionalnej - Portal Gov.pl*. https://www.gov.pl/web/fundusze-regiony/dyrektywa-w-sprawie-nalezytej-starannosci
56. Miranda, D.D., Briley, D. (2021). Digital tourist: Variables that define their purchasing behaviour. *Investigaciones Turisticas*, *21*, 1-21. https://doi.org/10.14198/INTURI 2021.21.1
57. Moyle, C., Moyle, B., Ruhanen, L., Bec, A., Weiler, B. (2018). Business Sustainability: How Does Tourism Compare? *Sustainability*, *10*(4), 968. https://doi.org/10.3390/ su10040968
58. Oliver, R.L. (1977). Effect of expectation and disconfirmation on postexposure product evaluations: An alternative interpretation. *Journal of Applied Psychology*, *62*(4), 480-486. https://doi.org/10.1037/0021-9010.62.4.480
59. Oliver, R.L. (1980). A Cognitive Model of the Antecedents and Consequences of Satisfaction Decisions. *Journal of Marketing Research*, *17*(4), 460-469. https://doi.org/10.1177/002224378001700405
60. Pérez-Villalba, M., Fernández-Gavira, J., Caballero Blanco, P. (2017). The CSR concept presence in Andalusian active tourism websites and its value to schools centers. *Espiral. Cuadernos del Profesorado*, *10*(21), 118-125. https://doi.org/10.25115/ECP.V10I21.1035
61. Pérez, A., Del Bosque, I.R. (2015). Corporate social responsibility communication in the Spanish hospitality sector. *Cuadernos de Turismo*, *36*. https://doi.org/10.6018/ TURISMO.36.231031
62. Prendergast, G., Ko, D., Yuen, S.Y.V. (2015). Online word of mouth and consumer

purchase intentions. *International Journal of Advertising*, *29*(5), 687-708. https://doi.org/10.2501/S0265048710201427

63. Rabadán-Martín, I., Aguado-Correa, F., Padilla-Garrido, N. (2019). Facing new challenges in rural tourism: signaling quality via website. *Information Technology & Tourism*, *21*(4), 559-576. https://doi.org/10.1007/s40558-019-00157-y
64. Rutecka, P. (2023). *Sustainable development of the Polish agritourism enterprises [Zrównoważony rozwój polskich przedsiębiorstw agroturystycznych]*. University of Economics in Katowice. https://bip.ue.katowice.pl/fileadmin/user_upload/jednostki/komitety-naukowe/doktoraty/rutecka/Rozprawa-doktorska-Paulina-Rutecka.pdf
65. Santos, M.C., Veiga, C., Águas, P., Santos, J.A.C. (2019). Sustainability communication in hospitality in peripheral tourist destinations. *Worldwide Hospitality and Tourism Themes*, *11*(6), 660-676. https://doi.org/10.1108/WHATT-08-2019-0049
66. Sarstedt, M., Ringle, C.M., Hair, J.F. (2017). Partial Least Squares Structural Equation Modeling. *Handbook of Market Research, Iss. January*. Springer International Publishing, pp. 1-40, https://doi.org/10.1007/978-3-319-05542-8_15-1
67. Schuitema, G., Anable, J., Skippon, S., Kinnear, N. (2013). The role of instrumental, hedonic and symbolic attributes in the intention to adopt electric vehicles. *Transportation Research Part A: Policy and Practice*, *48*, 39-49. https://doi.org/10.1016/J.TRA.2012.10.004
68. Scott, D.M. (2011). *Real-Time Marketing and PR: How to Instantly Engage Your Market, Connect with Customers, and Create Products that Grow Your Business Now*. Wiley.
69. Sharma, S.K., Sharma, M. (2019). Examining the role of trust and quality dimensions in the actual usage of mobile banking services: An empirical investigation. *International Journal of Information Management*, *44*, 65-75. https://doi.org/10.1016/j.ijinfomgt.2018.09.013
70. Sharpley, R. (2009). *Tourism, Environment and Development Series Tourism Development and the Environment: Beyond Sustainability?* Earthscan.
71. Strzelecki, A. (2023). To use or not to use ChatGPT in higher education? A study of students' acceptance and use of technology. *Interactive Learning Environments*, 1-14. https://doi.org/10.1080/10494820.2023.2209881
72. Sun, B., Liu, L.Y., Chan, W.W., Zhang, C.X., Chen, X. (2021). Signals of Hotel Effort on Enhancing IAQ and Booking Intention: Effect of Customer's Body Mass Index Associated with Sustainable Marketing in Tourism. *Sustainability*, *13*(3), 1279. https://doi.org/10.3390/su13031279
73. Tiago, F., Gil, A., Stemberger, S., Borges-Tiago, T. (2021). Digital sustainability communication in tourism. *Journal of Innovation & Knowledge*, *6*(1), 27-34. https://doi.org/10.1016/j.jik.2019.12.002
74. Tölkes, C. (2018). Sustainability communication in tourism – A literature review. *Tourism Management Perspectives*, *27*, 10-21. https://doi.org/10.1016/j.tmp.2018.04.002
75. Treen, K.M. d'I., Williams, H.T.P., O'Neill, S.J. (2020). Online misinformation about

climate change. *WIREs Climate Change*, *11*(5). https://doi.org/10.1002/wcc.665

76. Wang, Y., Wang, S., Wang, J., Wei, J., Wang, C. (2020). An empirical study of consumers' intention to use ride-sharing services: using an extended technology acceptance model. *Transportation*, *47*(1), 397-415. https://doi.org/10.1007/s11116-018-9893-4
77. World Economic Forum, & University of Surrey (2024). *Travel & Tourism Development Index 2024*. https://www.weforum.org/publications/travel-tourism-development-index-2024/
78. Xu, Y., Jeong, E. (2019). The effect of message framings and green practices on customers' attitudes and behavior intentions toward green restaurants. *International Journal of Contemporary Hospitality Management*, *31*(6), 2270-2296. https://doi.org/10.1108/IJCHM-05-2018-0386
79. Zeqiraj, V., Nimani, A. (2022). Impact Of the Quality of Hospitality Services on Customer Satisfaction – Kosovo Case Study. *Quality - Access to Success*, *23*(186), 104-110. https://doi.org/10.47750/QAS/23.186.14
80. Zhang, Y., Xu, J., Jiang, Z., Huang, S.-C. (2011). Been There, Done That: The Impact of Effort Investment on Goal Value and Consumer Motivation. *Journal of Consumer Research*, *38*(1), 78-93. https://doi.org/10.1086/657605

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SOURCES OF STARTUP FINANCING IN POLAND: MARKET ANALYSIS AND OPTIMAL FINANCING PATH MODEL

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Purpose: The purpose of this article is to analyze the sources of startup financing in Poland and to identify the factors that shape access to capital at different stages of development. The paper synthesizes findings from academic research and industry reports and presents a model of an optimal financing pathway tailored to the Polish startup ecosystem.
Design/methodology/approach: The study applies literature analysis, comparison of data from industry reports (*Startupy w Polsce*, *Rynek Akceleracji*, *Transakcje VC*), and information from European grant programs and the GSER. The approach includes classification of financing instruments, systemic analysis of the market and modelling of startup development stages.
Findings: The study applies literature analysis, comparison of data from industry reports (*Startupy w Polsce*, *Rynek Akceleracji*, *Transakcje VC*), and information from European grant programs and the GSER. The approach includes classification of financing instruments, systemic analysis of the market and modelling of startup development stages.
Research limitations/implications: The main limitations arise from the lack of a unified system for monitoring the startup financing market in Poland and methodological inconsistencies across reports. Further empirical studies are needed.
Practical implications: The proposed model can support founders, investors and public institutions in selecting appropriate financing instruments and designing support programs.
Originality/value: The article integrates dispersed data and proposes a coherent model of startup financing in Poland, offering value for practitioners, policymakers and researchers.
Keywords: startup financing; venture capital; grants; quasi-debt instruments; acceleration.
Category of the paper: Research paper.

1. Introduction

Start-ups are one of the key elements of modern knowledge-based economies, contributing to innovation, productivity growth and the diffusion of new technologies. The literature on the subject emphasises that the ability of start-ups to survive and scale up their operations largely depends on access to appropriately selected sources of financing, especially in the early stages of development (e.g. Salazar, 2021; Zhou et al., 2023; Ström et al., 2025; Indrawati, Suarman,

2020). Despite the dynamic development of the start-up ecosystem in Poland over the last decade, raising capital remains one of the most significant challenges for young companies, as confirmed by both scientific research (e.g. Michalczyk, 2022; Gemzlik-Slawach, Petrz, 2023) and industry reports (PFR, 2024; Startup Poland, 2022, 2023, 2024).

Previous studies have focused mainly on selected financing instruments (e.g. venture capital, business angels or public grants), while less frequently attempting to provide a comprehensive overview of the structure of start-up financing in the Polish economy. There is also a lack of consistent models showing the sequential matching of financing sources to the stages of startup development, taking into account the specifics of the domestic ecosystem and the role of public and hybrid instruments.

The aim of this article is to analyze the sources of financing for startups in Poland and to identify the factors influencing access to capital at different stages business development. The article is synthetic and conceptual in nature – it integrates the results of scientific research, data from industry reports and information on public and EU programmes, and then proposes an original model of the optimal path for financing a start-up in Polish conditions.

The article uses a literature review, a comparative analysis of secondary data from industry reports, and a systemic analysis of the start-up financing market. On this basis, the following research hypotheses were formulated and verified:

H1: In the early stages of startup development in Poland, domestic sources of financing, in particular bootstrapping and public grants, play a dominant role.

H2: The importance of hybrid and quasi-debt instruments increases as startups move into the growth and scaling phase.

H3: Effective startup development requires sequential matching of funding sources to the stage of development and risk profile of the enterprise.

The novelty of the article lies in the integration of scattered empirical and conceptual data and in proposing a funding path model that can serve as a reference point for both practitioners and further scientific research on startup financing in Poland.

2. Literature review

2.1. Startup Financing Conditions in Poland The Concept of Social Innovation

Startup financing in Poland is developing within a diverse yet still maturing ecosystem (Michalczyk, 2020). Its development is influenced by factors such as:

- the availability of public capital (PARP programs, NCBR, PFR Ventures funds),
- the increased number of privately and hybrid financed seed and venture capital funds,
- the growing interest of business angel investors,

- the development of alternative financing sources, such as equity crowdfunding (Leoński, 2023),
- the internationalization of Polish startups and their expansion into foreign markets,
- the increased importance of organizational resources, team competencies, and network relationships.

These conditions create a mosaic of opportunities that, if properly utilized, enable startups to progress from the initial idea phase to scaling their operations and securing subsequent rounds of financing.

2.2. Key Sources of Startup Financing

Innovation and finance are closely intertwined drivers of economic growth and structural change. Innovation generates new products, services and industries, while finance allocates capital to high‑potential projects, enabling firms to transform ideas into marketable solutions. This interdependence is particularly salient in the startup sector, where innovative concepts typically require substantial upfront investment to be developed, validated and scaled. Consequently, financial strategies constitute a critical determinant of how startups navigate a complex and often unpredictable business environment (Bu et al., 2024).

Financing is a key element in their ability to enter the market, scale their operations, and build a competitive advantage. Due to high uncertainty, lack of credit history, and limited assets, startups face significant "financing gaps", which often make traditional forms of capital unavailable or insufficient. The literature (e.g. Narwal, 2023; Čalopa et al., 2014; Bauwens et al., 2024) emphasizes that the selection of financing sources must be tailored to the startup's development stage, risk, business model, and scaling strategy.

The classic dichotomy between equity and debt capital (Nawrot, 2007) is analytically insufficient, as modern startups utilize a broad spectrum of hybrid and non-traditional financing instruments. Equity capital encompasses both the founders' private funds, i.e., bootstrapping, investments from business angels, venture capital funds, and corporate venture capital, as well as crowdfunding in the form of equity crowdfunding. Debt and quasi-debt capital, on the other hand, encompasses bank loans, preferential loans, venture debt, revenue-based financing, and mezzanine instruments, which combine the characteristics of debt and equity. Non-repayable financing sources are also available, such as grants and subsidies offered by the Polish Agency for Enterprise Development (PARP), the National Centre for Research and Development (NCBiR) and the European Innovation Council (EIC), which support research and development projects and early-stage commercialization. Hybrid instruments also play an important role. These include accelerators with a financial component, convertible notes, SAFE agreements and matching programs that combine private and public capital, thereby increasing contractual flexibility and partially mitigating financing risk borne by startups. Moreover, the evolving landscape of startup financing highlights the increasing significance of public funding sources in Poland. Research indicates that domestic capital sources have gained

prominence over international alternatives, with public grants and subsidies becoming essential for startups navigating their early stages (e.g. Mańkowska, Szymanowska, 2024). This shift not only underscores the reliance on government support but also raises questions about the sustainability and long-term viability of such funding mechanisms. As startups continue to balance between traditional and innovative financing options, understanding how these public funds interact with private investment will be crucial for fostering a resilient entrepreneurial ecosystem that can adapt to future uncertainties. Table 1 presents the full spectrum of startup financing.

Table 1.
Forms of financing

EQUITY	**Private investors**	**Public or hybrid equity/ quasi-equity investors**	**Equity for work/ resources**
	- Business angels (BA). - Venture capital funds. - Growth/Private Equity funds. - Corporate Venture Capital (CVC). - Investor syndicates. - Equity crowdfunding.	- EIC Fund (EU) – equity investments up to approximately €15-30 million. - PFR Ventures (e.g., PFR Starter, Biznest, Otwarte Innowacje). - Brinc/EIT/accelerators with an equity component – if they include shares. - Regional Investment Funds (RIFs). - BRIdge/NCBR Investment funds.	- Bootstrapping. - Sweat equity. - Non-cash contributions (contributions in kind) – e.g. IP, software, know-how.
DEBT / QUASI-DEBT	**Debt financing (with repayment obligation)**	**Quasi-debt instruments (soft debt)**	**Grants and subsidies (non-repayable, non-equity capital)**
	- Bank loans. - Preferential loans (e.g., BGK). - Development/ innovation loans (PARP, RIF). - Working capital loans. - Leasing (equipment, technology). - Factoring.	- Venture debt – often linked to a prior VC round. - Revenue-Based Financing (RBF) – repayment based on a percentage of future revenues. - Mezzanine – debt with an option to convert to equity	- PARP grants. - NCBR grants. - EIC grants (Pathfinder/ Transition). - Regional grants (RPO). - Industry grants (e.g., ESA BIC for space-tech, EIT Health/Climate).
Hybrid sources of financing	- Accelerators with a financial component (sometimes equity, sometimes grant, sometimes mixed). - Convertible notes (loan convertible to shares). - SAFE (simple investment document). - Matching programmes (PFR, NCBR) – co-financing with investors.		

Source: Prepared based on: Scaling Deep Tech in Europe - European Innovation Council - Impact Report 2025; NCBR, 2024; PARP, 2025b.

One of the most commonly associated forms of startup financing is private investors—venture capital and so-called business angels. An investor, known as a **business angel**, is someone who is willing to share their financial resources and has the ability to finance a company in its early stages in exchange for shares. One of the key characteristics of this type of investor is that they invest exclusively their own funds, which distinguishes them from, for example, venture capital funds (Mikołajczyk, Nawojowicz, 2013). Business angel networks, such as COBIN Angels or Lewiatan Business Angels, are becoming an increasingly important

element of the market. Angels offer capital, mentoring, and a network of contacts, as well as support in building market entry strategies. Literature-based evidence (Cumming et al., 2022; Bessière et al., 2020) suggests that angel investments are associated with higher survival rates and growth prospects for startups in the seed phase.

Venture capital (VC) funds are specialized investment vehicles that allocate capital to high‑growth, innovation‑oriented startups in exchange for equity stakes. In exchange for the investment, investors receive shares or stock in the company (Włodarska-Zoła, 2016). Using venture capital funds as a source of external capital has many advantages. These include: an improved image and credibility for the startup, the ability to obtain capital for innovative and high-risk projects, and support for the company with new business contacts and know-how in many fields (PRF, 2025). The VC market in Poland is growing, and a key component is PFR Ventures, which partially finance the activities of young funds. The greatest activity is seen in the tech, deep-tech, space, and space & satellite sectors (Kerr, Nanda, 2015).

According to global research (Colombo, Grilli, 2010), VC has the greatest impact on the scaling of technology companies and their international expansion.

Growth/Private Equity (PE) funds invest specific financial capital in companies that possess and leverage the potential for market value growth. Their core activity involves identifying, financing, and supporting ventures with a working business model and stable revenues. PE focuses on restructuring, optimization, and expansion, utilizing instruments such as leveraged buyouts (LBOs). Investment risk is lower here than in VC, and the primary goal is to improve the company's efficiency and increase its value before a sale or IPO (PRF, 2025; Sosnowski, 2014). A significant element of the modern financing ecosystem, permeating both the VC market and early forms of private financing, are investor syndicates. They represent a form of co-investment between several entities—usually business angels or smaller VC funds—in a single project, allowing for risk diversification, increasing the available capital pool, and acquiring complementary competencies and networks. Syndicates play a key role in overcoming the information asymmetry and capital constraints inherent in early-stage startups, while also lowering transaction costs for individual investors. As a result, they bridge the gap between individual investors and professional VC funds, complementing the market structure for financing innovative ventures.

Equity crowdfunding is a significant alternative to raising capital for startups, enabling financing through public offerings of shares or stocks implemented through specialized platforms (Qian et al., 2026). This solution is particularly effective for companies targeting their products or services to a broad audience, especially in a B2C model, and for young technology companies seeking funds to scale their operations. Despite its growing availability, equity crowdfunding presents challenges, as it requires companies to present a mature product or prototype and conduct intensive communication with potential investors, who expect transparency, reliable information about risks, and a clear development strategy. A successful campaign therefore presupposes a relatively high level of organizational maturity, particularly

in terms of communication capabilities and investor-oriented disclosure. Furthermore, new regulatory requirements arising from the ECSP Regulation (Regulation (EU) 2020/1503, Journal of Laws 2024, item 984), including the obligation to conduct knowledge tests and simulate the ability to bear losses, while increasing investor protection, also increase formal entry barriers, which may limit the number of market participants and the rate of capital inflow into crowdfunded projects.

Bootstrapping and FFF often constitute the most constrained source of capital – the founders' own funds, including savings and money from family and friends (the so-called FFF – friends, family and fools). A company financed from its own funds is referred to as a "bootstrapper". According to Polish research, the most common source of capital used when founding startups is founders' own funds (Mańkowska, Szymanowska, 2024; Michalczyk, 2022).

Bootstrapping is used at the early stages—when the startup is in the "idea" phase, Minimum Viable Product (MVP), or proof-of-concept phase. At that stage, costs are high, seeking other sources can be risky, and formalities and investor expectations can be difficult to meet. The advantages of this solution also include full control over the company, no need to share shares, and flexibility in decision-making (consistent with the lean startup philosophy). The disadvantages, however, include limited funds, a significant burden on the founders, and personal risk. Bootstrapping is often a starting point—especially if the startup is taking its first steps in an environment of uncertainty. However, very often—to survive the "valley of death" (a period when a company absorbs resources but does not generate revenue)—additional sources of capital are needed. Empirical studies (Chien et al., 2024; Ström et al., 2025) provide evidence that bootstrapping is positively associated with startup survival, especially in technology sectors where the costs of developing an MVP are relatively low.

When founders' own funds are insufficient, **public grants and subsidies** become a significant source of capital for startups. Poland offers a wide range of support programs, including national initiatives implemented by institutions such as the PARP or the PFR, as well as EU programs and structural funds available through PARP and Bank Gospodarstwa Krajowego (BGK), among others (PARP, 2025a). Specialized incubation and acceleration programs (PARP, 2025b) also offer not only financing but also mentoring and access to networking. Grants and subsidies cover the costs of research, product development, MVP development, testing, and employment, often serving as a key support instrument in the early stages of development. At the same time, this type of financing is associated with limitations—high formal requirements, the need for precise planning, and rigid project goals—which can be difficult to reconcile with the dynamically evolving business model characteristic of startups.

Other forms of financial support for startups include **bank loans**, other credit facilities and debt financing/leasing (Brealey, 2020, pp. 577-644). Traditional financial institutions – banks and lending institutions – offer loans, credit, leasing and other debt instruments.

This option is less popular in the initial stages of startups but is still present. As Kapler and Love (2011) point out, more innovative and competitive companies have easier access to trade credit. Hai et al. (2022) note that in the development and growth phase, startups often struggle to secure support from financial institutions due to strict rules regarding financing structures. Factors such as limited operating history, lack of credit history and insufficient collateral significantly influence financial institutions' lending decisions.

The advantage of this form of funding is the predictability of capital costs, as interest rates are known in advance. It is worth considering this form if a startup is already generating revenue or has credible revenue forecasts, especially for financing fixed assets such as equipment, infrastructure and production capacity. However, for many startups – especially those without significant collateral and with high risk – bank loans can be difficult to obtain. Banks often require collateral, guarantees and a detailed business plan, which together constitute a significant barrier for early‑stage companies without revenues. To overcome these barriers, startups can also utilize preferential loans, venture debt, or revenue-based financing (Chien et al., 2025). These instruments are gaining importance, especially among startups generating recurring revenues (e.g., SaaS).

Quasi-debt instruments, often referred to as ‘soft debt’, constitute an intermediate form of financing situated between traditional bank lending and pure equity investment. These mechanisms enable capital acquisition while maintaining ownership control, while offering the investor limited risk exposure through partial participation in the company's future profits or the option of converting debt into equity. In the context of the startup ecosystem, they are particularly important during the growth and scaling phase, when companies are already generating initial revenues but are not yet ready for a large equity round or wish to minimize share dilution. The most commonly used quasi-debt instruments include venture debt, revenue-based financing (RBF), and mezzanine. **Venture debt** is debt financing offered to startups that have previously raised capital from VC funds. The presence of a reputable investor reduces the lender's risk and allows for the granting of debt without traditional collateral. This instrument is primarily used to finance expansion, product development, or extend the runway before the next capital round. Typical features include more favorable terms than traditional loans and the option to use warrants as compensation for the financier (Cumming, 2009).

Revenue-Based Financing (RBF) involves repaying debt by transferring a fixed percentage of future revenues until a specified return is achieved. This solution is effective for companies with recurring revenues, as it adjusts the debt burden to the current financial situation and does not cause dilution, providing a flexible alternative for startups with growing but unstable cash flows (European Commission, 2021).

Mezzanine is a form of financing that combines the characteristics of debt and equity, most often in the form of subordinated debt with the option to convert to equity or with an equity component (Cassar, 2004; Kerr, Nanda, 2015) It is used in later stages of

development, when the company generates stable revenues but requires growth capital without losing ownership control. This instrument increases the flexibility of the capital structure and can serve as a bridge between VC rounds and private equity investments.

Accelerators with a financial component provide young companies with both substantive support and capital in the form of equity, grants, or mixed models. These instruments enable rapid product testing and access to a network of mentors and investors, with a relatively low entry threshold (Kozłowski, 2010).

Convertible notes are short-term debt that can be converted into shares during the next investment round. This instrument reduces the need for early-stage company valuation and lowers transaction costs, while providing the investor with preferential entry conditions (European Commission, 2021).

Simple Agreement for Future Equity (SAFE) is a simplified investment document enabling the acquisition of future shares without accruing interest and without a maturity date, which distinguishes it from traditional convertible loans. This solution simplifies the capital raising process, minimizes formalities, and reduces transaction costs.

Matching programs (e.g. PFR, NCBR) involve co-financing startups by public institutions and private investors. These mechanisms reduce investment risk, mobilize private capital and support the development of early-stage technological ventures, particularly in areas of high market uncertainty (PARP, 2023a; PFR, 2023).

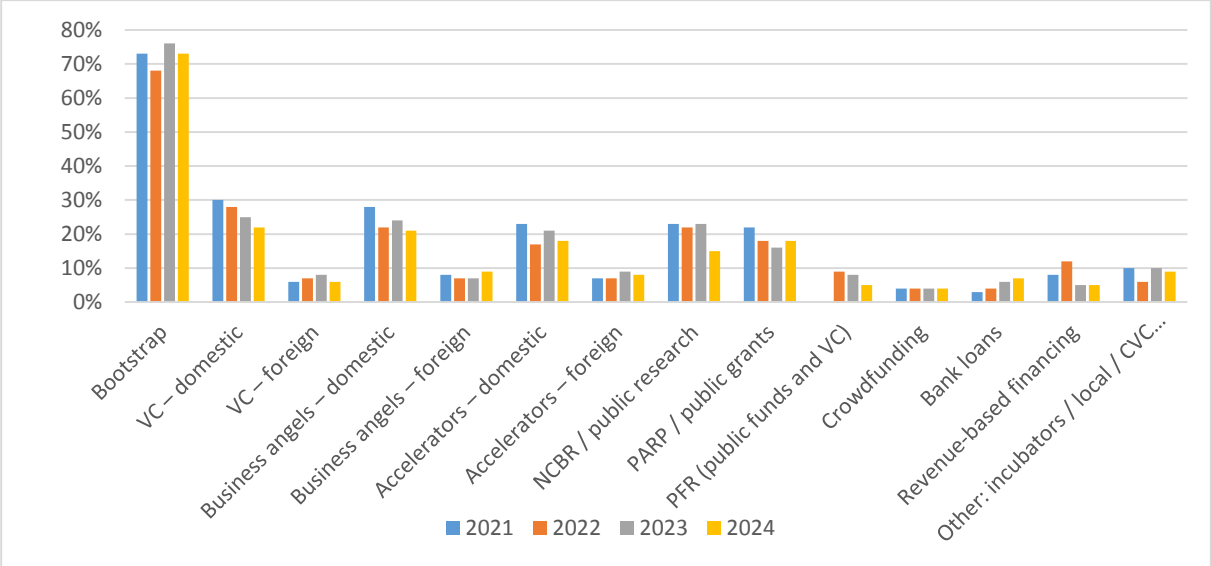


Figure 1. Sources of capital financing Polish startups in 2022-2024.

Source: Own study based on: Fundacja Startup Poland 2021, 2022, 2023, 2024.

The startup financing ecosystem encompasses a wide range of instruments that vary in risk levels, investor expectations, and impact on the ownership structure. Although startups in Poland primarily use bootstrapping (Figure 1; according to report 6, 73% of startups use this form of financing), a key role is also played by private investors – business angels (30% of financing) and venture capital funds (28% of financing) – who, in addition to capital, provide

mentoring, networking and strategic support, contributing to a higher likelihood of market success. Debt and quasi-debt instruments, crowdfunding, and equity financing are alternatives or complements, and can be particularly important in the earliest stages of development. Grants and public programs, including matching mechanisms, also play a significant role, reducing investment risk and enabling the financing of high-uncertainty innovations.

3. A Model for the Optimal Startup Financing Path in Poland

Drawing on market analysis and prior empirical findings, the paper proposes a stage-based model of the optimal startup financing path in Poland (Table 2). This model takes into account the company's development stages and available financial instruments.

Table 2.
Optimal Startup Financing Path Model

Stage	Business Goals	Available Financing Instruments	Typical Amounts	Key KPIs/Criteria
0. Bootstrap / Founders' equity	Validation of the idea, creation of the MVP, first traction	Founders' savings, funds from family and friends, income from services	0-200 thousand PLN	Initial demand, prototype, early adopters
1. Pre-seed / Grant / Accelerator	Model validation, customer testing, PMF refinement	Grants (NCBR, PARP, regional), accelerators (corporate, public and private), innovation competitions	50-500 thousand PLN (grant) + 50-200 thousand PLN (accelerator)	First paid pilots, retention, references, readiness for commercialization
2. Seed / Business Angels / Early VC	Building a team, first scalable sales, entering the EU market	Business angels, angel syndicates, seed VC funds, SAFE / convertible notes	0.5-3 million PLN	MRR/ARR*, user growth, LTV/CAC**, first repeatable sales processes
3. Series A / Growth VC	International expansion, product scaling, increasing market share	Late-stage VC funds, venture debt, international rounds	3-50+milion PLN	ARR***, churn, gross margins, sales efficiency, operational scalability
4. Late Stage / Pre-exit	Preparing for IPO/M&A, maximizing market share	Private equity, strategic industry investors (M&A), public markets	PLN 50 million – several hundred million PLN	EBITDA****, stable revenues, international presence, high scalability

* MRR (Monthly Recurring Revenue) and ARR (Annual Recurring Revenue), * * LTV (Lifetime Value) and CAC (Customer Acquisition Cost), *** ARR (Annual Recurring Revenue), **** EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization).

Source: Own study based on: Fundacja Startup Poland 2022, 2023, 2024; NCBR, 2024; PRF, 2024, Q1 2025, Q2 2025 and Q3 2025; PARP, 2024b.

The proposed model is broadly consistent with international empirical studies (including Narwal, 2023), which document a sequential relationship between firm development stages and preferred financing instruments. At the same time, the model is indicative rather than

prescriptive and should be adapted to sector-specific dynamics and the risk preferences of founders and investors. However, special attention should be paid to the opportunities for startups to develop into "unicorns", of which there are relatively few in Poland.

4. Summary and Conclusions

Despite the significant development of the innovation ecosystem in Poland, startups still face numerous barriers to effective capital raising. The most important of these include a limited number of industry investors and insufficient networking, which translates into difficult access to business partners and financing sources. Limited availability of debt financing, resulting from banks' low willingness to lend to young companies without operational history and adequate collateral, further hinders growth. Regulatory instability and skills gaps in sales, management and finance therefore constitute structural constraints that may inhibit scalable growth.

Regulatory instability in startup financing stems primarily from dynamic changes in regulations regarding crowdfunding, venture debt, and EU grants. The introduction of the ECSP Regulation requires platforms and investors to complete new formalities, such as knowledge tests and investor identification, which increases costs and the barrier to entry. Differences in the implementation of national regulations and the lack of established practice create legal uncertainty that can limit startups' access to capital and discourage investors, especially less experienced ones.

From a managerial perspective, startups should prioritize building credibility by presenting measurable performance metrics, engaging in early financial modelling and cultivating relationships with investors and industry partners.

From an investor perspective, evaluation should extend beyond technological novelty to encompass founding‑team quality, governance structures and unit economics, while syndication can be used to diversify risk and pool complementary expertise. This approach strengthens the entire ecosystem and increases the likelihood of startups' market success.

Analysis of the Polish startup financing market indicates that the ecosystem is maturing and becoming increasingly competitive. The availability of capital—both public and private—enables the transition from the idea stage to international scaling. At the same time, organizational resources, team competencies, and the ability to effectively utilize available financial instruments remain key success factors.

The optimal financing path model presented in this article thus provides a structured heuristic for startups seeking capital, as it captures both the specific features of the Polish market and broader global trends in financing technology‑driven entrepreneurship.

References

1. Bauwens, T., Hartley, K., Hekkert, M., Kirchherr, J. (2024). Building innovation ecosystems for circularity: Start-up business models in the food and construction sectors in the Netherlands. *Journal of Cleaner Production, Vol. 481,* https://doi.org/10.1016/j.jclepro.2024.143970
2. Berger, A.N., Udell, G.F. (1998). The Economics of Small Business Finance: The Roles of Private Equity and Debt Markets in the Financial Growth Cycle. *Journal of Banking and Finance, 22(6-8),* pp. 613-673.
3. Bessière, V., Stéphany, E., Wirtz, P. (2020). Crowdfunding, business angels, and venture capital: an exploratory study of the concept of the funding trajectory. *Venture Capital, 22(2),* pp. 135-160. https://doi.org/10.1080/13691066.2019.1599188
4. Brealey, R.A., Myers, S.C., Allen, F. (2020). *Principles of Corporate Finance*. McGraw-Hill Education.
5. Bu, Y., Du, X., Wang, Y., Liu, S., Tang, M., Li, H. (2024). Digital inclusive finance: A lever for SME financing? *International Review of Financial Analysis, Vol. 93,* https://doi.org/10.1016/j.irfa.2024.103115
6. Čalopa, K.M., Horvat, J., Lalić, M. (2014). Analysis of financing sources for start-up companies. *Management: Journal of Contemporary Management Vol. 19(2),* pp. 19-44. https://hrcak.srce.hr/file/196722
7. Cassar, G. (2004). The Financing of Business Start-up. *Journal of Business Venturing, Vol. 19(2),* pp. 261-283.
8. Chien, F., Zhang, Y., Sadiq, M. (2025). Fintech innovation in green finance: A disruptive force or a complementary tool? *International Review of Economics and Finance, Vol. 104,* https://doi.org/10.1016/j.iref.2025.104658
9. Colombo, M.G., Grilli, L. (2010). On growth drivers of high-tech start-ups. *Research Policy, Vol. 39(7),* pp. 925-938.
10. Cumming, D. (2009). *Venture Capital and Private Equity Contracting: An International Perspective*. Retrieved from: https://doi.org/10.1016/C2012-0-06081-4, 02.12.2025.
11. Cumming, D.J., Kumar, S., Lim, W.M., Pandey, N., (2022). *Venture Capital and Private Equity Research. A Bibliometric Review and Future Research Agenda*. https://doi.org/10.31124/advance.19205001.v1
12. European Commission (2021). *Study on Access to Finance for SMEs and Startups in the EU.* Publications Office of the European Union. Retrieved from: https://single-market-economy.ec.europa.eu/system/files/2021-11/Analytical%20report%202021.pdf, 02.12.2025.
13. Frank, M.Z., Goyal, V.K. (2003). Testing the Pecking Order Theory of Capital Structure. *Journal of Financial Economics, Vol. 67(2),* pp. 217-248.

14. Fundacja Startup Poland (2021). *Polskie startupy. Raport*. Warszawa: Startup Poland. Retrieved from: https://startuppoland.org/report/polskie-startupy-raport-2021/
15. Fundacja Startup Poland (2022). *Polskie startupy. Raport*. Warszawa: Startup Poland. Retrieved from: https://startuppoland.org/wp-content/uploads/2022/11/Polskie-Startupy-2022-1.pdf
16. Fundacja Startup Poland (2023). *Polskie startupy. Raport*. Warszawa: Startup Poland. Retrieved from: https://startuppoland.org/report/polskie-startupy-2023/
17. Fundacja Startup Poland (2024). *Polskie startupy. Raport*. Warszawa: Startup Poland. Retrieved from: https://startuppoland.org/report/polskie-startupy-2024/
18. Gemzik-Salwach, A., Perz, P. (2023). Startups financing in Poland. *Humanities and Social Sciences, Vol. 26, No. 3,* https://doi.org/10.7862/rz.2019.hss.24
19. Hai, B.L., Yin, X.M., Xiong, J., Chen, J. (2022). Could more innovation output bring better financial performance? The role of financial constraints. *Financial Innovation, 8(1),* pp. 115-140.
20. Indrawati, H., Suarman, C. (2020). Barriers to technological innovations of SMEs: how to solve them? *International Journal of Innovation Science, Vol. 12, No. 5,* pp. 545-564.
21. Kerr, W., Nanda, R. (2015). Financing Innovation. *Annual Review of Financial Economics, Vol. 7,* pp. 445-462.
22. Klapper, L., Love, I. (2011). The impact of the financial crisis on new firm registration. *Economics Letters, Vol. 113(1)*. Elsevier, pp. 1-4.
23. Kozłowski, T. (2010). Financial accelerator as an idea of a mechanism of external economic disturbances amplification. *Ekonomia i Prawo [Economics and Law], Vol. 6, No. 1,* pp. 157-166. Doi: 10.12775/EiP.2010.011
24. Leoński, W. (2023). The role of crowdfunding platforms in financing startups in Poland: a case study of wspieram.to. *Organization and Management Series, Iss.176,* pp. 365-373. DOI: 10.29119/1641-3466.2023.176.22
25. Mańkowska, N., Szymanowska, A. (2024). Finansowanie start-upów w Polsce w latach 2015-2022. *Kwartalnik nauk o przedsiębiorstwie, Vol. 2,* pp. 17-31.
26. Michalczyk, W. (2022). Finansowanie działalności startupów w Polsce. In: A. Kuźmińska-Haberla, S. Bobowski (Eds.), *Rola ekosystemu w rozwoju startupów. Przypadek Wrocławia.* Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.
27. Mikołajczyk, K., Nawojowicz, D. (2013). *Start-up po polsku. Jak założyć i rozwinąć dochodowy e-biznes.* Gliwice: Onepress.
28. Narwal, K.P. (2023). A Review of Financing Structure of Start-up Firms. *Journal of Management and Entrepreneurship, Vol. 17(2),* pp. 107-128. https://doi.org/10.70906/20231702107128
29. Nawrot, W. (2007), Struktura finansowa przedsiębiorstw w Polsce na tle badań międzynarodowych. *Gospodarka Narodowa, Vol. 7-8,* pp. 19-42.

30. NCBR (2024). Rynek akceleracji w Polsce Badanie Aces, NBCR oraz Antal, Retrieved from: https://antal.pl/wiedza/raport/rynek-akceleracji-w-polsce, 10.12.2025.
31. OECD (2020). *Financing SMEs and Entrepreneurs: An OECD Scoreboard*. OECD Publishing.
32. *On Crowdfunding for Business Ventures and Assistance to Borrower* (O finansowaniu społecznościowym dla przedsięwzięć gospodarczych i pomocy kredytobiorcom PL). Act of July 7, 2022 Journal of Laws [Dz.U.] 2024, item 984 (Pol.) Retrieved from: https://orka.sejm.gov.pl/opinie9.nsf/nazwa/2269_u/$file/2269_u.pdf, 12.12.2025.
33. PARP (2023a). *Global Entrepreneurship Monitor*, https://www.parp.gov.pl/storage/publications/pdf/Raport-GEM-Polska-2023.pdf
34. PARP (2024a). *Global Entrepreneurship Monitor*, https://www.parp.gov.pl/storage/publications/pdf/RAPORT-z-badania-GEM---Polski_WCAG-11_10_2024.pdf
35. PARP (2024b). *Crofunding. Diagnoza potrzeb i uwarunkowań pod kątem projektowania instrumentu wsparcia.* Retrieved from: https://www.parp.gov.pl/storage/publications/pdf/Raport-CROWDFUNDING.pdf, 02.12.2025.
36. PARP (2025a). *Raport o stanie sektora małych i średnich przedsiębiorstw w Polsce*. Retrieved from: https://www.parp.gov.pl/component/publications/publication/raport-o-stanie-sektora-malych-i-srednich-przedsiebiorstw-w-polsce-2025
37. PARP (2025b). *Twój pomysł nasze wsparcie. PARP dla startupów*. Warszawa: PARP, https://www.parp.gov.pl/storage/publications/pdf/02-FE-broszura-210x210startup.pdf
38. PFR Venturs (2024). *Transakcje na polskim rynku VC w 2024*. Retrieved from: https://pfrventures.pl/artykul/transakcje-na-polskim-rynku-vc-w-2024
39. PRF Venture (2025a). *Transakcje na polskim rynku VC w Q1 2025*. Retrieved from: https://pfrventures.pl/artykul/transakcje-na-polskim-rynku-vc-w-q1-2025, 09.12.2025.
40. PRF Venture (2025b). *Transakcje na polskim rynku VC w Q2 2025*. Retrieved from: https://pfrventures.pl/artykul/transakcje-na-polskim-rynku-vc-w-q2-2025, 09.12.2025.
41. PRF Venture (2025c). *Transakcje na polskim rynku VC w Q3 2025*. Retrieved from: https://pfrventures.pl/document/2649, 09.12.2025.
42. Qian, C., Li, Z., Fu, Q. (2026). Managing inventory and financing decisions under ambiguity. *Omega, Vol. 140*, https://doi.org/10.1016/j.omega.2025.103460
43. Regulation (EU) 2020/1503 of the European Parliament and of the Council of 7 October 2020 on European crowdfunding service providers for business, and amending Regulation (EU) 2017/1129 and Directive (EU) 2019/1937 (Text with EEA relevance). Retrieved from: https://eur-lex.europa.eu/eli/reg/2020/1503/oj
44. Robb, A., Robinson, D. (2014). The Capital Structure Decisions of New Firms. *Review of Financial Studies, Vol. 27(1)*, pp. 153-179.
45. Salazar, A.J. (2021). Organizational resources and survival of startups firms – a qualitative analysis in the Peruvian context. *Academia Revista Latinoamericana de Administracion, Vol. 34, No. 1,* pp. 59-87, doi: https://doi.org/10.1108/ARLA-04-2020-0080

46. *Scaling Deep Tech in Europe*, European Innovation Council. Impact Report 2025, doi: 10.2826/1391424
47. Sosnowski, T. (2014). *Dezinwestycje Funduszy Private Equity metodą IPO*. Łódź: Wydawnictwo UŁ.
48. Ström, V., Sanandaji N., Esmaeilzadeh S., Esmaeilzadeh, M. (2025). Equity capital financing of Swedish SMEs, innovation, and decentralized management. *International Journal of Innovation Science, Vol. 17, No. 1,* pp. 184-201, https://doi.org/10.1108/IJIS-10-2022-0200
49. Włodarska-Zoła, L. (2016). Venture capital jako źródło finansowania przedsięwzięć innowacyjnych w świetle polityki wspierania innowacyjności. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, Vol. 436,* pp. 278-286.
50. Zhou, M., Kartanaitė, I., Norvaišienė, R., Kovalov, B., Krušinskas, R. (2023). 'Unicorns' growth and financial flexibility before and after the IPO. *Heliyon, Vol. 9, Iss. 9,* https://doi.org/10.1016/j.heliyon.2023.e20313

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DIGITAL TRANSFORMATION OF CORPORATE GOVERNANCE IN POLAND: ONLINE GENERAL MEETINGS OF SHAREHOLDERS IN THE LIGHT OF COMPANY LAW

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Purpose: This article aims to analyse the legal barriers preventing the full digitisation of general meetings (GMs) of shareholders in Poland, on the assumption that virtual-only GMs are the next logical step in the digital transformation of corporate governance.
Design/methodology/approach: This article discusses the importance of technological development for the digitisation of corporate governance, presenting the legal framework applicable in Poland to online GMs. These are presented as mechanisms of contemporary digital corporate governance, with the necessary legislative changes indicated. The article emphasises that the digitisation of corporate processes must take into account the legal security of the company and its stakeholders. The analysis is based on company law standards, literature on the subject, and source texts. Content analysis and legal text analysis methods were employed.
Findings: Despite the formal possibility of remote participation in GMs, the study showed that Polish company law still does not allow for virtual-only GMs in joint-stock companies. Key restrictions include the requirement for a physical meeting place, electronic participation by shareholders being optional rather than mandatory, and the obligation to draw up notarial minutes. It was suggested that the German regulatory model could inform the reform of Polish law, given that it permits the total exclusion of shareholders' physical presence and comprehensively regulates the protection of their corporate rights in a virtual environment. Furthermore, it was emphasised that digitising GMs strengthens corporate governance mechanisms based on transparency, accountability, responsibility, fairness, and stakeholder participation.
Originality/value: The article addresses key issues concerning the functioning of a joint-stock company in the modern era. It identifies the main barriers to the digitisation of GMs in Poland and proposes solutions based on the German model. It also highlights areas where digitisation can reinforce the practical implementation of corporate governance principles.
Keywords: digital corporate governance, virtual general meeting, joint-stock company.
Category of the paper: Viewpoint.

1. Introduction

In a joint-stock company, the role of corporate governance is to ensure a "balance between the interests of those involved" in its operation (Tamowicz, Dzierżanowski, 2002, p. 13). This balance is achieved through economic and legal mechanisms (Shleifer, Vishny, 1997). These mechanisms are based on the fundamental principles of corporate governance, which are: transparency, accountability, responsibility, fairness, independence and stakeholder participation (European Commission, n.d.; Khandbahale, Pachorkar, 2025; OECD, 2023; Tricker, 2025). The scope of corporate governance in a joint-stock company is determined by generally applicable laws, internal company regulations and whether the company is public or private (Tricker, 2025). Corporate governance establishes a framework of rules, practices, and processes through which companies are managed and controlled (Committee on the Financial Aspects of Corporate Governance, 1992; Khandbahale, Pachorkar, 2025; Tricker, 2025). It establishes the conditions for setting objectives within the company, the means of achieving them and the means of monitoring results (OECD, 2023). Corporate governance encompasses the set of relationships between the company's governing bodies, i.e. the general meeting (GM), the management board and the supervisory board, as well as the relationships between these bodies and the company's stakeholders. It also provides a structure for these relationships (OECD, 2023). This structure now often takes a digital form. "The use of digital technologies and data" (OECD, 2019, p. 18), as well as the connections between them, is what is meant by the term "digitalisation" (OECD, 2019, p. 18). The result of this is the creation of new activities or changes to existing ones (OECD, 2019, p. 18). Digitalisation can strengthen governance practices by increasing transparency, improving decision-making processes, and creating new opportunities for data analysis (Khandbahale, Pachorkar, 2025). Therefore, the digitisation of corporate governance can contribute to balancing the interests of parties in corporate relationships with the protection of their rights (Laptev, Feyzrakhmanova, 2021). However, digitalisation also presents challenges relating to privacy protection, cybersecurity, and the ethical use of technology (Khandbahale, Pachorkar, 2025; Tricker, 2025). The digital transformation of corporate governance refers to managing corporate activities using digital technology-based tools and solutions (Laptev, Feyzrakhmanova, 2021). This transformation is also occurring at general meetings (GMs) of shareholders in joint-stock companies (Brochet, Chychyla, Ferri, 2023; Denis, Blume, 2021; Fontenot, 2018; ICLEG, 2022). However, Polish company law currently prohibits holding GMs of shareholders entirely online, i.e. without designating a physical meeting venue (Szumański, 2020, p.10). This solution does not allow for the full utilisation of the opportunities offered by the digitisation of business processes (OECD, 2019).

This article analyses the legal barriers preventing the full digitisation of GMs of shareholders in Poland, assuming that virtual-only meetings are a natural stage in the digital transformation of corporate governance. A virtual-only GM is one in which shareholders and company representatives participate remotely only, with no option for personal attendance, while being legally guaranteed access to all the rights and functions enjoyed by participants in a traditional GM (Buellingen, 2019). The analysis focuses on legal norms contained in Polish company law, related literature, and source texts. Content analysis (Babbie, 2009) and legal text analysis (Chauvin, Stawecki, Winczorek, 2014) were used as the research methods. The proofreading and translation were carried out using the DeepL tool (DeepL SE, n.d.a, n.d.b).

2. Legal framework for online GMs of shareholders in Poland

The legal framework for online GMs of shareholders in Poland is set out in Article 406(5) of the Commercial Companies Code (CCC) of 15 September 2000 (ISAP, 2024). It should be noted that, under Article 412, §1 of the CCC, "a shareholder may participate in a general meeting and exercise their voting rights in person or through a proxy" (ISAP, 2024). According to Article 406(5), §1 of the CCC, shareholders or their proxies can attend GMs of joint-stock companies via electronic communication (ISAP, 2024). This solution applies to both public and private companies (Kidyba, 2025). However, the possibility of participating in a GM electronically may be excluded in the company's articles of association – Article 406(5), §1 CCC (ISAP, 2024; Szumański, 2020). Nevertheless, it's important to note that participation in the GM should be interpreted broadly (Kidyba, 2025). "This applies to both physical participation of a shareholder or their proxy at the venue where the meeting is held and absence of physical presence. Participation in the latter sense means the ability to communicate and speak, as well as exercising voting rights" (Kidyba, 2025). This follows directly from Article 406(5), §2 of the CCC, according to which participation in a GM using electronic means includes two-way, real-time communication, whereby the parties can speak during the proceedings and vote in person or via proxy (ISAP, 2024). However, whether a shareholder or their proxy can participate in the GM using electronic means of communication is at the discretion of the meeting convener – Article 406(5), §1 of the CCC (ISAP, 2024). The supervisory board lays down the rules for the participation of shareholders or their proxies in the GM using electronic means of communication in the form of regulations – Article 406(5), §3 CCC (ISAP, 2024). The rules may only include requirements or restrictions that are necessary to ensure the security of electronic communications and the identification of shareholders – Article 406(5), §3 CCC (ISAP, 2024). The obligation to ensure the security of electronic communications and the shareholder authentication process in e-voting lies with the

company (Dumkiewicz, 2024; Kidyba, 2025). It should be noted that the legislator has adopted a position of technological openness; no particular technical solutions have been specified for use in this area (Dumkiewicz, 2024; Szumański, 2020). Additionally, all modes of passing resolutions by the GM are considered equivalent, including both traditional and electronic voting (Kidyba, 2025). However, the articles of association may regulate this matter differently (Kidyba, 2025).

Article 406(5) of the CCC does not introduce "virtual or remote" GMs into the Polish legal system (Michalski, 2020, p. 603). Instead, it creates the possibility for shareholders or their proxies to participate in a GM "using means of direct remote communication in real time" (Michalski, 2020, p. 603). This allows them to "follow the proceedings, speak on individual agenda items, present motions" and "vote in this manner" (Michalski, 2020, p. 603). According to the Supreme Court's ruling of 6 June 2018 (III CSK 403/16), unjustifiably preventing a shareholder or their representative from entering the physical meeting venue may result in the resolutions being declared null and void (Łazarewicz, 2021; SN, 2018). Article 406(5), §2 of the CCC also precludes holding a GM of shareholders online only, i.e. without designating a physical location where the chair and minute-taker of the meeting are present (Dumkiewicz, 2024; Szumański, 2020). However, the necessity of the chairperson being physically present at the GM is debated in legal doctrine (Leśniak, 2020a; Mazgaj, 2022). Regarding the minute-taker, Article 421, §1 of the CCC states that "resolutions of the general meeting should be included in the minutes drawn up by a notary public" (ISAP, 2024). The notary public plays an "active role" in recording the resolutions of the GM (Uliasz, 2024, p. 88). This means that they should refuse to perform the act if, while drawing up the minutes or preparing for the notarial act, they find "that the content of the proposed resolution, the manner of convening the general meeting, or the manner of conducting the vote" is contrary to the law (Uliasz, 2024, p. 94). When drawing up the minutes of the GM, the notary must be physically present at the venue of the GM (Leśniak, 2020a). According to Article 403 of the CCC, GMs can only be held within the territory of the Republic of Poland at a specific location, e.g. the company's registered office (ISAP, 2024). The legislator's use of the term 'place' should be understood as referring to a geographical space, not a virtual one (Horwath, 2007; Leśniak, 2020b).

3. Online GMs as a mechanism of digital corporate governance

The GM is the most important body in a joint-stock company, playing a key role in corporate governance (Denis, Blume, 2021; FRC, 2020; Modrzejewski, Wiśniewski, 2016). Digitising GMs of shareholders should improve information transparency within companies and strengthen other corporate governance principles. This includes holding the management board accountable and responsible, ensuring fair treatment of all shareholders and encouraging their

involvement in company affairs (Denis and Blume, 2021; FRC, 2020). To strengthen corporate governance principles in joint-stock companies, online GMs should adhere to best practices for virtual shareholders' meetings (Magnusson, Blume, 2022; The Best Practices Committee…, 2018). These relate to the format of the meeting, which should always be disclosed in advance in a statement by the proxy. All participants in the meeting should also be given equal access to exercise their corporate rights. Universal rules of conduct should be established and communicated to shareholders prior to the GM. It is also recommended that guidelines be established regarding the time allocated for shareholder questions. Any questions received online during the meeting should also be published. Technical assistance should be provided to shareholders and virtual meetings should be archived for later reproduction (Magnusson, Blume, 2022; The Best Practices Committee…, 2018). Improvements in corporate governance transparency can be achieved through the use of blockchain technology and smart contract technology (Van Der Elst, Lafarre, 2017). These technologies can be used in the voting process at GMs, for example (Van Der Elst, Lafarre, 2017). Platforms dedicated to handling virtual GMs provide real-time access to electronic voting results and statistics (Abdennadher, Cheffi, 2020). These platforms increase the reliability of results and the legitimacy of decisions (Panisi, Buckley, Arner, 2019). New technologies also reduce costs associated with the entire voting process (Panisi et al., 2019). They may also facilitate dialogue during the voting process (Abdennadher, Cheffi, 2020). They also ensure greater transparency between stakeholders in terms of corporate governance (Panisi et al., 2019). Furthermore, digitising GM processes can streamline shareholder identification, registration, and vote verification (Abdennadher, Cheffi, 2020). Digitising GMs also strengthens corporate governance principles by facilitating shareholder participation and the exercise of corporate rights, particularly for minority, institutional and foreign shareholders (Denis, Blume, 2021; Magnusson, Blume, 2022). In this respect, digitisation aligns with the G20/OECD corporate governance principles, which emphasise ensuring shareholders can participate in and vote at GMs, treating them equally and developing company procedures that facilitate voting without exposing them to high costs (OECD, 2023). Digitisation may also increase shareholder attendance at GMs (Fontenot, 2018) thereby raising their substantive value (Brochet et al., 2023). This is because digitising GMs facilitates access to them and strengthens their informational, decision-making and control functions (Abdennadher, Cheffi, 2020).

However, the digitisation of GMs also poses potential threats to the equal treatment of shareholders, as well as risks related to proper verification. It is important to acknowledge the difficulty of direct contact between shareholders and company management and the inability to gauge the mood in the room. This weakens one of the basic principles of corporate governance: accountability (Denis, Blume, 2021; Fontenot, 2018; FRC, 2020). Attention should also be paid to how GMs are managed (FRC, 2020). There are concerns about how questions asked at GMs via remote communication methods are processed. This relates to the potential for question manipulation. This includes selecting, filtering or ignoring inconvenient questions, rephrasing

them, or grouping them together (Brochet et al., 2023; Denis, Blume, 2021; Fontenot, 2018; FRC, 2020; Nili, Shaner, 2022). This may result in shareholders' questions going unanswered, or complex questions being answered very generally (FRC, 2020). Building trust in digital GMs is therefore extremely important. This can be achieved by implementing clear guidelines for asking and answering questions. Transparency is essential when selecting which questions to ask and which to leave unanswered, and when recording comments, questions and answers (ASIC, 2021; Denis, Blume, 2021). However, the digitisation of GMs also entails risks of failure during voting and security issues, which should also be taken into account. Verifying which shareholders are entitled to vote may be too complicated for some, as it involves assigning reference numbers and passwords (FRC, 2020). Problems may also arise from a lack of standardisation in voting systems or participant authentication at GMs, which could lead to increased inequality between shareholders (Abdennadher, Cheffi, 2020). It is therefore necessary to develop secure procedures for verifying shareholders and proxies that are also acceptable and understandable to all (Fontenot, 2018).

As business processes become increasingly digitised, cybersecurity and digital trust are becoming ever more important (Magnusson, Blume, 2022). Effective digital security risk management is essential for informed decision-making (Magnusson, Blume, 2022; OECD, 2015). Companies must incorporate these into their overall risk management framework (Magnusson, Blume, 2022; OECD, 2025b). In terms of cybersecurity, this includes investing in appropriate digital security infrastructure, conducting regular audits and developing incident response plans (Khandbahale, Pachorkar, 2025, p. 99). When digitising GMs of shareholders, ensuring the adequate protection of participants' personal data becomes paramount (ICLEG, 2022).

4. Directions of legislative changes in Poland

Digitisation is transforming corporate governance and the manner in which GMs are conducted within joint-stock companies (Magnusson, Blume, 2022). Many OECD countries have incorporated the option of remote shareholder participation into their company law. Some of these countries have also decided to permit virtual-only GMs (OECD, 2025a). In Poland, although remote participation in GMs is permitted, it is not yet possible to hold a GM entirely online in a joint-stock company (ISAP, 2024). Systemic restrictions on virtual-only GMs in joint-stock companies include the requirement for a physical venue (Article 403 CCC), the limited scope of Article 406(5) CCC (which allows, but does not require, shareholders to participate electronically in the GM) and the requirement for a notarial record (Article 421 CCC) (ISAP, 2024; Leśniak, 2020a). When considering legislative changes in Poland in this area, it is worth examining the solutions adopted in Germany. This is due to the

similarity between the German and Polish legal systems, and the strong tradition of legal certainty in Germany, which is important for the functioning of capital companies (Szczepańska, Ryszkowski, 2025). Section 118a of the German Joint Stock Companies Act of 6 September 1965 (AktG) introduced the concept of virtual GMs (Gesetze im Internet, 2024). According to Section 118a of the AktG, a GM can be held without shareholders or their proxies being physically present at the venue where it is held. This must be specified in the company's articles of association or authorised by the management board. The possibility of organising virtual meetings is limited to a maximum of five years. Members of the management board, and usually members of the supervisory board, must be present at the venue of the GM unless they can participate via online transmission in accordance with §118, subsec. 3 AktG. In addition, the chair of the meeting and, in cases provided for by law, auditors should be present. According to §130 AktG, a notary public must take the minutes of the GM and should also be present at the venue (Gesetze im Internet, 2024). Section 118a of the AktG sets out specific technical requirements, including image and sound transmission, electronic voting, submitting motions and nominations online, and obtaining information, asking questions, making comments, speaking and raising objections electronically (Gesetze im Internet, 2024). In view of the above, the question arises as to what conclusions can be drawn from the German experience for Poland. One barrier to organising purely virtual GMs of shareholders in Poland is the requirement for a designated physical meeting place (ISAP, 2024; Leśniak, 2020a). This requirement also exists in German company law (Gesetze im Internet, 2024). However, it should be emphasised that, although both Polish and German law require the formal indication of the venue of the GM, German law permits it to be held virtually, without the physical presence of shareholders or their proxies (§118a AktG) (Gesetze im Internet, 2024). In such a situation, the company is not obliged to provide a room for shareholders and can focus solely on digital solutions (Gesetze im Internet, 2024). Another barrier to organising purely virtual GMs in Poland is the limited scope of Article 406(5) of the CCC, which only gives shareholders or their proxies the option to participate in a GM electronically (ISAP, 2024). In contrast, §118a AktG sets out in great detail the requirements that must be met for a virtual GM, thereby safeguarding the legal interests of shareholders (Gesetze im Internet, 2024). An additional barrier in Poland is the requirement to draw up a notarial protocol and to have a notary present at the meeting (ISAP, 2024; Leśniak, 2020a). A similar solution can be found in German company law (Gesetze im Internet, 2024).

In summary, while German solutions do not eliminate the formal requirement for a venue for the GM, they permit the total exclusion of shareholders' physical presence. They also comprehensively regulate the protection of corporate rights in the virtual space. The German model may therefore serve as a valuable reference point for amending Polish company law.

5. Conclusion

Like many other business processes, the digitisation of corporate governance is inevitable (Denis, Blume, 2021; Magnusson, Blume, 2022; OECD, 2019). While it creates new opportunities, it also generates new risks (Khandbahale, Pachorkar, 2025). The rapid development of electronic communication methods will undoubtedly force Polish legislators to amend the organisation of GMs and permit virtual formats in future (Szumański, 2020). However, it is crucial to maintain a balance between the technology used and the legal security of the company and its GM participants (OECD, 2023, 2025a, 2025b). Introducing digital solutions to the organisation of GMs undoubtedly strengthens the company's compliance system by increasing transparency, improving corporate communication, enabling more effective formal and legal control, and ensuring more comprehensive documentation of decision-making processes (Khandbahale, Pachorkar, 2025, pp. 103-104). However, digitisation also poses cybersecurity and personal data protection challenges. Protecting sensitive information is becoming increasingly important, as is the need for encrypted communication channels and multi-factor authentication. Regular security audits are also becoming essential as they enable potential threats to be identified and mitigated continuously (Khandbahale, Pachorkar, 2025, p. 104). Therefore, a company's digitisation processes must take into account issues related to its legal security and that of its stakeholders.

In the context of the above considerations and trends in business process digitisation, however, a de lege ferenda proposal can be formulated. It seems reasonable to clarify Article 406(5), §1 of the CCC by explicitly stating that the convener of the GM may decide to exclude shareholders or their proxies from attending the meeting in person, provided they are given the opportunity to exercise their rights electronically during the meeting.

References

1. Abdennadher, S., Cheffi, W. (2020). The effectiveness of e-corporate governance: An exploratory study of internet voting at shareholders' annual meetings in France. *Corporate Governance: The International Journal of Business in Society*, *20*(4), 673-702. https://doi.org/10.1108/CG-04-2019-0116
2. ASIC (2021, August 18). *ASIC guidelines for investor meetings using virtual technology* [News item]. Retrieved from: https://www.asic.gov.au/, 04.11.2025.
3. Babbie, E. (2009). *Podstawy badań społecznych*. Warszawa: PWN.
4. Brochet, F., Chychyla, R., Ferri, F. (2023). Virtual Shareholder Meetings. *University of Miami Legal Studies Research Paper, No. 3743064. European Corporate Governance*

Institute – Finance Working Paper No. 777/2021, Management Science, Forthcoming. https://doi.org/10.2139/ssrn.3743064

5. Buellingen, M.C. (2019, October 10). *Virtual Shareholder Meetings in the U.S. The Harvard Law School Forum on Corporate Governance website*. Retrieved from: https://corpgov.law.harvard.edu/2019/10/10/virtual-shareholder-meetings-in-the-u-s/, 21.07.2025.
6. Chauvin, T., Stawecki, T., Winczorek, P. (2014). *Wstęp do prawoznawstwa* (9th edn). Warszawa: C.H. Beck.
7. Committee on the Financial Aspects of Corporate Governance (1992). *Report of the Committee on the Financial Aspects of Corporate Governance*. London: The Committee on the Financial Aspects of Corporate Governance and Gee and Co. Ltd., Burgess Science Press. Retrieved from: https://www.frc.org.uk/library/standards-codes-policy/corporate-governance/corporate-governance-overview/, 07.11.2025.
8. DeepL SE (n.d.a). *Tłumacz DeepL*, https://www.deepl.com/pl/translator.
9. DeepL SE. (n.d.b). *DeepL Write*, https://www.deepl.com/pl/write.
10. Denis, E., Blume, D. (2021). *Using digital technologies to strengthen shareholder participation* (No. 9). Paris: Organisation for Economic Co-Operation and Development (OECD). OECD Publishing. https://doi.org/10.1787/0fe52016-en
11. Dumkiewicz, M. (2024). *Kodeks spółek handlowych: Komentarz* (2nd edn). Warszawa: Wolters Kluwer.
12. European Commission (n.d.). *Company law and corporate governance—European Commission.* Retrieved from: https://commission.europa.eu/business-economy-euro/doing-business-eu/company-law-and-corporate-governance_en, 25.10.2025.
13. Fontenot, L.A. (2018). Public Company Virtual-Only Annual Meetings. *The Business Lawyer*, *73*(Winter 2017-2018), 35-51.
14. FRC (2020). *Corporate Governance AGMs: An Opportunity For Change*. London: Financial Reporting Council. Retrieved from: www.frc.org.uk, 21.07.2025.
15. Gesetze im Internet (2024). *Aktiengesetz vom 6. September 1965 (BGBl. I S. 1089), das zuletzt durch Artikel 18 des Gesetzes vom 23. Oktober 2024 (BGBl. 2024 I Nr. 323) geändert worden ist*. Retrieved from: https://www.gesetze-im-internet.de/aktg/BJNR010890965.html?utm, 25.10.2025.
16. Horwath, O. (2007). Elektroniczne walne zgromadzenie w świetle regulacji dyrektywy 2007/36/WE oraz prawa polskiego. *Transformacje Prawa Prywatnego*, *3-4*, 45-74.
17. ICLEG (2022). *Report on virtual shareholder meetings and efficient shareholder communication*. The Informal Company Law Expert Group. European Commission. Retrieved from: https://commission.europa.eu/business-economy-euro/doing-business-

eu/company-law-and-corporate-governance_en#expert-groups-and-stakeholder-platforms, 18.07.2025.

18. ISAP (2024). *Ustawa z dnia 15 września 2000 r. Kodeks spółek handlowych (Dz. U. 2024 poz. 18, 96.)*. Retrieved from: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20240000018, 25.10.2025.
19. Khandbahale, S., Pachorkar, S. (2025). *Corporate Governance Essentials: From Theory to Practice*. Wrocław: Amazon Fulfillment Poland Sp. z o.o.
20. Kidyba, A. (2025). art. 406(5). In: A. Kidyba, *Komentarz aktualizowany do art. 301-633 Kodeksu spółek handlowych*. LEX/el. Retrieved from: https://sip.lex.pl/#/commentary/587251282/785219/kidyba-andrzej-komentarz-aktualizowany-do-art-301-633-kodeksu-spolek-handlowych?cm=URELATIONS, 31.10.2025.
21. Laptev, V.A., Feyzrakhmanova, D.R. (2021). Digitalization of Institutions of Corporate Law: Current Trends and Future Prospects. *Laws*, *10*(4), 93. https://doi.org/10.3390/laws10040093
22. Łazarewicz, S. (2021). Glosa do wyroku Sądu Najwyższego z 6 czerwca 2018 r., III CSK 403/16, dotycząca niedopuszczenia wspólnika do udziału w zgromadzeniu spółki kapitałowej jako przyczyny stwierdzenia nieważności podjętych uchwał. *Studia Prawnoustrojowe*, *53*. https://doi.org/10.31648/sp.6896
23. Leśniak, M. (2020a). *Rekomendacja dobrych praktyk notarialnych*. Ministerstwo Aktywów Państwowych, Ministerstwo Sprawiedliwości, Notariat Rzeczpospolitej. Retrieved from: https://krn.org.pl/static/upload/store/test/Rekomendacja_dobrych_praktyk_notarialnych.pdf, 16.09.2025.
24. Leśniak, M. (2020b). Udział w zgromadzeniu spółki kapitałowej za pomocą środków komunikacji elektronicznej po zmianach Kodeksu spółek handlowych dokonanych w ramach tzw. tarczy antykryzysowej. *Prawo Mediów Elektronicznych*, *2*, 20-24.
25. Magnusson, C.M., Blume, D. (2022). *Digitalisation and corporate governance* (No. 26). Paris: Organisation for Economic Co-Operation and Development (OECD). OECD Publishing. https://doi.org/10.1787/296d219f-en
26. Mazgaj, M. (2022). Wirtualne zgromadzenia w spółkach kapitałowych. *Annales Universitatis Paedagogicae Cracoviensis, Studia de Cultura*, *14*(1), 140-149. https://doi.org/10.24917/20837275.14.1.10
27. Michalski, M. (2020). Art. 406(5). In: A. Kidyba, J. Frąckowiak, K. Kopaczyńska-Pieczniak, M. Michalski, A.J. Witosz (Eds), *Kodeks spółek handlowych. T. 3: Komentarz do art. 301-490* (pp. 600-610). Warszawa: Wolters Kluwer.
28. Modrzejewski, J., Wiśniewski, C. (2016). Walne zgromadzenie. In: J. Okolski, M. Modrzejewska (Eds), *Prawo handlowe* (pp. 390-403). Warszawa: Wolters Kluwer.

29. Nili, Y., Shaner, M.W. (2022). Virtual Annual Meetings: A Path Toward Shareholder Democracy and Stakeholder Engagement. *Boston College Law Review*, *63*(1), 123-198.
30. OECD (2015). *Digital Security Risk Management for Economic and Social Prosperity: OECD Recommendation and Companion Document*. Paris: OECD Publishing. https://doi.org/10.1787/9789264245471-en
31. OECD (2019). *Going Digital: Shaping Policies, Improving Lives*. Paris: OECD Publishing. https://doi.org/10.1787/9789264312012-en
32. OECD (2023). *G20/OECD Principles of Corporate Governance 2023*. Paris: OECD Publishing. https://doi.org/10.1787/ed750b30-en
33. OECD (2025a). *OECD Corporate Governance Factbook 2025*. Paris: OECD Publishing. https://doi.org/10.1787/f4f43735-en
34. OECD (2025b). *Recommendation of the Council on Digital Security of Critical Activities, OECD/LEGAL/0456*. Paris: OECD Publishing.
35. Panisi, F., Buckley, R.P., Arner, D. (2019). Blockchain and Public Companies: A Revolution in Share Ownership Transparency, Proxy Voting and Corporate Governance? *Stanford Journal of Blockchain Law & Policy*, *2.2*, 189-220.
36. Shleifer, A., Vishny, R.W. (1997). A Survey of Corporate Governance. *The Journal of Finance*, *52*(2), 737-783. https://doi.org/10.1111/j.1540-6261.1997.tb04820.x
37. SN (2018). *Wyrok Sądu Najwyższego z dnia 6 czerwca 2018 r. III CSK 403/16. Skutki niedopuszczenia akcjonariusza do udziału w walnym zgromadzeniu. Uniemożliwienie wstępu przedstawicieli akcjonariusza na salę obrad walnego zgromadzenia jako przesłanka stwierdzenia nieważności uchwał podjętych na tym zgromadzeniu. LEX nr 2557164.* Retrieved from: https://sip.lex.pl/#/jurisprudence/522650860, 31.10.2025.
38. Szczepańska, K., Ryszkowski, K. (2025). Problem adekwatności rozwiązań prawnych przyjętych przez polskiego ustawodawcę dla zgromadzeń online wspólników spółek kapitałowych – ze szczególnym uwzględnieniem regulacji dotyczących prostej spółki akcyjnej. *Białostockie Studia Prawnicze*, *30*(3), 37-55. https://doi.org/10.15290/bsp.2025.30.03.03
39. Szumański, A. (2020). Nowa regulacja udziału w zgromadzeniu spółki kapitałowej przy wykorzystaniu środków komunikacji elektronicznej. *Przegląd Prawa Handlowego*, *maj*, 4-14.
40. Tamowicz, P., Dzierżanowski, M. (2002). *Biała księga nadzoru korporacyjnego*. Gdańsk: Instytut Badań nad Gospodarką Rynkowa.
41. The Best Practices Committee for Shareowner Participation in Virtual Annual Meetings (2018). *Principles and Best Practices for Virtual Annual Shareowner Meetings*. Broadridge Financial Solutions, Inc. Retrieved from: https://www.broadridge.com/_assets/pdf/broadridge-vasm-guide.pdf, 21.07.2025.

42. Tricker, B. (2025). *Corporate Governance. Principles, policies, and practices* (5th edn). Oxford: Oxford University Press.
43. Uliasz, R. (2024). Rola notariusza na zgromadzeniu spółki kapitałowej a sprzeczność uchwał tego zgromadzenia z prawem - uwagi de lege lata i de lege ferenda. *Rejent*, *3*(395), 81-103.
44. Van Der Elst, C., Lafarre, A. (2017). Bringing the AGM to the 21st Century: Blockchain and Smart Contracting Tech for Shareholder Involvement. *European Corporate Governance Institute (ECGI) - Law Working Paper, No. 358/2017*. https://doi.org/10.2139/ssrn.2992804

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IMPROVING ENVIRONMENTAL COMMUNICATION. OVERVIEW OF DIRECTIONS AND RECOMMENDATIONS

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Purpose: The aim was to review the latest research on environmental labels and present directions for improving the communication process resulting from this research.
Design/methodology/approach: A library search and systematic literature review were used to achieve the objective. Thematic categorization was performed to group the results into logical sets.
Findings: The results of the study made it possible to identify and categorize directions and recommendations for improving and perfecting environmental labelling systems. The analysis identified seven areas requiring improvement and refinement. These are: the scope and rigour of ecolabel standards, the graphic design and presentation of the label, the trustworthiness and credibility of the standard, public policy and incentive instruments for producers, the adaptation of labels to a diverse consumer market, information campaigns and public education, and measures targeting producers and supply chain operators.
Research limitations/implications: In order to reduce the limitations of these studies in the future, it is recommended to extend the period of time covered by the studies and to search additional publication databases.
Practical implications: The results of this study highlight the need for continuous improvement and refinement of environmental communication systems. An analysis of the latest research in this field has identified many areas where ecolabels could perform even better. The recommendations collected have been grouped into seven thematic areas. The results of the article are a valuable resource for decision-makers and certification bodies, indicating what improvement measures should be implemented.
Originality/value: The paper presents an original approach, based on a systematic review of the literature, to identifying, synthesizing and highlighting areas of environmental communication that need to be improved in order to adapt requirements to changing conditions.
Keywords: ecolabels, market communication, sustainable development, environment, systematic literature review.
Category of the paper: Literature review.

1. Introduction

The growing concern and anxiety about the environment observed in developed countries is contributing to increased pressure for the multilevel implementation of sustainable development (Alhamdi, Al-Kahtani, Abdullah, 2024). Climate change and progressive environmental degradation are forcing action toward more responsible consumption patterns and responsible production and business practices (Al-Swidi et al., 2022). At a time of growing concern and anxiety about environmental issues, market-based enterprises in particular should not only monitor their activities and impact on the environment, but above all must take full responsibility for the environmental and social consequences of their operations (Nyamtseren, Feng, Deo, 2018).

Organisations that fail to respect social expectations regarding environmental protection will lose their competitive advantage, both in the local and international markets (Cerciello, Busato, Taddeo, 2022). Understanding this mechanism will very quickly translate into a change in corporate management strategy, which will increasingly focus on implementing sustainable development requirements (Wang, Sueyoshi, 2018).

Research conducted by Xin et al. (2025) indicates that manufacturers should prioritize investments in energy-efficient and green technologies. This approach provides an opportunity to strengthen and consolidate the company's market position in relation to inefficient manufacturers (Xin et al., 2025).

Governments and supranational organisations focus their efforts on shaping and stimulating environmental awareness among consumers. Their goal is to promote and highlight sustainable products and environmental practices in order to encourage their purchase (Alhamdi, Al-Kahtani, Abdullah, 2024). These measures are more effective among people who are aware of climate change and threats and make purchasing decisions based on environmental factors. Their opposites are consumers who are not sensitive and do not pay attention to environmental protection and sustainable development issues (Chen, Shang, Li, 2014).

Certification systems and environmental labels have been introduced to support the pursuit of sustainable development goals. They are tools used to guide choices and encourage market participants to adopt sustainable practices (Ceballos-Santos et al., 2025). These voluntary programs aim, among other things, to raise consumer awareness of environmental issues and allow comparison of products on offer.

Despite the large number of studies, there is a lack of publications that address the subject of environmental communication in a comprehensive and holistic manner. This is a gap that arises from an analysis of the literature on the subject. There are a significant number of studies that focus on individual elements of the communication process. However, there is a lack of a comprehensive analysis and presentation of the latest research and the resulting directions to improve the environmental communication process. Conducting a comprehensive review and

verification of the latest research fills this gap. Research is needed to condense and accumulate the latest knowledge and research achievements related to environmental labels.

To support the achievement of this objective, the research question RQ1 was adopted: What are the directions to improve the environmental communication process? This article consists of an introduction, literature review, methodology, results, discussion, and conclusion.

2. Literature review

Ecolabels inform consumers about the environmental impact of a given product. They confirm that the certification process has been completed (Balzarova, 2021). Ecolabels and other forms of environmental information are used to attract consumers' attention and interest (Srinivasan, 2025). Another direction and additional effect is the attempt to make the purchase act fully credible and consistent with the declared properties.

According to Spence's signalling theory describing how companies convey information, consumers face information asymmetry. Ecolabels allow consumers' information expectations to be met. This in turn contributes to the expansion of the market for new customer groups, increased demand, and sales (Bukharii et al., 2025).

The positive effects of the labeling systems implemented are products that appear on the market that do not contain undesirable or harmful ingredients. For example, palm oil, pesticides, GMOs, parabens, etc. (Brécard, Chiroleu-Assouline, 2025). Environmental labeling also allows active reduction of waste and emissions, as well as significant improvement in the efficiency of input resource consumption (Brandi 2017; Ojiako et al., 2024).

Other benefits and implications of the increasingly widespread use of ecolabels include consumer education. Some consumers shape their preferences based on the information on the labels. This applies, for example, to the harmfulness of a given ingredient. Given such experiences, consumers are more aware and willing to pay for certified and labelled products.

This mechanism has been recognised by large retail chains (Reardon et al., 2024). To rapidly increase the sales of eco-labelled products, these entities are increasingly requiring their suppliers to provide larger quantities of certified products (Reardon et al., 2024). Research by Bukhari et al. (2025) on voluntary labelling schemes confirms that their implementation is an important strategy for increasing market competitiveness locally and internationally. These strategies are particularly beneficial in developing economies.

However, not all experiences with environmental labelling systems are always positive. It is difficult to assess the extent to which they fulfil their purpose (Vlaeminck, Vandoren, Vranken, 2014). Problems in performing a full and comprehensive impact analysis stem from insufficient data, a lack of standardised documentation, and limited access due to confidentiality rights (Balzarova, Cohen, 2020). Another problem is the destabilisation of the environmental

labelling system due to so-called ‘greenwashing’ and misleading labelling. This poses a threat due to the atmosphere of uncertainty, anxiety, and misunderstanding among consumers.

Another weakness of eco-labelling is that the vast majority of ecolabels only verify one-dimensional standards and requirements that mainly focus on environmental aspects. Considering the pillars of sustainable development, which are the environment, the economy, and society, the prevailing approach is strongly and disproportionately focused on environmental aspects (Wognum et al., 2011). Undoubtedly, the full implementation of sustainable development principles cannot ignore economic and social aspects.

To better complement all aspects of sustainable development, eco-labelling should take the form of a vertically integrated, multidimensional framework that evenly combines environmental, social, and economic aspects (Chandan et al., 2025). This approach will provide the best guarantee for building consumer confidence, promoting the circular economy as the best form of rational and sustainable use of resources, and minimising waste.

3. Methodology

A library search was conducted to achieve the research objective. A systematic literature review methodology was used to examine the directions to improve environmental labelling systems. The search criteria were selected based on defined criteria to achieve the research objective. The search was conducted in a structured manner. It was based on sources from the Scopus database, using the keyword ‘ecolabel’. This term was searched for in the title, abstract, or keywords of peer-reviewed publications.

Due to the need to keep the topic highly topical and the high probability of obtaining a very large number of results, the search was limited to scientific articles published in 2024 and 2025. This also ensured that the sources were of great relevance. The study focused on such a short period of time to capture the most recent and current trends. This approach allowed us to avoid outdated articles.

In order to select data obtained from the Scopus database, a multistage verification process was used to ensure that the results were consistent with the objective of the study. The selection of articles was based on the methodology and guidelines of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Moher et al., 2009). Both authors carefully reviewed publications that met the review criteria to remove those that did not fit the scope and purpose of the study. Given the large number of publications on eco-labelling, a horizontal approach was taken to identify areas for improvement in labelling, focusing mainly on solutions with a wide scope and applicability. The database was searched and the publications reviewed between October and November 2025. The exclusion criteria defined and adopted in this review were taken into account:

– language (only publications in English were included),
– type of document (only peer-reviewed research publications, excluding review papers),
– the subject area (only if the main topic was environmental labelling and ecolabels).

Only manuscripts that met all of the above criteria were considered eligible and included in the review. Therefore, the criteria for selecting the literature should be considered to meet the conditions of a systematic, repeatable, and transparent research procedure. The procedure used is presented in Figure 1.

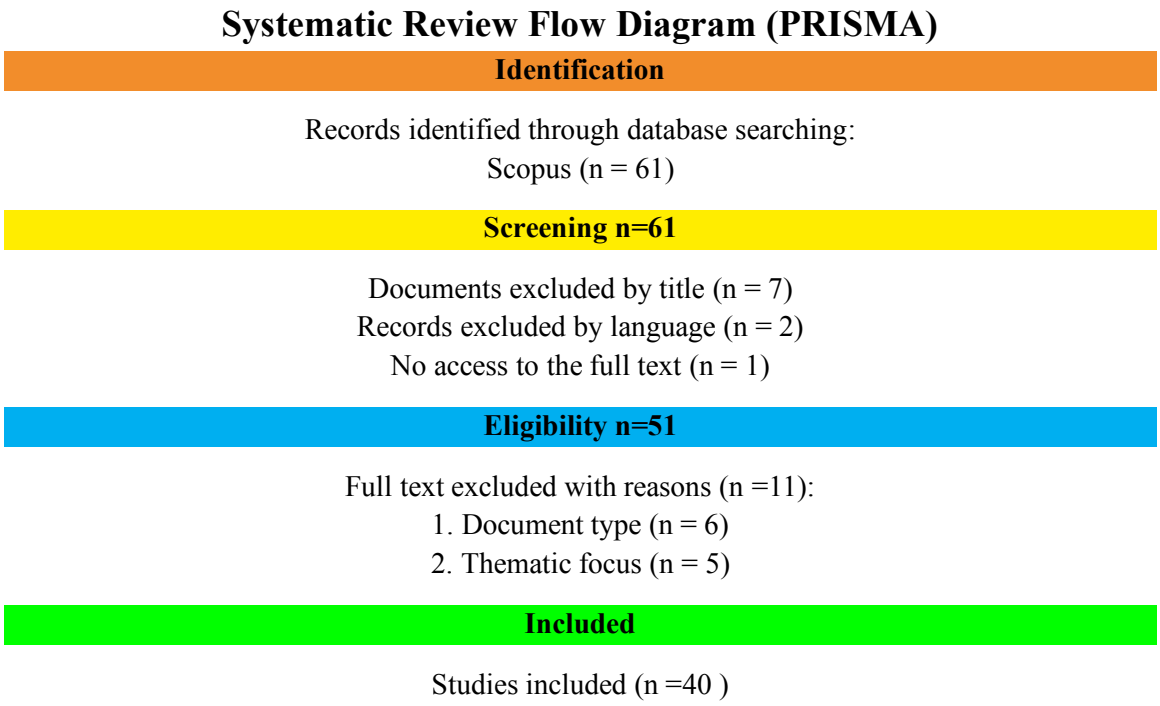


Figure 1. The procedure used to select manuscripts.

Source: own study based on (Moher et al., 2009).

A total of 61 articles were identified, including 6 review articles, 2 without an English version, and 1 without access to the full version. A multistage source selection process was used in accordance with the accepted review principles and research objectives. Finally, 40 articles were selected to serve as source material for this study.

After analysing the research articles relevant to the objective of the study, evaluating and assimilating the data, the most important conclusions are presented below.

4. Results

The narrative literature review allowed us to select trends in eco-labelling and environmental communication improvement from the latest scientific literature. From among the areas identified in the course of scientific research, suggestions for their improvement were

formulated and grouped into several more general categories. For this purpose, thematic categorisation was carried out to group the research results into logical sets (Braun, Clarke, 2022). The analytical categories created concern recommendations for improving and enhancing eco-labelling systems in the following areas:

- the scope and rigour of ecolabel standards,
- the graphic design and presentation of the label,
- the trustworthiness and credibility of the standard,
- public policy and incentive instruments for producers,
- adaptation of labels to a diverse consumer market,
- information campaigns and public education,
- actions towards producers and supply chain entities.

The first of the analytical categories refers to the requirements imposed on entities applying for certification, the completeness of the environmental impact assessments, and the degree of standardisation of the labelling system. These recommendations, which are the result of scientific research, propose that the certification system should be based on more stringent requirements, even at the cost of fewer companies being able to meet them (Zhao, Dunan, 2025; Cadrin, Nakatsuka, 2024). In addition, other recommendations for improving environmental labelling systems include the proposal to expand the assessment criteria to include aspects such as biodiversity loss, water consumption, and selected socioeconomic indicators (Ceballos-Santos et al., 2024; Wang et al., 2024). Attention is also drawn to the need to extend certification to new product groups (Desaulniers, Brousseau, 2024).

The next analytical category groups recommendations from the literature on the graphic design and presentation of ecolabels. These concern the way in which environmental information is presented, organised, and made available to consumers. Due to changes in retail channels, this issue also applies to presentation in online stores (Rafael, Pires, Simões, 2025). The studies analysed in this category recommend increasing legibility and using an intuitive format (Hay et al., 2024). R. Yuan and Z. Tang (2024) propose the use of a 'traffic light' system, which is very accessible and understandable to consumers. Furthermore, it is recommended to expand the scope of information presented on the label to include, for example, the region of origin or the production process, which allows for a better assessment of the sustainability of the product (Pablo-Cano et al., 2024). It is also pointed out that the choice of form and method of communication should be varied depending on the product category (Tanaka et al., 2024). In addition to these aspects, attention is drawn to the role of labels in online sales (Houf, Szymkowiak, Shepherd, 2024) and their presentation at the point of purchase, such as restaurants (Fang, Gao, Zhang, 2024).

The third analytical category brings together the results of research that has led to the development of recommendations to improve the credibility and trustworthiness of labelling systems. The issues grouped here concern the actions that need to be taken to create an image

of ecolabels as reliable tools for providing information about a given product or service. To achieve this goal, transparency must be ensured throughout the entire product supply chain, involving all participants (Damberg et al., 2024). The literature emphasises the importance of Cradle-to-Cradle Certified® certificates. The credibility of ecolabels depends on specific and precise information, presented in a clear and consistent manner (Alhamdi, Al-Kahtani, Abdullah, 2024). This builds consumer confidence in the actual sustainability of the product, rather than just declarations. Authors such as Chandan et al. (2025) propose the implementation of advanced solutions such as blockchain to enable product traceability and monitoring of environmental criteria compliance. Another important direction is the standardisation of environmental data in product databases (e.g., EBM), which will further strengthen the system by enabling the comparability and verifiability of declarations (Pham et al., 2024). These recommendations are intended to directly strengthen confidence in the environmental certification system and minimize the phenomenon of 'greenwash' (Bottega et al., 2024).

The fourth category concerns the role of the state, decision-makers, and public institutions. In this case, the authors of scientific studies point to the need to create conditions conducive to the development and dissemination of environmental labelling systems. Bukhari et al. (2025) emphasise that the promotion of voluntary environmental standards by governments should be supported and implemented. Some researchers argue that it would be necessary to provide fiscal and financial support to companies that join certification systems. This could even include the creation of a system of tax incentives for such companies (Dias et al., 2024). Another axis of support and promotion by governments is public procurement. The use of the concept of green public procurement to increase the presence of eco-certified products and services is also a proposed measure (Ullah et al., 2024). It is pointed out that the systematic inclusion of environmental requirements in public tenders may increase market players' interest in certification. This will generally contribute to its widespread use. Further directions for improving the environmental communication system through ecolabels include government measures aimed at shaping energy demand. This can be achieved through standards or labeling programs, where it will serve more as a tool for managing energy consumption in households (Twerefou et al., 2025).

The results of the studies grouped in this category confirm that without the involvement of governments and public policy, the potential of ecolabels as tools for supporting sustainable development will remain largely untapped.

The fifth category groups studies on the adaptation of labels to a diverse consumer market. These studies aimed to determine the form and content of ecolabels for different consumer segments, product characteristics, and purchasing contexts. Current research indicates that the effectiveness of labels is not uniform. Both willingness to pay (WTP) and sensitivity to information vary depending on the target group (Völker, Oestreich, Meyerding, 2025; Kitano, Horie, Yamamoto, 2025). The literature also points to the diversity of labelling systems within product groups, which can be beneficial if consumers have sufficient knowledge to understand

and interpret these differences (Wakamatsu, Maruyama, 2024). In summary, this category groups together studies on the design of eco-labelling in a differentiated and adaptive manner, rather than in a uniform manner. Such a postulate may be difficult or even impossible to implement. However, heterogeneous consumer profiles and the significant specificity of individual markets and distribution channels seem to confirm this need.

The sixth category of recommended areas for improvement in environmental communication concerns issues related to information campaigns and public education. These activities include initiatives aimed at giving ec0labels a real informational function. The results of the analysed studies confirm that labels should be consciously designed communication tools, widely supported and accompanied by information campaigns (Brécard, Chiroleu-Assouline, 2025). These campaigns increase the recognition of environmental labels, explain their meaning, and reduce consumer uncertainty and distrust. The results show that providing reliable information significantly increases the willingness to pay for a product bearing an ecolabel (Kitano, Horie, Yamamoto, 2025). Another area within this category is the need for systematic education and promotion of environmental certification systems (Yao et al., 2024). It is often stated that the gap between consumer perceptions and actual behaviour is due to insufficient information about sustainable practices and manufacturer certifications. Therefore, it is recommended to improve the presentation of information at the point of purchase, on websites, and in marketing materials. According to research by Bottega et al. (2024), decision makers should subsidise informational advertisements that explain the content and meaning of labels in the interest of the common good.

The last analytical category proposed was a group of studies on recommendations for producers and supply chain entities. It includes the results of research that focused on the behaviour of entities on the production side and the organisation and management of the entire supply chain. The analysed studies show that ecolabels and certification should also be treated as tools for shaping economic and development incentives for producers (Kesselring, 2025; Xin et al., 2025). The work of Sogn-Grundvåg et al. (2025) draws attention to the need to share the benefits of certification fairly with other participants in the supply chain. This is so that they are also encouraged and motivated to implement more sustainable practices. Research findings in the literature point out that manufacturers with higher environmental efficiency of their processes should prioritise investment in sustainable technologies and actively use ecolabels as a competitive advantage in environmentally sensitive markets (Xin et al. 2025). Another important issue is the role of transitional programs and national certification systems. As indicated by the research by Wakamatsu and Maruyama (2024), such solutions can bring high benefits and enable manufacturers to gradually recover the costs incurred for sustainable practices even during the certification process.

5. Discussion

Through the analysis and observations resulting from the research, several gaps in the current eco-labelling systems were identified. Thus, the research conducted allowed us to answer the research question RQ1: What are the directions for improving the environmental communication process? and, as a result, to identify the following areas for improvement and refinement of eco-labelling systems:

- the scope and rigour of ecolabel standards,
- graphic design and presentation of the label,
- the trustworthiness and credibility of the standard,
- public policy and incentive instruments for producers,
- adaptation of labels to a diverse consumer market,
- information campaigns and public education,
- – actions towards producers and supply chain entities.

These data are consistent with the findings of other scholars (Plakantonaki et al., 2023; Reardon et al., 2024; Ceballos-Santos et al., 2025; Srinivasan, 2025). However, in this study they are much more comprehensive and up-to-date. Reardon et al. (2024) identified critical gaps and areas for improvement such as lack of representativeness, incomplete assessment, and unintuitive communication with consumers. The directions identified in this study are, in a sense, consistent with what we observe in the literature on the subject.

Undoubtedly, the need to build trust and promote ecolabels, as indicated in many positions, is one of the fundamental conditions for the success of environmental communication initiatives.

This study creates a framework and categorises areas for the improvement of ecolabels based on the most up-to-date and latest data. Thus, this research gap is filled, and this work precisely identifies and describes the directions for improvement. In turn, in the work of Plakantonaki et al. (2023), they propose increasing government involvement and activities related to defining and enforcing environmental standards as key efforts toward improving the eco-labelling system. Other recommendations included educating consumers and systematically encouraging them to make sustainable purchasing decisions. Other researchers, such as Grolleau et al. (2015) propose supplementing regional, national, and international policies with issues related to ecolabels and increasing research on the effectiveness of ecolabels by the academic community.

6. Conclusions

This manuscript is the result of a review of the literature aimed at identifying and defining the main directions for improving the environmental communication process. Given the global importance of sustainability issues, this topic is very important from the point of view of both consumers and companies as market participants. The results of this study identify, synthesize, and assist decision makers and certification bodies in choosing directions for improving and refining environmental labelling systems. The analysis carried out has identified seven key categories within which action should be taken. These relate to different areas, which means that a systemic approach is required for their implementation. From the current perspective, it is difficult to assess which directions are the most important, but their effectiveness should be measured by improving objective environmental indicators.

The studies cited in this review indicate a wide scope for possible improvements. Gradual modification of environmental certification systems is necessary to strengthen trust, guide consumer demand, and keep pace with a changing world. Interestingly, a significant number of improvements were related to the scope of competence that is directly within the scope of certification bodies. The proposed requirement to improve the quality of eco-labelling, accompanied by reliable information on the ecolabel, helps to build consumer confidence. Entrepreneurs and management staff can also draw important suggestions and conclusions from this review. Above all, the data presented show that increased commitment and efforts toward environmental certification help to build a positive image and reputation for companies.

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References

1. Alhamdi, F.M., Al-Kahtani, S.M., Abdullah, E.A.M.F. (2024). Saudi women's attitude towards environmental marketing and its relationship to purchasing behavior. *Discover Sustainability, Vol. 5, Iss. 514*, doi: https://doi.org/10.1007/s43621-024-00784-4
2. Al-Swidi, A.K., Al-Hakimi, M.A., Gelaidan, H.M., Al-Temimi, S.K.A. (2022). How does consumer pressure affect green innovation of manufacturing SMEs in the presence of green

human resource management and green values? A moderated mediation analysis. *Business Ethics, the Environment & Responsibility*, *Vol. 31, No. 4,* pp. 1157-1173, doi: https://doi.org/10.1111/beer.12459

3. Balzarova, M.A. (2021). Blockchain technology – a new era of ecolabelling schemes? *Corporate Governance*, *Vol. 21, No. 1,* pp. 159-174, doi: https://doi.org/10.1108/CG-08-2020-0328
4. Balzarova, M.A., Cohen, D.A. (2020). The blockchain technology conundrum: quis custodiet Ipsos custodes? *Current Opinion in Environmental Sustainability*, *Vol. 45,* pp. 42-48, doi: https://doi.org/10.1016/j.cosust.2020.08.016
5. Bottega, L., Brécard, D., Delacote, P. (2024). Advertising, ecolabeling and consumers' beliefs: Greenwashing or not? *Economics Letters*, *Vol. 235,* doi: https://doi.org/10.1016/j.econlet.2023.111513
6. Brandi, C.A. (2017). Sustainability Standards and Sustainable Development–Synergies and Trade-Offsof Transnational Governance. *Sustainable Development*, *Vol. 25, No. 1,* pp. 25-34, doi: https://doi.org/10.1002/sd.1639
7. Braun, V., Clarke, V. (2022). *Thematic analysis: A practical guide.* Los Angeles: Sage.
8. Brécard, D., Chiroleu- Assouline, M. (2024). Information campaigns and ecolabels by environmental NGOs: Effective strategies to eliminate environmentally harmful components? *Journal of Economics & Management Strategy*, *Vol. 34, Iss. 2,* pp. 277-308, doi: https://doi.org/10.1111/jems.12595
9. Bukhari, A.A.A., Bukhari, W.A.A., Hayat, N., Troise, C., Bresciani, S. (2025). The Impact of Voluntary Environmental Standards on Domestic and Foreign Sales Growth: Evidence From Pakistan. *Sustainable Development*, *Vol. 33, Iss. 3,* pp. 3495-3510, doi: https://doi.org/10.1002/sd.3301
10. Cadrin, S.X., Nakatsuka, S. (2024). Marine Stewardship Council's Fisheries Standard: Updated best practices for promoting sustainable seafood. *Marine Policy*, *Vol. 163,* 106083, doi: https://doi.org/10.1016/j.marpol.2024.106083
11. Ceballos-Santos, S., Entrena-Barbero, E., Laso, J., Margallo, M., González-García, S., Moreira, M.T., Almeida, C., Marques, A., Quinteiro, P., Dias, A.C., Loubet, P., Erradhouani, B., Baptista de Sousa, D.A., Feijoo, G., Aldaco, R. (2024). Applying a water-energy-food nexus approach to seafood products from the European Atlantic area. *Journal of Cleaner Production*, *Vol. 163,* 140804, doi: https://doi.org/10.1016/j.jclepro.2024.140804
12. Ceballos-Santos, S., Martínez-Ibáñez, E., Laso, J., Bala, A., Fullana-i-Palmer, P., Margallo, M., Aldaco, R. (2025). Ecolabels and sustainability in the seafood sector: Key elements of the debate and shortcomings. *ACS Environmental Au*, *Vol. 5, Iss. 4,* pp. 330-341, doi: 10.1021/acsenvironau.5c00019
13. Cerciello, M., Busato, F., Taddeo, S. (2022). The effect of sustainable business practices on profitability. Accounting for strategic disclosure. *Corporate Social Responsibility and*

Environmental Management, *Vol. 30, Iss. 2,* pp. 802-819, doi: https://doi.org/10.1002/csr.2389

14. Chandan, A., Potdar, V., John, M. (2025). Enhancing sustainability in food supply Chain: a blockchain-based. Sustainability information management and reporting system. *Sustainability*, *Vol. 17, Iss. 17,* p. 8054, doi: https://doi.org/10.3390/su17178054
15. Chen, Y.C., Shang, R.A., Li, M.J. (2014). The effects of perceived relevance of travel blogs' content on the behavioral intention to visit a tourist destination. *Computers in Human Behavior*, *Vol. 30,* pp. 787-799, doi: https://doi.org/10.1016/j.chb.2013.05.019
16. Damberg, S., Saari, U.A., Fritz, M., Dlugoborskyte, V., Božič, K. (2024). Consumers' purchase behavior of Cradle to Cradle Certified® products - The role of trust and supply chain transparency. *Business Strategy and the Environment*, *Vol. 33, Iss. 8,* pp. 8280-8299, doi: https://doi.org/10.1002/bse.3919
17. Desaulniers Brousseau, V., Goldstein, B.P., Lachapelle, M., Tazi, I., Lefsrud, M. (2024). Greener green: The environmental impacts of the Canadian cannabis industry. *Resources*, *Conservation and Recycling*, *Vol. 208,* 107737, doi: https://doi.org/10.1016/j.resconrec.2024.107737
18. Dias, F., Lavaredas, A.M., Esteves, P. (2024). What is the value of an environmental certification label in tourism industry? Is it worth the effort? *Sustainability*, *Vol. 16, No. 19,* p. 8587, doi: https://doi.org/10.3390/su16198587
19. Fang, Y., Gao, Z., Zhang, X. (2024). Is there a demand for eco-labeled restaurants: Consumer preference and willingness to pay for eco-labeled seafood restaurants. *Aquaculture Economics & Management*, *Vol. 28, Iss. 4,* pp. 552-576, doi: https://doi.org/10.1080/13657305.2024.2368782
20. Grolleau, G., Ibanez, L., Mzoughi, N., Teisl, M. (2016). Helping eco-labels to fulfil their promises. *Climate Policy*, *Vol. 16, Iss 6,* pp. 792-802. https://doi.org/10.1080/14693062.2015.1033675
21. Hay, C., Meyer, K., Rutherford-Carr, G., Hill, J.P., Hort, J. (2024). Taking a Consumer-Led Approach to Identify Key Characteristics of an Effective Ecolabelling Scheme. *Sustainability*, *Vol. 16, No. 14,* p. 6260, doi: https://doi.org/10.3390/su16146260
22. Houf, L., Szymkowiak, A., Shepherd, L.A. (2024). Promotion of sustainable products: Can sustainability labels promote user selection of environmentally friendly products? *Sustainability*, *Vol. 16, No. 13,* p. 5390, doi: https://doi.org/10.3390/su16135390
23. Kesselring, A. (2025). Energy labels in the European Union: Consumer inattention and producer responses. *Energy Economics*, *Vol. 144*, 108275, doi: https://doi.org/10.1016/j.eneco.2025.108275
24. Kitano, S., Horie, R., Yamamoto, N. (2025). Effect of fishery information provision on sustainable consumption. *Journal of International Food & Agribusiness Marketing*, pp. 1-19, doi: https://doi.org/10.1080/08974438.2025.2501987

25. Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., Prisma Group (2009). Preferred reporting items for systematic reviews and metaanalyses: The PRISMA statement. *PLoS Med., 2009 Jul 21, 6(7),* e1000097. Epub 2009 Jul 21. PMID: 19621072; PMCID: PMC2707599, doi: 10.1371/journal.pmed.1000097
26. Nyamtseren, M., Feng, Q., Deo, R.A. (2018). Comparative study of temperature and precipitation-based aridity indices and their trends in Mongolia. *International Journal of Environmental Research*, *Vol. 12*, pp. 887-899, doi: https://doi.org/10.1007/s41742-018-0143-6
27. Ojiako, U., Bashir, H., Almansoori, H.B.B., AlRaeesi, E.J.H., Al Zarooni, H.A. (2024). Using ISO 14001 certification to signal sustainability equivalence: An examination of the critical success factors. *Production Planning & Control*, *Vol. 36, No. 10,* pp. 1287-1314, doi: https://doi.org/10.1080/09537287.2024.2358059
28. Pablo-Cano, M., Espejel-García, A., Hernández-Montes, A., Hernández-Rodríguez, L. (2024). Consumers' willingness to pay for attributes of sustainability, Origin and production process in Raicilla. *Sustainability*, *Vol. 16, Iss. 19,* pp. 8633., doi: https://doi.org/10.3390/su16198633
29. Pham, D.P., Park, S., Yonghan, A. (2024). A Natural language processing based machine learning approach on building material eco-label databases wrangling. *International Journal of Sustainable Building Technology and Urban Development*, *Vol. 15, No. 3,* pp 367-380. doi: https://doi.org/10.22712/susb.20240026
30. Plakantonaki, S., Kiskira, K., Zacharopoulos, N., Chronis, I., Coelho, F., Togiani, A., Kalkanis, K., Priniotakis, G. (2023). A Review of Sustainability Standards and Ecolabeling in the Textile Industry. *Sustainability*, *15*, 11589, https://doi.org/10.3390/su151511589
31. Rafael, C., Pires, A., Simões, A. (2024). Digital communication in Portuguese accommodation units awarded with the Green Key sustainability seal - the case of Madeira, Portugal. *Progress in Industrial Ecology, an International Journal*, *Vol. 17, Iss. 3*, pp. 227-239, doi: https://doi.org/10.1504/pie.2024.143808
32. Reardon, T., Awokuse, T., Belton, B., Saweda, L., Liverpool-Tasie, O., Minten, B., Nguyen, G., Qanti, S., Swinnen, J., Vos, R., Zilberman, D. (2024). Emerging outsource agricultural services enable farmer adaptation in agrifood value chains: A product cycle perspective. *Food Policy*, *Vol. 127,* 102711, doi: https://doi.org/10.1016/j.foodpol.2024.102711
33. Sogn-Grundvåg, G., Bronnmann, J., Pettersen, I.K., Asche, F., Johansen, O. (2025). Can eco-labels tune a supply chain? The case of MSC-certified haddock from Norway. *Ecological Economics*, *Vol. 236*, 108683, doi: https://doi.org/10.1016/j.ecolecon.2025.108683
34. Srinivasan, S. (2025). Energy efficiency gap and the limits to the effectiveness of non-price interventions: making the case for residential energy efficiency. *Energy Efficiency*, *Vol. 18, No. 4,* doi: https://doi.org/10.1007/s12053-025-10316-2

35. Tanaka, D., Dente, S.M.R., Hashimoto, S. (2024). How Do Eco-Labels for Everyday Products Made of Recycled Plastic Affect Consumer Behavior? *Sustainability*, *Vol. 16, No. 12*, p. 4878, doi: https://doi.org/10.3390/su16124878
36. Twerefou, D.K., Abeney, J.O., Toman, M.A., Baffour, P.T., Turkson, F.E. (2025). Household electricity consumption efficiency and poverty: Evidence from Ghana. *Energy Efficiency, Vol. 18, No. 3,* doi: https://doi.org/10.1007/s12053-025-10299-0
37. Ullah, A., Ghani, H.U., Gheewala, S.H. (2024). *Green public procurement and ecolabels towards sustainable consumption and production.* Encyclopedia of Sustainable Technologies (Second Edition), pp. 368-381, doi: https://doi.org/10.1016/B978-0-323-90386-8.00087-5
38. Vlaeminck, P., Vandoren, J., Vranken, L. (2014). *Are labels delivering what they intend? Explicit value of fair-trade labels versus implicit value of fair trade characteristics*. Ljubliana: EAAE.
39. Völker, J., Oestreich, H.M., Meyerding, S.G.H. (2025). The influence of labels on the front of in vitro chicken meat packaging on the choice behavior of German consumers. *Sustainability*, *Vol. 17, No. 15,* p. 6685, doi: https://doi.org/10.3390/su17156685
40. Wakamatsu, H., Maruyama, Y. (2024). Consumer preference for fisheries improvement project: Case of bigeye tuna in Japan. *Sustainability*, *Vol. 16, No. 6,* p. 2530, doi: https://doi.org/10.3390/su16062530
41. Wang, D.D., Sueyoshi, T. (2018). Climate change mitigation targets set by global firms: Overview and implications for renewable energy. *Renewable and Sustainable Energy Reviews*, *Vol. 94,* pp. 386-398, doi: https://doi.org/10.1016/j.rser.2018.06.024
42. Wang, Y., Wang, C., Wang, H., Chen, Z. (2023). Prediction of consumers' adoption behavior of products with water efficiency labeling based on hidden Markov model. *Water*, *Vol. 16, No. 1,* p. 44, doi: https://doi.org/10.3390/w16010044
43. Wognum, P.N., Bremmers, H., Trienekens, J.H., Van der Vorst, J.G., Bloemhof, J.M. (2011). Systems for sustainability and transparency of food supply chains–Current status and challenges. *Advanced Engineering Informatics*, *Vol. 25, Iss. 1,* pp. 65-76, doi: https://doi.org/10.1016/j.aei.2010.06.001
44. Xin, Y., Ali, I.M., Shi, Y., Essam, D.L., Chakrabortty, R.K. (2025). Optimizing multinational manufacturing supply chains under diverse carbon policies using carbon gaming. *Transportation Research Part E: Logistics and Transportation Review*, *Vol. 198,* 104091, doi: https://doi.org/10.1016/j.tre.2025.104091
45. Yao, J., Guo, X., Wang, L., Jiang, H. (2024). An evolutionary game and system dynamics approach for the production and consumption of carbon-labeled products-based on a media monitoring perspective. *Journal of Environmental Management*, *Vol. 360,* 121154, doi: https://doi.org/10.1016/j.jenvman.2024.121154

46. Yuan, R., Tang, Z. (2024). Does carbon labelling encourage the consumption of low-emission meat products? Evidence from China. *Australian Journal of Agricultural and Resource Economics*, *Vol. 69, Iss. 1,* pp. 80-99, doi: https://doi.org/10.1111/1467-8489.12602
47. Zhao, S., Duan, H. (2025). Economic and environmental impacts of ecolabeling under different product cost structures. *Omega*, *Vol. 133*, 103275, doi: https://doi.org/10.1016/j.omega.2025.10327

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FROM SQUADS TO ENTERPRISES: A TIERED MODEL ANALYSIS OF TEAMS SCALING MODELS IN MULTILAYERED ORGANIZATIONS

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Purpose: The paper investigates how team size, structure, and coordination practices influence delivery performance, satisfaction, and predictability in multilayered technology organizations operating under concurrent, multi-workstream environments. It explores how Human Resources (HR) / People & Culture (P&C) frameworks, delivery lifecycles, and strategic governance interact to create scalable value streams. The aim is to codify a model (empirically derived from practice) that links tactical delivery (using Scrum/Kanban) with operational lifecycles and strategic portfolio management under unified vision and SLA/KPIs control.
Design/methodology/approach: The study applies a mixed-methods empirical design using structured surveys conducted among development and platform engineering teams within a large, globally distributed technology enterprise. Quantitative measures capture relationships between autonomy, backlog ownership, collaboration density, and delivery predictability; qualitative inputs contextualize observed tensions between standardization and flexibility. Statistical and thematic analyses are used to identify patterns, and results are interpreted through a comparative organizational lens linking Project Development Lifecycle (PDLC) maturity with matrix and team network-based scaling.
Findings: Results indicate that balanced autonomy, standardized work-lifecycle tools, and transparent backlog governance yield higher delivery predictability and employee satisfaction. PDLC/SDLC integration reduces context switching and clarifies accountability, while strategic program steering enables measurable gains in cost control, quality, and innovation velocity. AI-assisted tools amplify, but do not replace, human domain expertise.
Research limitations/implications: Results reflect one enterprise context and rely partly on self-reported data. Future work should test cross-industry adaptability and quantify correlations between culture maturity, lifecycle discipline, and value-delivery metrics.
Practical implications: The proposed model provides a governance reference for large organizations adopting agile-at-scale, clarifying how development, quality assurance analysts/engineers, HR/P&C, DevOps, and PMO functions can coevolve under unified lifecycle management. It supports measurable efficiency gains through visibility, predictability, and empowered teams.
Social implications: By reinforcing people-centric scaling, responsible tooling and AI augmentation, the model promotes effective and healthier digital workplaces and knowledge retention in large engineering ecosystems.

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Originality/value: The paper unifies implementation/tactical agile practice, project/operational lifecycles, and financial/strategic governance into a single comparative architecture of scaling. It offers a reproducible blueprint for enterprises pursuing agility at scale while maintaining cultural cohesion and measurable business value.
Keywords: scaled agile, team scaling models, SDLC, PDLC, organizational agility, autonomy and alignment, AI-augmented delivery.
Category of the paper: Research Paper (primary); Technical Paper (secondary).

1. Introduction

Modern technology enterprises operate as multi-layered sociotechnical systems where numerous autonomous teams, shared platforms, and business programs interact in parallel. As organizations scale, the challenge shifts from building individual agile teams to sustaining coherence, predictability, and human motivation across tens to hundreds of concurrent workstreams. The rapid evolution of digital ecosystems, coupled with hybrid work and generative-AI augmentation, further amplifies the need for models that integrate people, process, and governance into a unified delivery architecture.

The problem examined in this study arises from the tension between team-level agility that is embodied in frameworks such as Scrum and Kanban and enterprise-level coordination, which requires to be structured life-cycle governance and strategic oversight. This study focuses on balancing (a) top-down direction, from strategy through program operations to implementation, and (b) bottom-up feedback, from technology implementation back to financial and strategic target monitoring, while reconciling the discipline of hierarchical governance with the integration, quality, and creativity enabled by flat, autonomous teams. While many scaling frameworks, such as: Spotify Matrix Model (Kniberg, Ivarsson, 2012), Large Scale Scrum (LeSS) (Larman, Vodde, 2016), Scaled Agile Framework (SAFe) (Leffingwell, 2018), Disciplined Agile (DAD) (Ambler, Lines, 2012) propose partial solutions, few have been empirically validated in real, multi-platform environments that must balance innovation speed with regulatory, financial, and cultural stability. Although, the frameworks are established on foundations of Scrum (Cohn, 2004) they differ in the larger organizations culture and introduce differences in roles and teams formation. The research therefore investigates how structural/team-formation mechanisms, human-resources (HR) and People & Culture (P&C) policies, and Project Delivery Lifecycles (PDLCs) (Goodpasture, 2015) interact to produce measurable business value introduced iteratively.

Anchored in the classic people-process-technology (PPT) lens (Pee, Kankanhalli, 2009; Williams, Leask, 2011), the organization's operating model across three complementary dimensions: project, product, and platform; where (a) *project* denotes time-boxed change delivery governed by schedule, scope, and budget; (b) *product* denotes an enduring stream of

customer value, steered by a roadmap and evaluated by outcomes and revenue/impact; (c) *platform* denotes shared capabilities that accelerate many products and projects by increasing leverage and reliability while managing technical maintenance needs, operating cost and performance. These dimensions are mutually reinforcing: projects catalyse change within products; products set direction for projects; and platforms institutionalise reusable capabilities that reduce the marginal cost and risk of future work.

The context of analysis is a globally distributed technology organization maintaining systems of integrated platforms exceeding seven million lines of code. Within this environment, squads and chapters constitute the basic tactical units, coordinated through a PDLC and integrated with platform Software Delivery Lifecycles (SDLCs) (Gupta, Rawal, 2021). This tiered architecture of implementation/tactical (SDLC), projects/operational (PDLC), financial/strategic, forms the theoretical *triangle model* used throughout the paper (Figure 1).

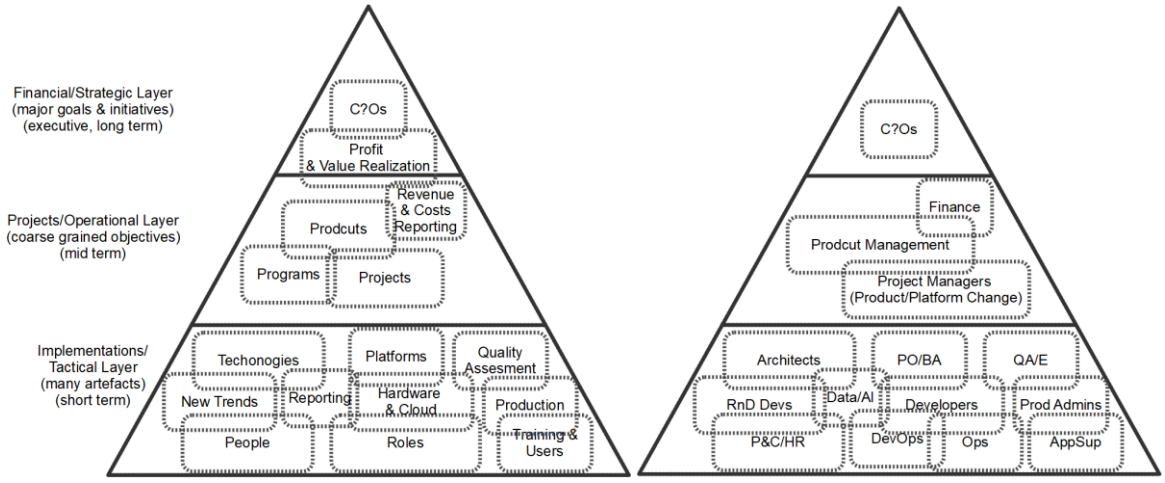


Figure 1. A three-tier triangle model shows how short-term implementation layer activities (people, technologies, platforms, QA, production, training, reporting) roll up into mid-term operational layer objectives (programs, projects, products, revenue & cost reporting) and ultimately into long-term strategic layer outcomes led by team of executives (CxOs) for profit and value realization). The left part focuses on activities and functions, whilst the right, on roles and organization departments.

The research builds on mixed-methods empirical research design: (I) a qualitative synthesis of organizational process documentation describing formation of squads, chapters, and platform teams, but also lifecycle, governance, and program coordination; and (II) three quantitative surveys ($N \approx 114$) exploring (1) AI impact on work, (2) career paths and aspirations, and (3) team size and structure. Together they capture relationships between autonomy, backlog refinement discipline, collaboration density, satisfaction, and delivery predictability. The surveys provide a data-driven complement to qualitative organizational observation, allowing cross-validation between perceived and measured outcomes.

The principal research question is: **How do structure, size, and coordination practices influence performance, satisfaction, and predictability in large-scale development organizations?**

Supporting questions include:

1. How can HR and P&C functions enable scalable autonomy through competency development frameworks in supports of the best fir of career-paths to corporate needs and hybrid-work policy?
2. How can PDLCs (treated as the program/project operational middle layer) integrate effectively with platform SDLCs to reduce waste and clarify accountability?
3. Which strategic governance mechanisms (programs, portfolio KPI control, AI-assisted knowledge management, coding and analytics) ensure alignment between local delivery and corporate value creation?

The paper contributes a comparative model of scaling that connects tactical delivery practices (SDLC; Scrum, Kanban) with projects operational lifecycle governance (PDLC) and strategic program steering. The model emphasises balanced autonomy, with a degree of freedom at squad level, aligned with lean software delivery monitoring and forecasting (Little, 2011; Little, Graves, 2008; Al-Baik, Miller 2015), combined with standardised lifecycle interfaces and transparent backlog governance (Alaidaros, Omar, Romli, 2018; Damij, Damij, 2021), as a predictor of both performance and employee satisfaction. It further identifies AI-augmented lifecycle tooling as an amplifier, not a replacement, of human expertise.

By bridging agile theory, organizational design, and empirical data, this work aims to codify a reproducible reference for enterprises pursuing agility at scale. It defines how tactical, operational, and strategic layers can co-evolve under unified vision, culture, and measurement systems, establishing foundations for the subsequent analysis of PDLC/SDLC integration and program-level value realization. The novelty of this research lies not in introducing new agile methods, but in **empirically demonstrating an integrated, tiered scaling architecture** that links people systems, delivery lifecycles, and strategic governance within a single operational model. By synthesizing insights from established scaling literature with quantitative and qualitative evidence, the paper contributes a reproducible reference model suitable for scientific discussion and further validation.

2. Literature Review

The study is grounded in the interdisciplinary field of organizational scaling, where agile software delivery, systems theory, and human-centric management converge. Over the past two decades, research has increasingly emphasised that sustainable agility depends on sociotechnical coherence; how team autonomy, process discipline, and structural alignment interact to sustain learning and predictability across layers of the enterprise (Larman, Vodde, 2016; Denning, 2018).

2.1. Scaling Frameworks and Matrix Organization Models

Prominent scaling frameworks, following *Agile Manifesto* (Fowler, 2001), *Lean software development principles* (Poppendieck, Poppendieck 2003) and *Iterative Development Delivery* (Larman, Basil 2003) including: Spotify, Large-Scale Scrum (LeSS), Scaled Agile Framework (SAFe), and Disciplined Agile Delivery (DA), offer complementary but partial approaches. The Spotify model (Kniberg, Ivarsson 2012) emphasises cultural autonomy through *squads, chapters, tribes,* and *guilds*, demonstrating that micro-units can deliver at speed when bound by shared values and transparent alignment. LeSS extends the Scrum model to multiple teams by promoting whole-product focus and systems thinking. SAFe adds a hierarchical structure of *Agile Release Trains* and *Program Increments*, providing financial and portfolio alignment. DAD seeks to unify these approaches through process-goal frameworks and contextual tailoring.

In practice, enterprises often implement hybrid constructs combining Spotify-style autonomy with SAFe-like governance. This hybridization creates what the applied model terms the matrix organization (Figure 2), where vertical delivery lines (of *squads* allocated to workstreams changing platforms) intersect with horizontal competency structures (*chapters*). Squads are organised technology teams against the business needs for fast flow and low cognitive load (Skelton at al. 2019). Since architecture follows communication (Conway, 1968; Herbsleb et al., 1999), Product Owner (PO) hierarchy (product office reaching strategic tier), platform interfaces, delivery teams ceremonies, and stage gates are used to deliberately shape communication paths, in result producing cleaner system boundaries and more predictable delivery. Such arrangements reconcile specialization and cross-functional collaboration, but they also introduce coordination complexity that must be mitigated through clear lifecycle and governance interfaces.

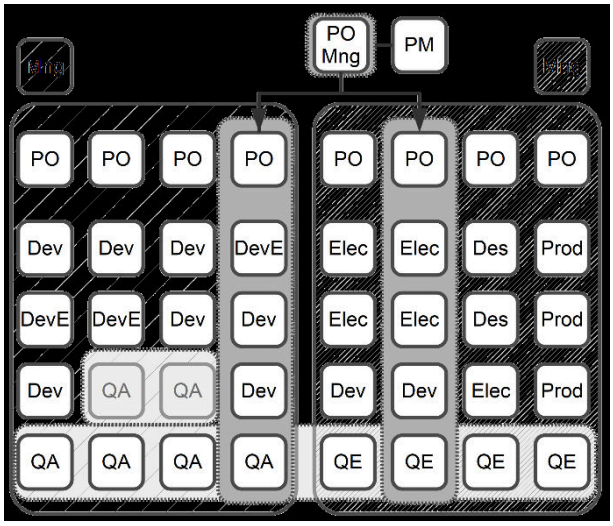


Figure 2. An example of a flat, matrix-oriented structure, under SDLCs, integrated with a hierarchical overlay used to steer larger platforms and introduce strategic initiatives at the operational level via PDLC. The product-ownership spine links team-level Product Owners (POs) to a PO Manager and Product Manager (PM) for unified backlog direction and product portfolio alignment. QA/QE chapters operate as shared enablement pools across teams. Visual encoding: dark grey denotes squad value streams delivering projects; hatched program frames indicate platform/enterprise scope; grey vertical bands show the PO spine hierarchy; light-grey blocks mark chapter pools. This clarifies how governance and enablement scale beyond single squads.

2.2. Lifecycle Governance and Delivery Coherence

The PDLC concept links tactical team execution with strategic oversight tiers. PDLCs formalize planning, design, build, and release phases while preserving iterative feedback from SDLC cycles. The implementation illustrates how PDLCs operate as the middle layer connecting product, technology, and business governance. It aligns with Lean-Agile principles (Beck et al., 2001; Poppendieck, 2003; Ries, 2011) by emphasizing flow efficiency, incremental value delivery, and risk transparency through use of *Kanban* (Ahmad et al., 2013, 2018) and *Kanban-of-Kanbans* project coordination (Brechner, 2015).

At the tactical level, Software Development Lifecycles (SDLCs) provide discipline in execution. Integration between PDLC and SDLC phases ensures that multi-team programs share common definitions of scope of work, readiness, quality, and completion (DoR/DoD).

The tiered model operationalises organisational ambidexterity (O'Reilly, 2013): strategic tiers fund exploration, PDLC gates convert validated options into exploit streams, and platform services sustain efficiency at scale. This reduces context switching, improves accountability, and reinforces alignment between various roles engaged: Product Owners (PO), Business Analysts (BA), Technology Platform Managers (TPM), and Chapter Leads. Empirical studies in large organizations (Rigby et al., 2018) highlight that such hybrid lifecycle governance is a prerequisite for predictable delivery.

2.3. The Socio-Technical and People-Centric View

Following Trist & Emery's (1960) sociotechnical system theory, the paper adopts the premise that human motivation and structural clarity are interdependent. Agile scaling succeeds only when People & Culture (P&C) functions institutionalize continuous learning, psychological safety, and flexible career paths. Chapters serve as communities of practice maintaining shared standards, while squads act as self-organizing micro-enterprises. Survey evidence from this study confirms that perceived autonomy, mentorship, and visibility correlate positively with satisfaction and quality outcomes.

2.4. Integrating AI-Augmented Delivery and Strategic Control

Recent literature introduces the impact of AI-assisted lifecycle tools (Taulli, 2024; Noor, 2025) on delivery performance and governance transparency. Generative AI (especially with use of LLM, RAG) supports knowledge retrieval, impact analysis, and test automation, but requires mature processes and ethical oversight. Within the triangle model adopted here: tactical (teams and platforms engineering), operational (lifecycles and coordination), strategic (program and major initiatives), AI acts as an amplifier of human capability, not a substitute. The theoretical synthesis therefore extends classical scaling models by embedding responsible automation and data-driven feedback loops into human-centric governance.

2.5. Conceptual Gap

Existing frameworks rarely integrate *people systems, lifecycle rigour, and strategic alignment* into a single comparative schema. This paper addresses that gap by analysing how HR/P&C-driven competency management, PDLC/SDLC integration, and program-level steering co-evolve in large enterprise. The result is a holistic architecture of scaling that unifies agile delivery practice with organizational design and empirical governance evidence.

2.6. From Literature to Research Constructs

Prior research on agile scaling consistently highlights the tension between team autonomy and coordination mechanisms as a determinant of delivery performance and predictability (Kniberg, Ivarsson, 2012; Larman, Vodde, 2016; Rigby et al., 2018). Studies grounded in sociotechnical systems theory further emphasize that autonomy yields positive outcomes only when supported by clear interfaces, shared standards, and governance structures (Trist, Emery, 1960; Pee, Kankanhalli, 2009).

Building on these findings, this study operationalizes "balanced autonomy" through survey measures capturing perceived autonomy, adherence to shared standards, and collaboration effectiveness. These constructs directly inform **H1**, which tests the relationship between autonomy-with-alignment and delivery predictability.

Similarly, literature on human-centric agile organizations identifies mentoring, career-path clarity, and P&C enablement as predictors of satisfaction and retention in scaled environments (Denning, 2018; O'Reilly, Tushman, 2013). These insights motivate **H2**, operationalized through survey items measuring perceived career clarity, organizational support, and mentoring behavior.

Research on lifecycle governance and flow-based coordination (Little, 2011; Brechner, 2015; Ahmad et al., 2018) underpins **H3**, which examines backlog orchestration across PDLC and SDLC layers as a predictor of predictability and reduced coordination waste.

Finally, emerging studies on AI-assisted software development emphasize productivity gains contingent on process maturity and governance safeguards (Forsgren et al., 2018; Taulli, 2024). These findings inform **H4**, which evaluates AI-assisted tooling as a moderated amplifier of delivery efficiency rather than a standalone driver.

3. Methodology

3.1. Research Design

This study employs a mixed-methods empirical design to explore the relationships between organizational structure, team coordination, delivery predictability, and employee satisfaction in large-scale technology organizations. The research combines quantitative survey analysis with qualitative process synthesis derived from internal organizational documentation, operational data, and lifecycle frameworks. The approach was selected to balance contextual depth with statistical reliability, ensuring that results can be interpreted both through the lived experience of practitioners and through measurable correlations among key variables.

The qualitative component captures the codified delivery governance architecture of the enterprise, encompassing team formation (squads and chapters), lifecycle integration (PDLC and SDLC), and strategic governance through program and portfolio management. These materials, documented in *Scaling Teams: Dev Teams Formation*, provide the theoretical and procedural backbone of the model.

The quantitative component consists of three structured surveys conducted across multiple platform engineering and product teams between September and October 2025, yielding a total of 114 valid responses. The surveys measure perceptions of AI impact on work and satisfaction, career progression and motivation, and team size, structure, and performance. Together, they operationalize the constructs of autonomy, lifecycle maturity, collaboration density, and satisfaction.

3.2. Conceptual Model and Hypotheses

The research is guided by a conceptual model derived from the “triangle” organizational theory developed internally within the organization tech department and supported by sociotechnical systems and scaling-agile literature. The model distinguishes three mutually dependent layers: (1) Tactical/Implementation Layer: Team formation, HR/P&C enablement, delivery ceremonies, and lifecycle discipline (Scrum, Kanban), (2) Operational/Project Layer: PDLC integration with SDLCs across platforms, risk control, and synchronization of backlogs (“Kanban of Kanbans”), (3) Strategic/Financial Layer: Program governance, KPI-based steering (in technology domain: DORA metrics, cost control, MTTP by CI/CD) (Humble, Farley, 2010; Forsgren et al., 2018; Beyer et al., 2018; Wilkes et al., 2023), and value realization mechanisms (Bowman, Ambrosini, 2000).

The following hypotheses guided the research:

H1: Balanced autonomy and standardized lifecycle interfaces are positively correlated with delivery predictability.

H2: Career path clarity and perceived support rise with mentoring activity.

H3: Backlog orchestration (integration between PDLC and SDLC across planned allocation of steams and squads) is positively associated with predictability; reduction of context switching and waste.

H4: AI-assisted tools improve perceived efficiency, but are moderated by process maturity and team autonomy.

3.3. Data Collection

Data were collected from employees working in software development, QA/QE, and DevOps roles across six platforms maintained by teams across Europe, Asia, and North America (participation was voluntary). Each survey employed 4 or 5 point Likert scale questions complemented by open-ended responses (Figures 3 and 4). Key indicators included:

1. Survey #2: AI Impact (N = 34):
   (S02-Q01) survey indicates 76% (n=26/34) began using AI in 2023..2025 (26% since 2022, 29% after 2024, 20% in 2025). Earlier adopters are fewer: 12% (n=4/34) started in 2020..2022 and 9% (n=3/34) before 2020. Only 3% have not used AI yet (N=34).
   (S02-Q02) Influence on daily work (Somewhat/A lot): 91.2% (31/34).
   (S02-Q03 Usage frequency: Regularly (multiple/day) 44.1% (n=15/34); Occasionally (weekly) 38.2% (n=13/34).
   (S02-Q04) Performance improved (Somewhat/Strongly): 79.4% (n=27/34).
   (S02-Q05) Job satisfaction increased (Slightly/More): 64.7% (n=22/34).
   (S02-Q06) Quality & flow improved (Somewhat/Greatly): 70.6% (n=24/34).
2. Survey #3: Career Path & Support (N=55)
   (S03-Q01) Career path clarity (Very/Somewhat): 56.4% (n=31/55), Very clear: 14.5% (n=8/55); Not very/Not at all: 43.6% (n=24/55).
   (S03-Q02) Feel supported (Very/Somewhat): 49.1% (n=27/55); Neutral 27.3% (n=15/55).
   (S03-Q03) Support you give others (Very high/High): 85.5% (n=47/55).
   (S03-Q04) Growth interests: multi-select (qualitative themes).
   (S03-Q05) Strongest support timing: multi-select (qualitative themes).
3. Survey #4: Team Size & Structure (N=32)
   (S04-Q01) Team size distribution: 3..5 28.1% (n=9/32); 6..9 21.9% (n=7/32); 10..15 37.5% (n=12/32); >15 12.5% (n=4/32).
   (S04-Q02) Cross-team collaboration (Mostly/Very): 71.9% (n=23/32).
   (S04-Q03) Autonomy vs standards (Mostly/Excellent): 78.1% (n=25/32).
   (S04-Q04) Backlog orchestration by POs (Mostly/Highly): 46.9% (n=15/32).
   (S04-Q05) Chapter/enablement influence (Moderate/Strong): 28.1% (n=9/32).
   (S04-Q06) Overall delivery rating (Good/High): 87.5% (n=28/32).
   (S04-Q07) Predictability & effectiveness (Mostly stable/Very predictable): 78.1% (n=25/32).

(S04-Q08) Matrix status: Yes 28.1% (n=9/32); No 43.8% (n=14/32); Partial 25.0% (n=8/32).

Perceived collaboration effectiveness (S04-Q02) lowers as team grows (S04-Q01): small teams of 3..5 show 78% good-or-better collaboration (n=7/9), medium 6..9 peak at 100% (n=7/7), while large 10..15 drop to 58% (n=7/12), and larger than 15 fall to 50% (n=2/4). (Note: overall association is weak, Spearman $\rho=-0.19$ (N=32)).

There are 66 unique respondents across all surveys S02, S03, S04. 43.9% participated once only (n=29/66), whilst 56.1% appeared in 2 or more surveys (n=37/66).

3.4. Analytical Procedures

The analysis proceeded in three stages:

1. Descriptive and Correlational Analysis: Using aggregated survey results, correlations were computed between team size, delivery performance, satisfaction, and lifecycle maturity. Smaller, autonomous squads with high ceremony adherence (refinement, review, retrospective) showed stronger predictability and quality outcomes.
2. Thematic Coding: Open-ended responses and document excerpts were analysed using grounded-theory coding (Glaser, Straus, 1967; Martin, 1986). Recurring themes included: (a) *Autonomy with Accountability*: teams value freedom when expectations and governance are clear (b) *Lifecycle Integration Reduces Waste*: teams in well-defined PDLC/SDLC environments report fewer delays and less rework; (c) *"I as Amplifier, Not Substitute*: developers emphasize that AI tools enhance speed and accuracy but must be constrained by governance and code-review processes.
3. Comparative Mapping: The model was compared with reference frameworks (Spotify, SAFe, LeSS, and DAD) to determine overlap and divergence. The comparative lens shows that while Spotify emphasizes cultural autonomy and SAFe emphasizes program governance, the approach integrates both dimensions through PDLC/SDLC unification, achieving structural coherence without suppressing flexibility.

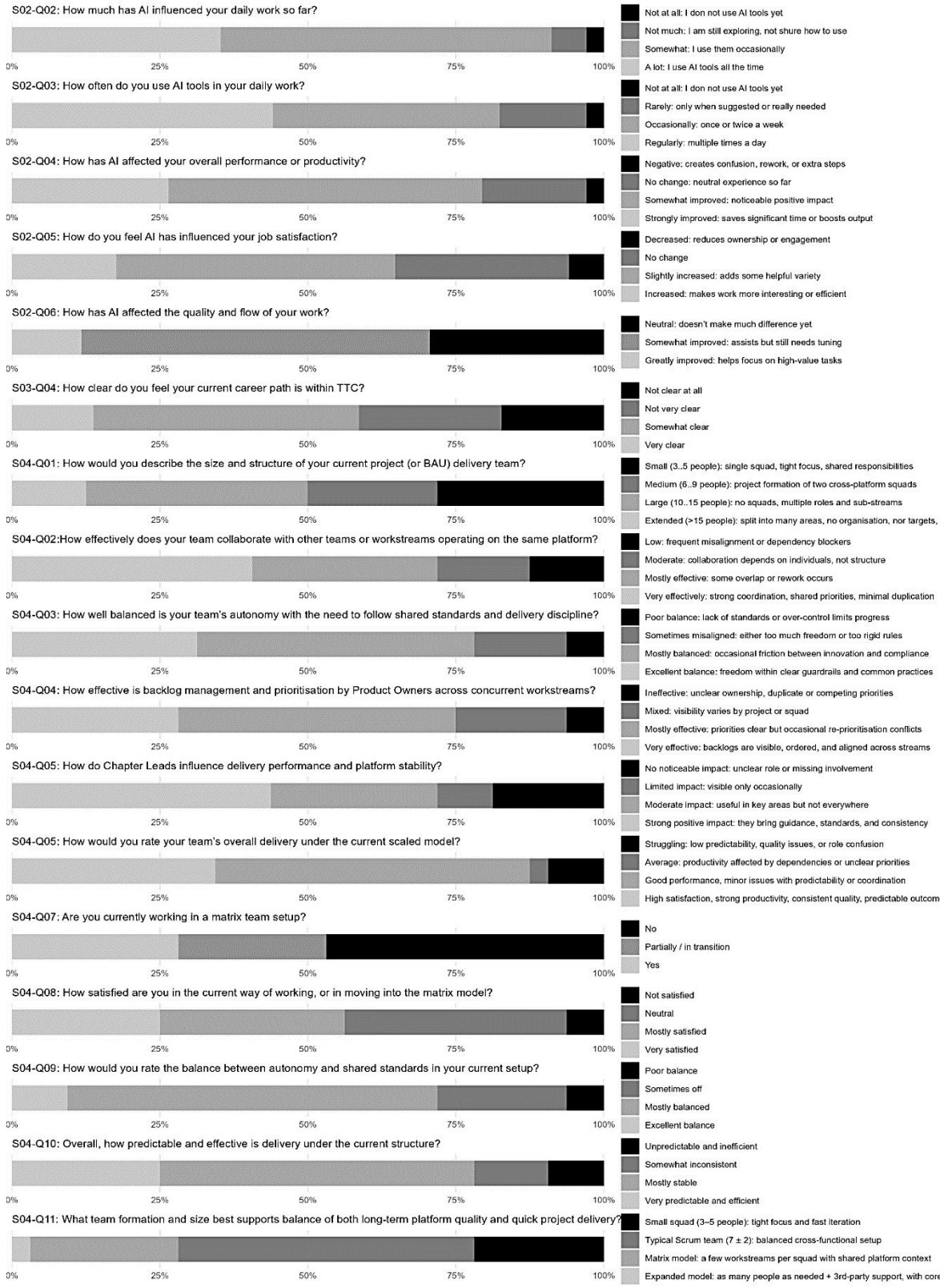


Figure 3. Survey #2, #3 and #4; AI influence, team size, structure, and ways of working: distribution of responses by question. Horizontal 100% stacked bars show the response distribution for each question with exact response options. Survey #2 (S02-01…S02-06: AI influence, frequency of use, productivity, satisfaction, and workflow quality), Survey #3 (S03-04: clarity of career path) and Survey #4 (S04-01…S04-11: team size/structure, collaboration, autonomy vs standards, backlog management, chapter influence, delivery, matrix status, satisfaction, predictability, and preferred formation). Each bar sums to 100%; segments represent ordered response categories (legend at right).

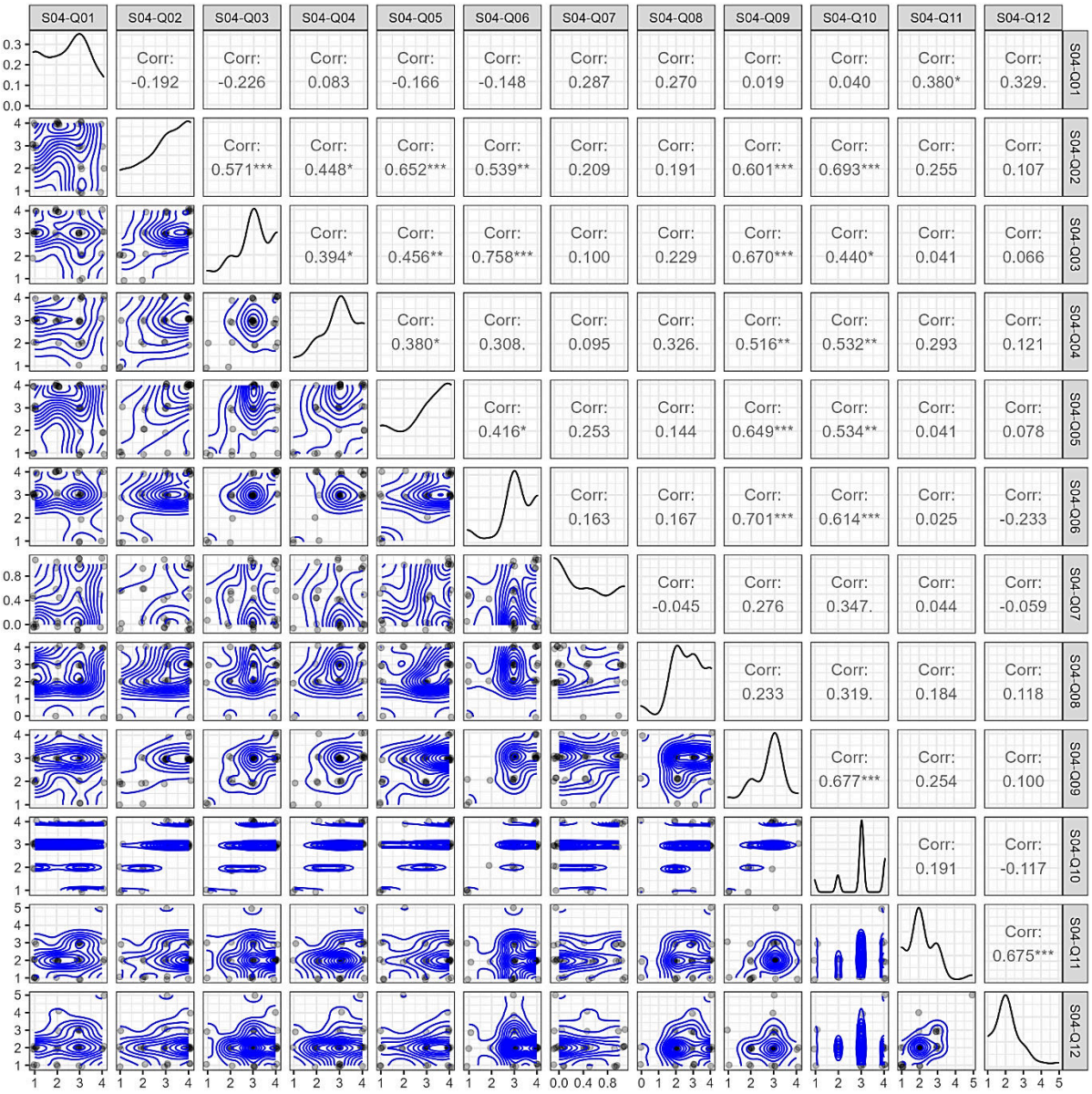


Figure 4. Pairwise association map for Survey #4 (S04-Q01..S04-Q12); Upper panels report Spearman's rank correlation coefficient ρ (ggplot2:GGally.ggpairs/wrap("cor", method = "spearman")); the diagonal shows univariate distributions; the lower panels show bivariate kernel-density contours (indicating distribution of responses). Items are Likert-coded treated as ordinal and plotted to screen relationships prior to multivariate analysis.

3.5. Validity and Reliability Considerations

To mitigate bias and subjectivity, multiple data sources were cross-referenced. Survey reliability was assessed through internal consistency of response distributions and replication across teams of varying maturity levels. Process observations were validated by senior TPMs and HR/P&C partners to ensure contextual accuracy. The study recognizes limitations inherent in single-enterprise case analysis; particularly the influence of corporate culture, existing process maturity, and respondent self-selection. However, triangulation of methods and transparency in data interpretation provide robustness supporting base of applied organizational research (Yin, 2018).

3.6. Ethical and Procedural Integrity

All surveys were complied with internal data protection policies and the Acceptable Use and AI Use Policies of the organization. Data were anonymized and aggregated for visualisation. Respondents were informed of the research purpose and potential use in academic publication. The author, serving as both practitioner and researcher, followed a reflexive stance to distinguish empirical observation from managerial influence.

3.7. Synthesis and Analytical Framework

The methodology thus integrates practice-based evidence with empirical inquiry. The triangle mode (linking tactical, operational, and strategic tiers) acts as both analytical and explanatory framework. At the tactical level, data illuminate the influence of HR/P&C alignment and agile ceremonies; at the operational level, PDLC/SDLC integration is analysed as a coordination mechanism; and at the strategic level, program governance. Cross-cutting concerns through the tiers, such as architecture working group or tool set use, including AI augmentation, are assessed as enablers of organizational learning.

This approach situates the research within the emerging field of scalable agile enterprise studies, contributing a reproducible methodology for evaluating large-scale delivery systems through both cultural and quantitative lenses. The mixed-methods strategy ensures that the findings are not only statistically supported but also grounded in the realities of day-to-day engineering, management, and human collaboration.

4. Results

The empirical surveys, complemented by organizational documentation, confirm that the studied enterprise functions as a multilayered sociotechnical system where delivery capability and satisfaction are determined by the interaction of three governance tiers: tactical, operational, and strategic/executive. Each tier contributes distinct mechanisms of alignment, autonomy, and feedback.

4.1. Tactical Layer: HR and People, Team Formation, and Delivery Discipline

Survey #4 (Team Structure and Collaboration) shows that 73 % of respondents work in small squads of up to nine people, with 46 % in 3..5-person teams. These smaller teams report the highest perceived predictability (62 % “high” or “very high”) and satisfaction levels.

4.2. Results and Tiered Model of Organization

Over the pre-research observation period (2023-Q2 to 2025-Q3), the product-engineering group grew from two cross-functional teams into a multi-team, platform-oriented structure. Growth was non-linear: a steady baseline in 2023-Q2..2023-Q4 was followed by two planned step-ups: first in 2024-Q1, aligned with scope increases and the rollout of a standardised PDLC and shared platform services; and second in 2024-Q3, as cross-platform initiatives scaled. The added capacity (2024-Q1..Q3) prioritised complementary roles (QA/QE, SRE/DevOps, data engineers) alongside core developers while maintaining a balanced senior-junior mix. From 2024-Q4 through 2025-Q3, hiring flattened as the focus shifted to consolidation; deepening domain and technical skills, tightening ceremonies, reducing coordination costs, and stabilising throughput. Exact counts remain confidential; the trajectory reflects deliberate scaling tied to demand and value-creation milestones rather than opportunistic headcount growth.

4.3. Operational Layer: Lifecycle Integration and Program Coordination

The operational tier, represented by PDLC and its integration with platform-level SDLCs, converts strategic intent into structured delivery flow.

Empirical data indicate that teams with clearly defined PDLC gates and synchronization practices experience fewer coordination losses. Over 60% of respondents report that consistent backlog governance and cross-squad visibility improved delivery predictability. Conversely, teams without such mechanisms cite duplicated testing and unclear ownership boundaries.

Survey #2 (AI Impact on Work) highlights the emergence of AI-augmented delivery intelligence as a new coordination layer: (1) 70% of respondents confirmed that AI tools improved productivity or quality; (2) 25% expressed concern over skill dilution or inconsistent outputs without proper review; (3) frequent use of AI (daily by 40%) correlated with higher perceived efficiency but only in teams with mature PDLC compliance.

4.4. Strategic and Executive Layers: Programs, Governance and, Value Creation

At the apex of the organization, strategic governance aligns programs and investments with measurable business value. Survey #3 results show that employees identify learning and growth opportunities (67%) and project impact (35%) as their primary career motivators; indicating that value creation is understood not only financially but intellectually.

Programs under the Strategic Planning (over 6 quarters) process provide top-down direction and financial oversight. They translate strategic KPIs (cost, revenue, quality, DORA metrics) into operational objectives. The executive layer integrates performance dashboards, risk analytics, and AI-assisted forecasting tools. These mechanisms enable continuous steering while maintaining human accountability in decision-making.

Across all layers, surveys confirm that respondents perceive stronger alignment and motivation when strategy is transparent between perceived alignment quality and satisfaction. This reinforces the proposition that strategic clarity and participatory governance directly enhance morale and predictability.

5. Discussion

Empirical analysis confirms that balanced autonomy, lifecycle integration, and transparent governance are decisive enablers of delivery predictability and satisfaction in large-scale enterprises. Survey data reveal that small, cross-functional squads (3..7 members) working under consistent PDLC/SDLC frameworks achieved the highest reported performance and morale. Teams with clear Definitions of Done, stable mentorship, and chapter support showed higher perceived delivery quality and lower rework rates.

Autonomy is valued but effective only when combined with shared standards: 68 % rated their autonomy/discipline balance as “good” or “excellent,” while excessive independence correlated with coordination issues.

P&C and HR functions serve as enablers of competence formation and role clarity. Survey #3 (Career Path and Aspirations) reveals that 68% of employees feel motivated by structured mentoring and clear progression paths, while 61% perceive alignment between personal growth and company goals. Chapters (acting as communities of practice) amplify this effect through mentoring and skill standardization.

Agile ceremonies and lifecycle discipline remain the core operationalizes of culture. Teams adhering consistently to Scrum/Kanban routines (refinement, review, retrospective) report 20 ..30% higher satisfaction and predictability. Thus, at the tactical tier, autonomy within alignment (supported by HR policy, mentoring, and standard definitions of readiness and completion) constitutes the human foundation of scaling.

5.1. Cross-Layer Dynamics and Feedback Loops

The organization operates through three interdependent feedback loops:

1. Bottom-up learning: performance metrics, AI insights, and retrospective feedback from squads aggregate into PDLC dashboards and inform strategic planning.
2. Top-down alignment: program KPIs cascade into backlog priorities, ensuring that day-to-day delivery reflects corporate objectives.
3. Lateral standardization: chapters and communities of practice connect peers across platforms, enabling horizontal knowledge diffusion.

These loops institutionalize the balance between agility and control. Survey evidence supports this: respondents who rated cross-team collaboration as “effective” or “very effective” (≈70%) also reported higher predictability and lower rework, confirming that structured information flow strengthens both speed and quality.

5.2. The Role of Technology and AI Across Layers

Technology operates as both an enabler and a regulator within the layered model. At the tactical level, AI-assisted coding and test-generation tools accelerate individual productivity. At the operational level, automated analytics aggregate delivery data, supporting lifecycle compliance. AI-powered feedback synthesise knowledge streams. The guiding principle is augmentation, not substitution; AI amplifies human capability while governance safeguards responsibility

5.3. Comparative Perspective and Summary

When contrasted with established scaling frameworks, the proposed tiered model demonstrates several distinctive advantages: (1) Compared with Spotify, it introduces formal lifecycle governance and cost visibility. (2) Relative to SAFe, it retains grassroots autonomy and cultural flexibility. (3) Beyond LeSS, it embeds HR/P&C and AI-augmented governance as first-class organizational systems.

Thus, the tiered architecture defines the enterprise as a system of systems (human, procedural, and strategic) where predictability, innovation, and wellbeing co-evolve. It explains how empirical findings from surveys on autonomy, lifecycle maturity, and AI adoption converge into a unified organizational pattern capable of sustaining large-scale delivery with measurable value.

5.4. AI, Experience and Collaboration

Recent AI diffusion and experience matters. Adoption is recent, 76.5% began in 2023..2025; only 2.9% have not used AI (N=34). Earlier adopters use AI more and feel stronger impact (timing/frequency $\rho=0.52$, $p=0.002$; timing/influence $\rho=0.37$, $p=0.032$), suggesting experience compounds everyday usage and perceived value.

AI usage intensity drives benefits. Frequency tightly tracks perceived influence (frequency/influence $\rho=0.84$, $p<1e-9$). With 44.1% using AI multiple times daily, higher frequency associates with better performance ($\rho=0.62$, $p<0.001$), improved quality/flow ($\rho=0.74$, $p<0.001$), and higher job satisfaction ($\rho=0.77$, $p<1e-7$).

Seen AI usage productivity gain, flow, and morale rise together, as perceived performance improvement co-occurs with smoother flow and higher morale: performance/quality/flow $\rho=0.79$, $p<1e-7$; performance/satisfaction $\rho=0.76$, $p<1e-6$. Overall, 79.4% (n=27/34) report better performance and 70.6% (24/34) better quality/flow; benefits appear systemic rather than

isolated.

Tenure alone is not enough; further AI enablement matters, as we observe adoption timing shows weak/insignificant links to performance (ρ=0.23, p=0.2) and quality/flow (ρ=0.3, p=0.09); converting usage into durable gains likely depends on governance, guardrails, and training; aligning with the tiered model's PDLC gates and enablement pools to operationalise AI effectively.

The adoption of AI-assisted tools increased perceived productivity (over 70% of respondents) but required mature processes and ethical safeguards. Teams emphasized that generative models enhanced velocity only when embedded within disciplined agile and review practices, validating the hypothesis that AI amplifies rather than replaces human expertise.

Career-path clarity (S03-Q01) strongly correlates with feeling supported (S03-Q02) (ρ=0.671, p<0.001). Support is 74.2% (n=23/31) among those Very/Somewhat clear 16.7% (n=4/24) when clarity is low. Implication would be to continue guidance, publish transparent role ladders and run regular career check-ins, carry on sponsorship, and coaching to lift perceived clarity at scale. Clearer paths associate with stronger prosocial behaviour (ρ=0.300, p=0.026): 96.8% (n=30/31) of clearer respondents report High/Very-high support to colleagues 70.8% (n=17/24) with low clarity. Further, Managers and P&C support clarifying growth routes to amplify mentoring and likely more informal enablement is needed.

Shown in (S04-Q04) backlog orchestration is positive for only 46.9% (n=15/32), yet it strongly explains outcomes: it highly correlates with S04-Q06 delivery (ρ=0.758***) and S04-Q10 predictability (ρ=0.614**). Raising orchestration should lift delivery, already 87.5% (n=28/32) across the sample (N=32).

Collaboration (S04-Q02) Mostly/Very 71.9% (n=23/32) and autonomy-with-standards S04-Q03 Mostly/Excellent 78.1% (n=25/32) reinforce each other (ρ=0.571**) and link to outcomes (see Q02/Q06 ρ=0.652**, Q02/Q10 ρ=0.649**) supporting platform-level standards with autonomous squads to reduce dependencies, improve interfaces, and sustain predictable cadence.

Predictability anchors delivery as seen in (S04-Q10) Mostly/Very 78.1% (n=25/32) aligns strongly with S04-Q06 Good/High 87.5% (n=28/32) (ρ=0.701***). Perceived best team formation for predictability S04-Q12 also aligns with delivery (ρ=0.675**), reinforcing a shared cadence and clear interfaces across the platform and programs.

Team size does not outcome driver; despite sizes: 3..5 28.1% (n=9/32), 6..9 21.9% (n=7/32), 10..15 37.5% (n=12/32), over 15 12.5% (n=4/32), responses to (S04-Q01) show negligible association with predictability (S04-Q10, ρ≈0.04) and modest with delivery (S04-Q06, ρ≈0.15). Thus, practices drive outcomes more than headcount scale.

In Survey #4 (N=32), the "operating" cluster of (S04-Q02) collaboration, (S04-Q03) autonomy-with-standards, and (S04-Q04) PO backlog orchestration, co-varies and is strongly associated with (S04-Q10) predictability and (S04-Q06) overall delivery (ρ≈0.65..0.76). Chapter influence (S04-Q05) is weaker. Structural levers of pairs (S04-Q01) team size and

(S04-Q08) matrix status, show notably weaker links.

Survey #4 with N=32 shows smaller teams show higher satisfaction: 3..5 and 6..9 post 100% good/high delivery (n=9/9; 7/7) versus 75% in 10..15 and over 15 (n=9/12; 3/4). Team size to delivery is weak ($\rho=-0.15$, $p=0.42$) and team size to predictability ($\rho=0.04$, $p=0.83$). Backlog orchestration and collaboration matter more. Integration between PDLC and platform SDLCs demonstrably improve targets clarity and backlog definitions, this in result, reduces context switching and coordination loss. Participants cited improved accountability and clearer ownership boundaries when lifecycle artefacts (briefs, reviews, and retrospectives) were standardized across projects. Conversely, loosely coupled or ad-hoc lifecycles correlated with duplicated testing and fragmented knowledge transfer.

Among valid responses (N=28), 89.3% (n=25/28) report TPM, PO and Chapter Lead in the same office. Co-location associates with stronger outcomes: (S04-Q03) autonomy-with-standards (point-biserial $r=0.66$, $p<0.001$), (S04-Q05) chapter influence ($r=0.61$, $p=0.001$), (S04-Q06) delivery ($r=0.55$, $p=0.003$), (S04-Q02) collaboration ($r=0.52$), (S04-Q10) predictability ($r=0.47$, $p=0.011$). Effects are weaker for (S04-Q04) PO backlog orchestration ($r=0.36$, $p\approx0.06$) and (S04-Q08) matrix status ($r=0.22$, $p=0.27$).

From a governance perspective, the triangle model proved effective in linking human-centric delivery with measurable value. HR/P&C policies fostering transparent career paths and hybrid-work structures reinforced cohesion, while strategic programs under KPI control ensured alignment with enterprise vision.

Practically, the study offers a reproducible scaling blueprint: small autonomous squads anchored in standardized lifecycles and connected to strategic dashboards form a stable architecture for complex delivery organizations. Conceptually, it extends agile theory by integrating lifecycle discipline, people systems, and AI-augmented governance within a single comparative framework for sustainable agility at enterprise scale.

6. Conclusions and Future work

This study examined how team structure, coordination practices, and lifecycle governance influence delivery predictability, performance, and employee satisfaction in large-scale, multilayered technology organizations. Across three empirical surveys, the most consistent and reproducible findings indicate that operating conditions of delivery (rather than structural headcount choices) are the dominant drivers of outcomes at scale.

Across three surveys, the strongest, most reproducible signals come from the operating conditions of delivery rather than structural headcount choices. In Survey 4, (S04-Q03) autonomy-with-standards, (S04-Q02) cross-team collaboration, and (S04-Q04) PO backlog orchestration co-vary and are consistently associated with (S04-Q10) delivery predictability

and (S04-Q06) overall delivery. By contrast, (S04-Q01) team size and (S04-Q08) matrix status show notably weaker standalone links. This points to a pragmatic organisation-scaling rule (implementation layer): keep squads autonomous, but tighten shared interfaces, prioritisation, and guardrails.

Leadership proximity amplifies these effects. Among valid responses, co-locating the TPM/PO/Chapter triad correlates with stronger (S04-Q03/Q02) operating practices and better (S04-Q10/Q06) outcomes, suggesting that synchronous decision-making and shared context accelerate alignment without adding ceremony.

On the people side, Survey 3 (S03) shows that (S03-Q01) career-path clarity and (S03-Q02) feeling supported move together, and both improve with (S03-Q03) mentoring/helping others. Clear ladders, regular check-ins, and recognition of mentoring behaviours are therefore central to sustaining motivation in scaled settings.

Finally, Survey 2 (S02) indicates AI is an amplifier: usage intensity and routine integration associate with higher performance (S02-Q04), better quality/flow (S02-Q06), and greater job satisfaction (S02-Q05). Tenure alone is weaker than embedded practice; AI improvements show most when woven into the same operating system (interfaces, prioritisation, review). Overall, the evidence favours a coherent blueprint: autonomous squads within clear guardrails, platform-level orchestration, leadership proximity, and AI embedded in disciplined lifecycle practice.

Beyond these specifics, the "three-tier triangle" and "People, Process, Technology" models provides the general backbone for scaling. People (capability building, (S03-Q01/Q02/Q03) clarity/support/mentoring) supply durable motivation and skills. Process (PDLC/SDLC integration, (S04-Q02/Q03/Q04) interfaces/standards/orchestration) shapes communication paths and reduces coordination loss. Technology (platform services, common tooling, and AI assist from S02) lowers cognitive load and enforces quality by default. Scaling, therefore, is not a headcount exercise but a triadic alignment: squads remain stream-aligned and autonomous, while platform teams institutionalise shared services and cadences, and leadership steers strategy through transparent governance and measurable outcomes. Practically: standardise cadence and interfaces first, strengthen chapter enablement, and then let structure follow flow—using the triangle model to keep incentives and mechanisms coherent across tactical squads, operational platforms, and strategic portfolio layers.

The study has several limitations. The results are derived from a single organizational context and rely partly on self-reported survey data, which limits generalisability and causal inference. Sample sizes constrain statistical power and prevent formal mediation or moderation analysis. These limitations suggest caution in extrapolating the findings beyond similar enterprise settings and underscore the need for broader empirical validation.

The inferences are based on modest samples (S02 N=34, S03 N=55, S04 N=32) with matched-by-email N only ~18–27 across surveys, which limits power, precision (wide confidence intervals), and any moderation/mediation tests (e.g., S02 joined S04 effects on (S04-

Q10/Q06)). To strengthen conclusions it is required to (1) run additional survey waves to at least double–triple Ns per cohort, (2) expand cross-firm sampling, (3) pre-register analyses and conduct power analyses, and (4) report bootstrap CIs with multiple-comparison controls. Larger, longitudinal panels will enable credible causal identification and robust generalisation.

In the future work the continuation of the research should, first, apply a causal-inference apparatus rather than relying solely on correlations. Define explicit direct acyclic-graphs (DAGs) that encode our hypotheses about the operating system: (S04-Q02) collaboration, (S04-Q03) autonomy-with-standards, and (S04-Q04) PO backlog orchestration as parents of (S04-Q10) predictability and (S04-Q06) overall delivery. Pre-register the analysis plan; when practices change asynchronously across teams, use staggered roll-outs / difference-in-differences to estimate treatment effects. For observational data, deploy propensity weighting / matching to balance covariates and explore instrumental variables where valid instruments exist (e.g., exogenous scheduling constraints) to bound causal effects.

Second, build larger, multi-firm datasets to improve precision and generalisability. Objectivise from the product delivery dimensions and harmonise the survey instruments across firms and domains, and test measurement invariance so that questions mean the same thing across contexts.

Third, run field interventions on the people system. For career path (S03), A/B test transparent ladders, sponsor-matching, and mentoring circles; track shifts in (S03-Q01) clarity, (S03-Q02) feeling supported, and (S03-Q03) helping others, alongside retention and time-to-promotion. In parallel, run skills growth experiments: short enablement sprints on product ownership, backlog hygiene, and interface design between teams; evaluate uplift on (S04-Q02/Q03/Q04) and downstream (S04-Q10/Q06). Introduce further queries if needed.

Fifth, expand survey on external tools (e.g. AI Copilots, general LLM chats) and internal AI for knowledge engineering.

Sixth, model the system correctly with multi-level statistics. Use hierarchical models with teams nested in platforms and platforms in business units to separate team-level from platform-level effects; test mediation paths (e.g., S02 frequency, S04 operating variables, S04 outcomes).

Finally, commit to open science and community building. Share an anonymised codebook and analysis scripts; invite replication studies; and present findings at Agile, DevOps Enterprise, and related practitioner–research venues. Convene an industry roundtable to refine a shared metric set for scaled delivery, turning today's correlational insights into reliable, causal guidance for enterprises that require support in their scaling phases.

References

1. Ahmad, M.O., Dennehy, D., Conboy, K., Oivo, M. (2018). Kanban in software engineering: A systematic mapping study. *Journal of Systems and Software, 137*, 96-113.
2. Ahmad, M.O., Markkula, J., Oivo, M. (2013, September). *Kanban in software development: A systematic literature review.* 39th Euromicro conference on software engineering and advanced applications. IEEE, pp. 9-16.
3. Alaidaros, H., Omar, M., Romli, R. (2018). Towards an improved software project monitoring task model of Agile Kanban method. *International Journal of Supply Chain Management (IJSCM), 7(3),* 118-125.
4. Al-Baik, O., Miller, J. (2015). The kanban approach, between agility and leanness: a systematic review. *Empirical Software Engineering, 20(6),* 1861-1897.
5. Beck, K., Beedle, M., Van Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M., Thomas, D. (2001). *Manifesto for agile software development*.
6. Beyer, B., Murphy, N.R., Rensin, D.K., Kawahara, K., Thorne, S. (2018). *The site reliability workbook: practical ways to implement SRE.* O'Reilly Media, Inc.
7. Bowman, C., Ambrosini, V. (2000). Value creation versus value capture: towards a coherent definition of value in strategy. *British Journal of Management, 11(1),* 1-15.
8. Brechner, E. (2015). *Agile project management with Kanban*. Pearson Education.
9. Cohn, M. (2004). *User stories applied: For agile software development*. Addison-Wesley Professional.
10. Conway, M.E. (1968). How do committees invent. *Datamation, 14(4),* 28-31.
11. Damij, N., Damij, T. (2021). An approach to optimizing Kanban board workflow and shortening the project management plan. *IEEE Transactions On Engineering Management, 71,* 13266-13273.
12. Denning, S. (2018). *The age of agile: How smart companies are transforming the way work gets done.* Amacom.
13. Forsgren, N., Humble, J., Kim, G. (2018). *Accelerate: The science of lean software and devops: Building and scaling high performing technology organizations*. IT Revolution.
14. Fowler, M., Highsmith, J. (2001). The agile manifesto. *Software development, 9(8),* 28-35.
15. Goodpasture, J. (2015). *Project management the Agile way*. J. Ross Publishing.
16. Gupta, A., Rawal, A., Barge, Y. (2021). Comparative study of different SDLC models. *Int. J. Res. Appl. Sci. Eng. Technol, 9(11),* 73-80.
17. Herbsleb, J.D., Grinter, R.E. (1999, May). *Splitting the organization and integrating the code: Conway's law revisited.* Proceedings of the 21st international conference on Software engineering, pp. 85-95.
18. Humble, J., Farley, D. (2010). *Continuous delivery: reliable software releases through build, test, and deployment automation.* Pearson Education.

19. Kniberg, H., Ivarsson, A. (2012). *Scaling agile @ spotify*. Retrieved from: http://www.agileleanhouse.com/lib/lib/People/HenrikKniberg/SpotifyScaling.pdf, 30.10.2025.
20. Larman, C., Vodde, B. (2016). *Large-scale scrum: More with LeSS*. Addison-Wesley Professional.
21. Larman, C., Basili, V.R. (2003). Iterative and incremental developments; a brief history. *Computer, 36(6),* pp. 47-56.
22. Leffingwell, D. (2018). *SAFe 4.5 Reference Guide: Scaled Agile Framework for Lean Enterprises.* AddisonWesley Professional.
23. Little, J.D. (2011). Little's Law as viewed on its 50th anniversary. *Operations research, 59(3),* 536-549.
24. Little, J.D., Graves, S.C. (2008). Little's law. In: *Building intuition: insights from basic operations management models and principles* (pp. 81-100). Boston, MA: Springer US.
25. Martin, P.Y., Turner, B.A. (1986). Grounded theory and organizational research. *The Journal Of Applied Behavioral Science, 22(2)*, 141-157.
26. Noor, N. (2025). *Generative AI-assisted software development teams: opportunities, challenges, and best practices*. Master Thesis. Lappeenranta–Lahti: University of Technology LUT.
27. O'Reilly III, C.A., Tushman, M.L. (2013). Organizational ambidexterity: Past, present, and future. *Academy of Management Perspectives, 27(4),* 324-338.
28. Pee, L.G., Kankanhalli, A. (2009). A model of organisational knowledge management maturity based on people, process, and technology. *Journal of Information & Knowledge management, 8(02),* 79-99.
29. Poppendieck, M., Poppendieck, T. (2003). *Lean software development: An agile toolkit*. Addison-Wesley.
30. Sikora, T.D. (2021). *Chapter "Scaling up the Enterprise and Large–scope Software Development", Adaptive monitoring and control framework in Application Service Management environment* (Doctoral dissertation). Birkbeck: University of London, p. 229.
31. Skelton, M., Pais, M., Malan, R. (2019). *Team topologies: organizing business and technology teams for fast flow.*
32. Taulli, T. (2024). *AI-Assisted Programming*. O'Reilly Media, Inc.
33. Trist, E., Emery, F.E. (1960). Sociotechnical systems. *Management Science, Models And Techniques, 2,* 83-97.
34. Trist, E., Pasmore, W.A., Sherwood, J.J. (1960). *Sociotechnical systems*. London: Tavistock.
35. Wilkes, B., Milani, A.M.P., Storey, M.A. (2023, October). *A framework for automating the measurement of devops research and assessment (dora) metrics*. IEEE International Conference on Software Maintenance and Evolution (ICSME). IEEE, pp. 62-72.

36. Williams, D.E., Leask, J. (2011). *People, process, technology strategy for enterprise 2.0.* USA: Booz, Allen, Hamilton.
37. Yin, R.K. (2018). *Case study research and applications (Vol. 6).* Thousand Oaks, CA: Sage.

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IDENTIFYING INNOVATION AMONG HOUSING DEVELOPERS IN POLAND

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Purpose: The aim of this study is to identify the innovation of housing developers in the real estate market in Poland.
Design/methodology/approach: Two research methods were used in this study. The first was Desk Research, which analysed existing data, including reports published by GUS, EUROSTAT and EIS, and the second was a narrative literature review of publications included in the SCOPUS database, among others. The second research method involved two CATI surveys conducted among developers implementing housing projects characterised by the construction of multi-storey, multi-family housing buildings in Poland.
Findings: The most important conclusions include, first and foremost, the fact that the activities of housing developers in Poland are characterised by a low degree of innovation. This level is similar to the overall level of innovation in Poland. It has been proven that developers with a broader scale of activity are more inclined to introduce innovations than those operating locally, and the most frequently introduced innovations belong to the technical and technological group. It has been pointed out that developers work on their own innovations to a negligible extent, without cooperating with external research units in this area.
Research limitations/implications: The general population of the survey was determined based on a market analysis of entities involved in multi-storey multi-family housing construction, rather than on the basis of the Polish Classification of Activities (PKD). This eliminates entities that are insignificant for the study, but makes it difficult to determine the general population in detail, which may be subject to an error of +/-5%. The study was general in nature and allowed for the identification of possible areas for future research, such as the analysis of technical and technological innovations taking into account RES or the analysis of factors determining the development of own innovations.
Social implications: The research indicates a low level of innovation and a small share of own innovations introduced by developers, with a simultaneous lack of cooperation with research units. This shows the need for systemic changes in order to increase innovation and establish research cooperation.
Originality/value: The article presents the level of innovation of housing developers in Poland, which is not examined in detail by statistical or other entities. The research can be used by public entities to imply systemic solutions.
Keywords: housing market, innovation, housing developer, RES, sustainability.
Category of the paper: Research paper, Literature review.

1. Introduction

In an era of dynamic technological development, its impact on various sectors of the economy is becoming very important. Therefore, a key element today is the implementation of broadly understood new technologies in economic activity through the introduction of innovation into business operations. Innovation increases competitiveness, but today its importance in many sectors has grown not only to increase competitive advantage in the market and achieve a leading position, but also to become a factor that determines whether a company can even survive in the market (Skibiński, Sipa, 2015).

So what is innovation and how has it been defined? The definition of innovation has evolved along with the changing environment, technology and needs. Joseph A. Schumpeter (Schumpeter, 1934) defined innovation as a concept relating to five areas:

1. the introduction of a completely new product or a new type of existing product,
2. the implementation of a new method of production or sale of a product,
3. entry into a new market where a given branch of the economy was not yet present,
4. the acquisition of a new source of supply of raw materials or semi-finished products,
5. introduction of a new structure or organisation of activities.

More recent definitions of innovation interpret the concept more broadly, also including the social aspect. Peter Drucker (Drucker, 1992) argues that innovation should be analysed in relation to the role of people in the process, thus elevating the aspect of entrepreneurship to a key factor in this area.

Michael Porter defines innovation as the successful exploitation of a new idea, which means that innovation is not only something new and unique, but also its successful implementation in the organisation's activities, resulting in certain economic benefits (Porter, 1990).

From 2018, the current "Oslo Manual" (OECD/European Union, GUS, 2018) provides a standard, broad definition of innovation used in economic practice and statistical research. The concept of innovation is defined as the implementation of a new or significantly improved product, service, process or organisational method in economic practice. This definition implies that innovation is a process in which new ideas are transformed into economic and social value through the implementation of a new or significantly improved product, process, marketing method or organisational method. The definitions emphasize that innovation is not only about groundbreaking inventions, but also about gradual improvements that lead to greater efficiency, quality, or competitiveness. The key elements are novelty, usefulness (benefit) and actual implementation.

In Poland, the Central Statistical Office defines innovation as the implementation of a new or significantly improved product (good or service) or process, or a new organisational method, whereby new processes or organisational methods are implemented when they begin to be used in the actual operation of the enterprise (GUS, 2012).

It follows from the above that innovation is currently a key element in gaining a competitive advantage for the entire economy, which is becoming extremely important in the reality of global competition. However, innovation is not only a way to increase competitiveness, but also a way to achieve sustainable development, which, according to the UN definition, is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The UN guidelines identify three key elements like economic growth, social inclusion, and environmental protection whose coherence is necessary to achieve sustainable development. Innovation is therefore becoming crucial not only for the purpose of increasing economic efficiency, but also for achieving environmental and social goals that are important for the entire planet, such as equalising opportunities and eliminating social exclusion in the broad sense (Sustainable Development GOALS, 2015).

From the point of view of real estate and its role in the economy, it can be said that the entire real estate sector should therefore be a field of intensive development of broadly understood innovation. Due to their high capital intensity, real estate properties constitute a large part of national wealth and play an important role in the economy as a whole, influencing, among other things, the financial system, which is largely a source of financing for the real estate market. Furthermore, real estate has a huge social dimension, satisfying the basic human need for a "roof over one's head", i.e. the need for shelter, or fulfilling the function of providing a place to conduct business activities.

Therefore, innovations implemented in the field of sustainable development must include the real estate market, as real estate is becoming the living environment in which people spend most of their lives. Real estate related to business activities can increase its efficiency by, for example, reducing property operating costs, obtaining energy from renewable sources, or organizing space, thereby increasing employee productivity. On the other hand, housing real estate can be more environmentally friendly, energy-efficient, or even zero-emission through the use of innovative solutions, or it can eliminate barriers related to social exclusion, such as disabilities. Therefore, the aim of this study is to identify the innovativeness of housing developers in the Polish property market.

2. Literature review

Due to the importance of innovation for entire economies, many institutions, agencies and researchers are addressing this topic. Among the most reliable data is the European Innovation Scoreboard (EIS) published by the European Commission, which contains a comparative assessment of research and innovation in EU Member States in 2018-2025. The summary innovation index presented in the scoreboard is calculated on the basis of 32 indicators covering the scope of activities and factors related to innovation.



Figure 1. Innovation index for Poland.

Source: https://projects.research-and-innovation.ec.europa.eu/en/statistics/performance-indicators/european-innovation-scoreboard/eis#/eis/countries/PL

As the chart shows, Poland ranks only 27th among EU countries, including neighbouring countries. Furthermore, in 2025, we achieved a score of 74.2 of the EU average baseline for 2018. Despite the complexity of the indicator and the possibility of presenting different variants, the European innovation scoreboard does not allow for specifying the level of innovation in the real estate sector, let alone more detailed areas such as the housing real estate market or the property development companies operating in it.

A similar situation occurs in the case of other reports presented by Eurostat or the Central Statistical Office (GUS), which are usually based on the CIS (Community Innovation Survey). Therefore, the reports do not provide detailed data characterising the real estate market as a whole, the housing real estate market, or the development companies operating in this market. Despite the publication of data broken down into the main sections of economic activity according to PKD (Polish Classification of Activities), we are unable to specify innovation in relation to the real estate market (GUS, 2024). Such information should therefore be sought in reports prepared by industry organisations or in articles published by researchers. These sources often focus on information about individual innovations or a group of innovations of a particular type. Therefore, it seems important to present the types of innovation, particularly in the context of real estate.

Until now, the definition of innovation based on the Oslo Manual 2005 (Piasecki, 2022) has been in force, which distinguished four types of innovation (OECD/Eurostat, 2008):

- product,
- process,
- organisational,
- marketing.

Product innovation was defined as a significant change, expressed in qualitative and quantitative indicators, which distinguished the product from solutions with similar functionality available on the market.

Process innovation, on the other hand, was defined as the introduction of a significant change in technology, equipment or software in an enterprise, expressed in qualitative and quantitative indicators.

The last two types of innovation mentioned above were complementary in nature.

The new Oslo Manual 2018 defines only two types of innovation, but significantly broadens the definition of product innovation by specifying functional characteristics (quality, technical specifications, reliability, durability, economy and robustness in use, affordability, convenience and usability) (OECD/European Union, GUS, 2018).

The second type of innovation in the business process concerns in particular the area of management, such as marketing, information and communication systems, administration, and product and business process development.

Innovations in the real estate market can also be classified according to the guidelines of the Oslo Manual, but authors focusing on the real estate market provide other classifications. Referring to the division of innovations according to the criteria used in the literature on real estate, the following classifications can be distinguished:

- means of creating innovations (Bac, 2014):
  - technical,
  - technological,
  - organisational innovations,
  - mixed,
- according to the field of activity to which they relate (Brzeziński, 2001):
  - product and subject innovations,
  - technological and process innovations,
  - organisational innovations,
  - functional innovations,
- by the effects of innovation (Prystom, 2012):
  - product and process innovations,
  - technical and product innovations,
  - process innovations,
  - organisational innovations.

Particular attention should be paid to modern technical and technological solutions used in construction, which constitute product and process innovations. These innovations are interrelated because the production of a new or modified product that requires a new combination of inputs is most often carried out using a new process innovation at the same time. At the same time, a new or improved production process forces product innovation because it changes the characteristics of the goods produced (Prystrom, 2012).

The fourth technological revolution, also known as Industry 4.0 in the real estate market, identified with PropTech, is the current phase of industrial development based on the combination of modern digital technologies with automation (Siniak, 2020; Bartkowiak et al., 2023), which defines PropTech as a small part of the broader digital transformation of the entire real estate industry. Shaw (Shaw, 2018), on the other hand, sees PropTech as the sum of digital platforms that connect various stakeholders in the real estate market.

PropTech is, on the one hand, a name that refers to all technological innovations in the real estate segment and, on the other hand, the industry itself, the business sector and, more generally, the trend driving change in the real estate industry's mindset (Bartkowiak et al., 2023).

The common denominator of all PropTech definitions is to achieve greater efficiency and effectiveness in real estate, which involves three main real estate industries: *facility*, *property* and *asset management* (Maududy, Gamal, 2019). The greatest investor activity is observed in the area related to meeting housing needs and property management (Luque, 2021).

The PropTech sector is relatively new, having emerged in the late 1990s, just before the technological revolution. This is the reason for the existence of various classifications (Tagliaro et al., 2020) and categorisations of PropTech (Bartkowiak et al., 2023). The figure shows industries as areas of PropTech application according to (Baum et al., 2020).



Figure 2. PropTech Elements by Baum.

Source: Bartkowiak et al., 2023.

The most important areas are: the property market, smart cities, smart buildings, the sharing economy, the construction sector and property financing.

The property market consists of platforms based on modern technologies that facilitate the operation and management of real estate, control the performance of buildings, and facilitate or control services (Baum, 2017).

Smart cities – are internet portals as knowledge bases, agglomerations equipped with information and communication technologies (ICT) (Anthopoulos, 2015).

Smart buildings – intelligent and computer technologies that facilitate the combination of comfort and energy consumption (Wang et al., 2012).

Shared economy – technology-based platforms that facilitate the use of real estate assets. Platforms may simply provide information to potential users and sellers of space, or they may more directly facilitate or conduct rental or fee-based transactions (Baum, 2017).

Construction sector (ConTech) – technological innovations in the design, planning and construction of real estate (Bartkowiak et al., 2023). ConTech construction technologies are concepts that integrate digital innovations, advanced materials and automated systems with the traditional model of the construction process.

Real estate financing (FinTech) – the use of technology and innovative business models in financial services (Szpringer, 2017). FinTech refers to innovative companies and technologies used to provide financial services through the use of modern technologies.

Another classification of PropTech segments is proposed by MIPIM (International Real Estate Exhibition for Professionals). This is an annual event, one of the most important in the world for the real estate market, which takes place in Cannes, France, dividing them into: mart buildings / IoT, smart city sustainability, market place, crowdfunding, ConTech, 3D / VR, data and research analytics (Tagliaro et al., 2021).

Under the influence of PropTech, the real estate industry is undoubtedly undergoing significant changes, which are mainly reflected in market transparency (Porter et al., 2019; Siniak et al., 2020). In a broader sense, PropTech is beneficial for territorial competition and territorial development strategies (Siniak et al., 2020). Finally, within the framework of various institutional solutions, PropTech can influence the changing structure of the real estate market (Braesemann, Baum, 2020).

3. Methodology

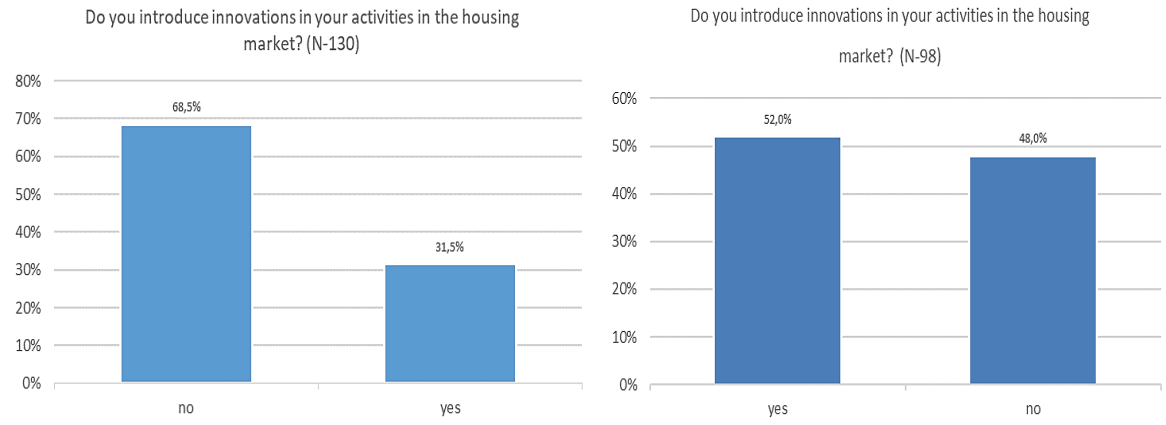
A combination of two research methods was used to conduct the study. The Desk Research method of analysing existing data, which involves the use of secondary data, i.e. data previously collected by other researchers, agencies or institutions. In the case of the study described, industry reports and reports published by GUS, EUROSTAT and EIS were used. In addition, a narrative literature review method was used in relation to data collected by researchers and published in works included, among others, in the SCOPUS database. To achieve the objective of the study, a second research method was also used, consisting of collecting primary data through CATI surveys, which involved conducting telephone interviews with respondents using a computer. The survey was addressed to managers of development companies implementing housing projects characterised by the construction of multi-storey, multi-family housing buildings. The first survey was conducted in August 2020 on a sample of 130 respondents out of a total population of 314 entities identified at that time. Then, at the turn of October and November 2022 another survey was conducted using the same method on a sample

of 98 respondents selected from a total population of 280 entities. The surveys conducted made it possible to identify and analyse the structure of innovation and draw conclusions for the future with regard to the activities of developers on the housing property market in Poland.

4. Results

The survey on innovation used by Polish housing developers is an important aspect showing the overall levels and trends on the housing property market. As a result, innovation in the real estate industry is not only about new sources of projects, financing or cooperation, but also about a thorough modernisation of IT and management systems – all in order to increase the flexibility, transparency and quality of projects. However, the specific effects associated with this need to be preceded by further, more detailed research. The study conducted allows us to identify precisely such areas.

The survey presented made it possible to determine, approximately, the level of housing developers who introduce innovations as part of their activities on the real estate market in Poland (Figure 3). Before answering the questions, the respondents were provided with all the necessary information and definitions to increase the reliability of the survey – in this case, the definition of innovation.



a) survey 2020 b) survey 2022

Figure 3. Percentage of developers innovating (2020 and 2022 survey).
Source: Own study based on data from (Sitek, 2023; 2023a; Sitek, Sipa, 2024).

Comparing the data presented in Figure 3, there has been an increase in the number of developers declaring that they introduce innovations into their projects over a two-year period. Furthermore, the increase from 31.5% to 48% should be considered a very good result. However, in order to interpret this data correctly, it is necessary to refer to the market conditions prevailing during the period under review. Namely, it was an extremely difficult period in which there were many risks affecting the activities of entire economies, including entities on the real

estate market. At that time, we had the COVID-19 pandemic, rising inflation affecting high interest rates and thus lending, the outbreak of war in Ukraine, which caused a sharp increase in the prices of raw materials and thus building materials, which drove inflation to very high levels.

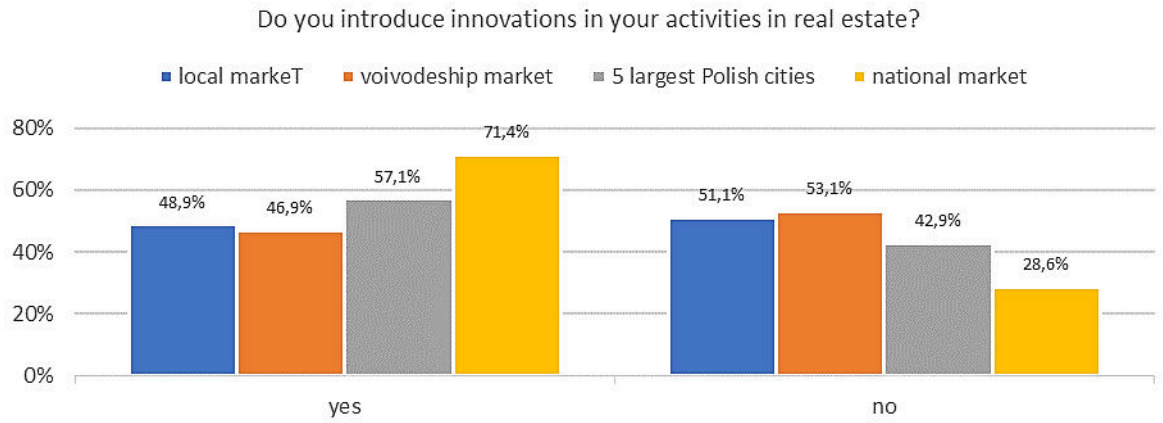


Figure 4. Developers' willingness to innovate according to their territorial scope of activity.

Source: Own study based on data from (Sitek, 2023; 2023a; Sitek, Sipa, 2024).

A detailed analysis of developers introducing innovations (Figure 3) based on the scope of the market in which they operate (Figure 4) showed the percentage of developers operating on the local market, the provincial market, the national market and within the five largest cities in Poland that introduce innovations. The data clearly shows that entities operating on a broad market, such as the national market, introduce innovations more often than those operating on a smaller scale, locally.

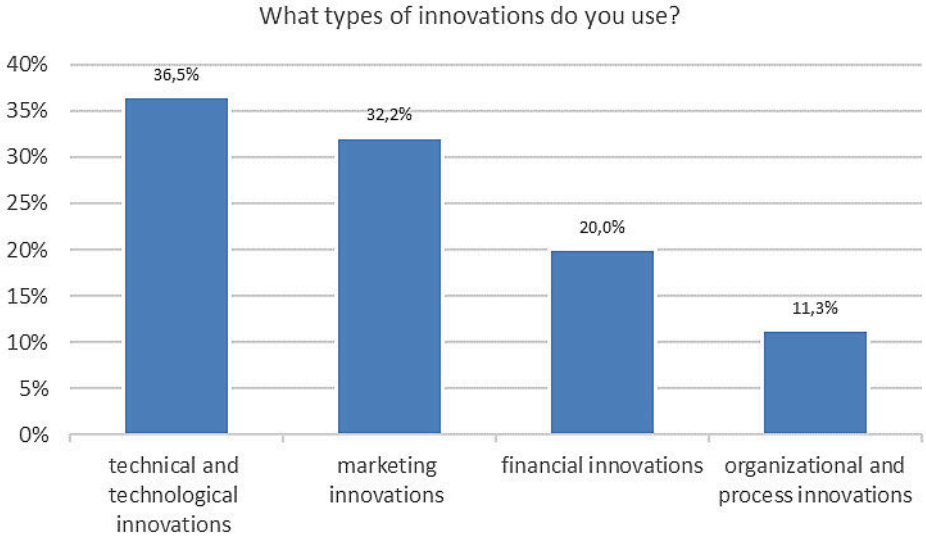


Figure 5. Types of innovations introduced by developers.

Source: Own study based on data from (Sitek, 2023, 2023a).

The next question analysed concerns the type of innovations used. As can be seen in Figure 4, the study adopted a different classification of innovations than the Oslo manual, which is the result of an analysis of publications on the types of innovations characteristic of real estate. In addition, the broader spectrum of innovations presented allows for more detailed conclusions. As presented, the most commonly used innovations include those from the technical and technological group, i.e., those that affect, among other things, operating costs or ecological solutions, where we can distinguish renewable energy sources or specific ecological building materials.

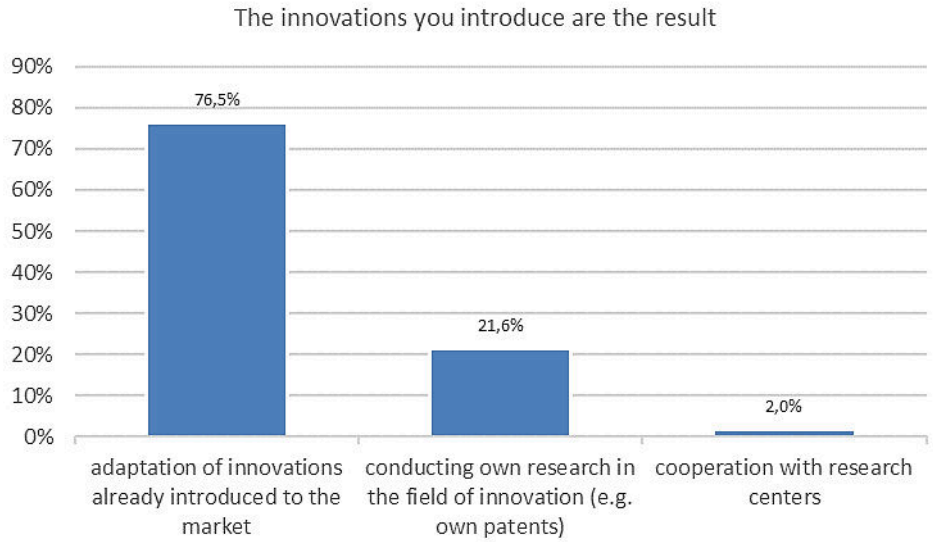


Figure 6. Ways to acquire innovations by developers.

Source: The Author's own elaboration.

Further analysis of the problem of innovation implementation by residential developers shows that developers adapt proven innovations, while conducting research on their own innovations to a small extent – 21.6% of respondents. Less than 2% cooperate with research centres to develop their own innovations.

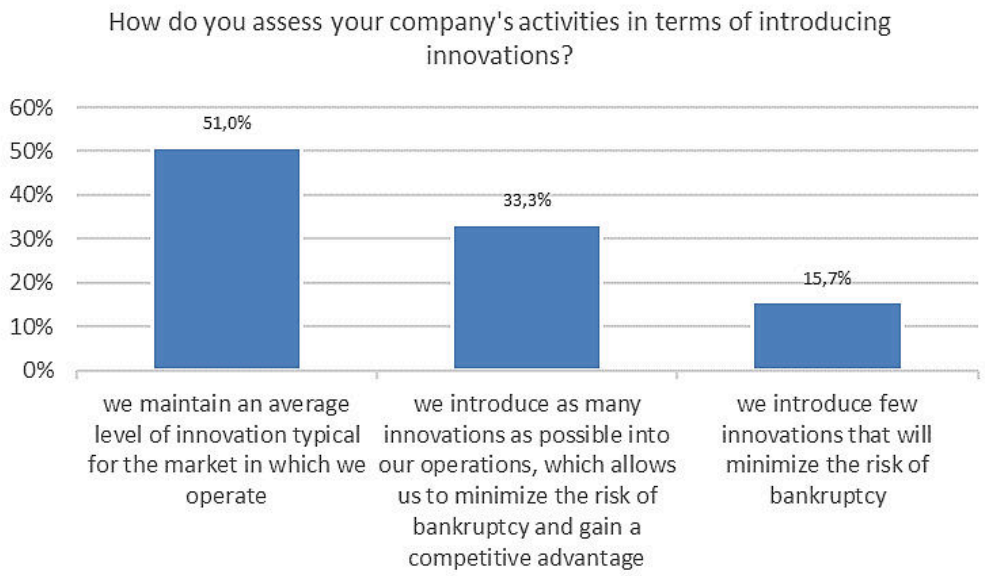


Figure 7. The scope of innovation in developer activities.

Source: The Author's own elaboration.

Developers declare that the majority (51%) maintain an average level of innovation characteristic of the market in which they operate, 33% of them express a willingness to introduce as many innovations as possible, motivated by the desire to gain a competitive advantage, while the smallest percentage (15%) introduces only a minimum amount of innovation to counteract the possible threat of bankruptcy. This shows how the market's need for innovation is shaping up.

To sum up, we note an increase in the number of housing developers in Poland declaring that they introduce innovation in their projects, but its dynamics require deeper analysis. Developers introducing innovations focus primarily on technical and technological innovations, as this group allows them to demonstrate, among other things, broadly understood energy efficiency, which, in conditions of high electricity and energy raw material prices, becomes an important decision-making factor for buyers. Furthermore, in-house research on innovation accounts for a small percentage, and cooperation with research institutions that could accelerate the dynamics of introducing "own" innovations is practically non-existent.

5. Discussion

Comparing the above data collected in our own research with the available existing data, it can be clearly stated that they supplement the current state of knowledge on the innovativeness of housing developers in Poland. When analysing the level of innovativeness of Polish enterprises, reference should be made to the reports presented by the Central Statistical Office (GUS) on the innovativeness of Polish enterprises.

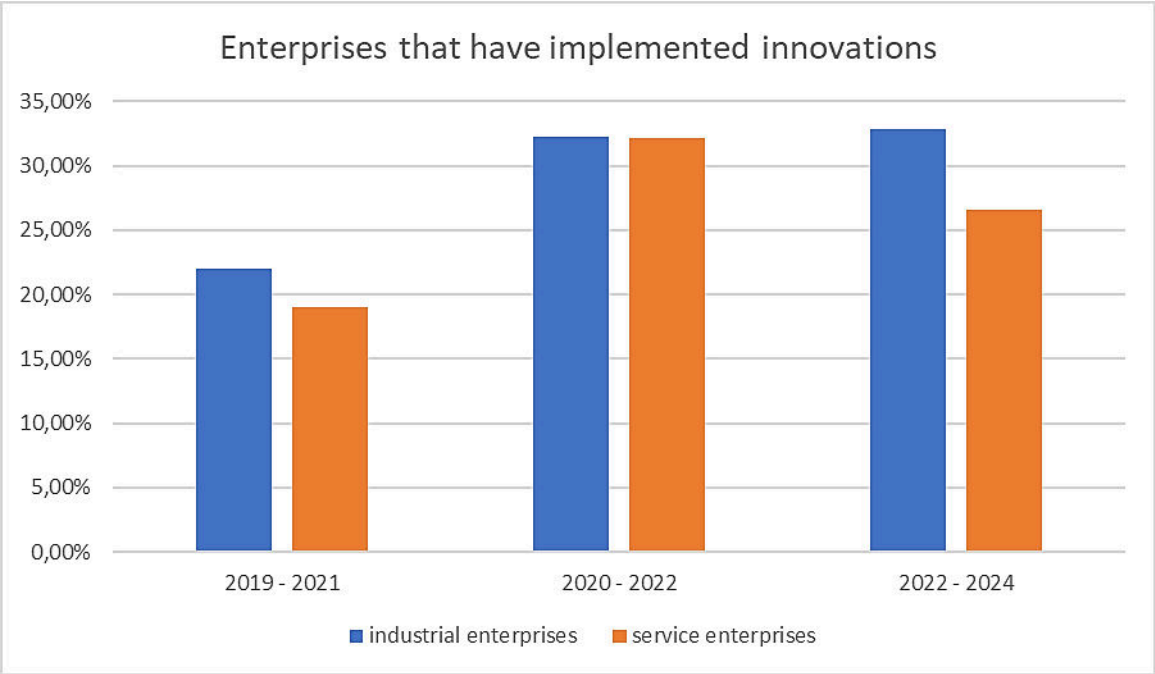


Figure 8. Enterprises that have implemented innovations.

Source: Own study based on data from (GUS, 2024).

The data presented in the figure does not show the level of innovation of housing developers. It could be assumed that developers are a component of industrial enterprises, but this is not entirely true. If a developer has its own resources to complete a project without the involvement of subcontractors, the result is a final product. A flat developed by a developer can be classified as a manufacturing enterprise. However, if a developer only manages a project by hiring subcontractors such as architects, solicitors or construction companies and then trades in real estate, i.e. sells it, we can classify them as a service company. It should therefore be emphasised that national or even European statistical data do not allow us to specify the level of innovation of housing developers. The only noteworthy similarity is the fact that in the period from 2020 to 2022 and in the similar period presented by the Central Statistical Office (GUS) from 2019-2021 to 2020-2022, both housing developers and enterprises in general recorded a clear increase in innovation. However, this increase was probably caused by difficult market conditions that resulted in business closures and even bankruptcies. It can therefore be assumed that companies that did not implement innovations and were thus less competitive disappeared from the market.

The results of the study showed that developers operating on a smaller scale, i.e. locally and within a province, were much less willing to innovate than those competing nationwide or in the market of the five largest cities, which is also the most demanding. It is therefore the need to compete that motivates innovation. This is confirmed by research conducted by Kilip and Owen (Klip, Owen, 2020), who report that entrepreneurs operating locally in the real estate market do not usually introduce innovations, unlike those who operate on a large scale.

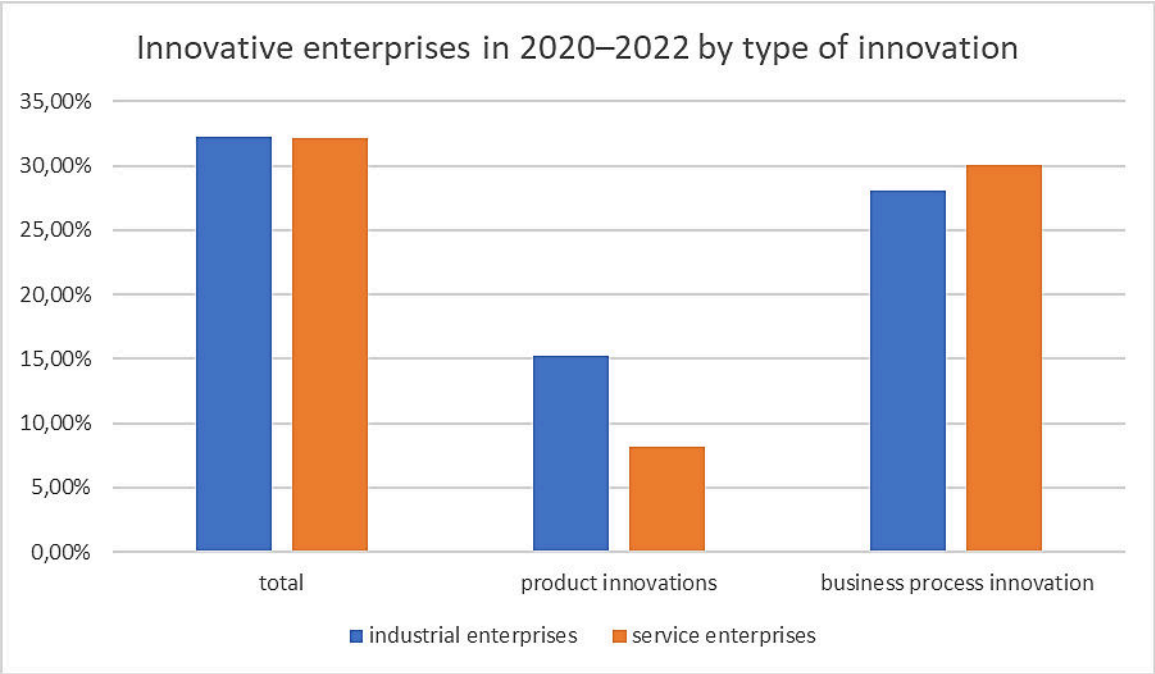


Figure 9. Innovative enterprises in 2020-2022 by type of innovation.

Source: Own study based on data from (GUS, 2024).

In the case of types of innovation, we see a complete discrepancy between the GUS research and the declarations of developers in the survey. Developers primarily introduce technical and technological innovations, which, according to the Oslo Manual classification, are classified as product innovations. This points to the need to conduct specific research within the scope of the activity in question – multi-family housing construction – because the real estate market is extremely specific.

Research conducted in 2022 in Poland on the use of renewable energy sources in housing construction (Szymańska et al., 2022) shows that RES are overwhelmingly introduced in single-family homes rather than in multi-family construction (43.38% vs. 5.40%) and in rural areas (48%). However, in the studies presented in this paper, the most frequently selected innovations belong to the group of technical and technological innovations, which include RES, and are most often introduced by developers operating on a national scale and in the five largest cities. Admittedly, these studies cannot be directly compared because in this case both new and older buildings were analysed, but the results differ so much that it is worth analysing this problem in depth, which may be the subject of future research.

The last two questions presented in the article concern the introduction of own innovations and cooperation with research units, as well as the intensity of innovation in their activities. These answers give a picture of innovation in the housing property market, namely the minimal share of developing own innovations and the virtual absence of cooperation with research units in this area. In addition, the majority of developers (over 50%) declare that they only introduce innovations at the standard level characteristic of the market in which they operate.

6. Conclusion

The presented research results provide a general overview of the innovativeness of housing developers in Poland and aim to identify areas for further detailed research, allowing for possible implications of solutions to improve the implementation of innovation in the housing property market in Poland.

The most important conclusions presented in connection with the research undertaken include, above all, the fact that the activities of housing developers in Poland are characterised by a low degree of innovation. This level is similar to the overall level of innovation in Poland, which, according to the EIS, is classified as emerging innovators.

Despite the presented increase in the level of innovation among developers from 31,5% of responders in the 2020 to 52% in the 2022, we cannot fully classify this increase as being solely related to the growth of applied innovations. This increase was influenced by market conditions that caused a decline in the number of developers operating on the market and, consequently, a decline in the general population and the research sample in 2022. The increase in innovation among developers is therefore seen as being linked to the withdrawal from the market of developers who do not implement innovations, as they are not very competitive. It should be noted, however, that no detailed research has been conducted in this area, so this is more of an author's hypothesis than a fact, which may also be a contribution to further research.

When analysing the structure of the innovations introduced, it is clear that the leading group are technical and technological innovations, pointed by 36,5% of responders, that have a tangible effect, i.e. the end product – a flat. This group includes, among others, RES and building materials that help to reduce the energy consumption of buildings and thus reduce operating costs. However, an interesting fact revealed in the discussion is that other studies show a small share of RES in multi-family housing construction. This is another research problem that could be the basis for future studies. Marketing innovations are the second most prevalent, accounting for 32.2% of all responses. These innovations are often characterised by their reduced cost and ease of implementation when compared with technical and technological innovations. This factor is likely to contribute to their popularity among developers.

According to other sources and existing data, the study showed that the scope and scale of developers' activities influence innovation. It was confirmed that the greater the scope of a developer's activities, the more willing they are to introduce innovations. A survey of developers operating within the broadest scope of activity analysed revealed that 71,4% of respondents operating on a national scale declared that they introduce innovations in their projects, compared to 48.9% of developers operating locally.

The last two questions presented reveal the weakness of Polish housing developers in terms of innovation. The vast majority of entities admit that they adapt innovations already implemented on the market (76,5%), and only a small fraction develop their own (21,6%),

with virtually no cooperation with research units in this area (only 2%). In addition, developers themselves are interested in introducing innovations that will ensure them a standard level characteristic of the market. Only slightly more than 30% of respondents want to introduce as many innovations as possible and become a leading entity. The final conclusion is therefore that efforts should be made to develop own innovations by developing attractive systems of cooperation between enterprises and research units. It is imperative to emphasise that the proposed recommendation must be informed by forthcoming research that investigates the prevailing barriers, alongside the expectations of developers with regard to support from the broader Romanian state. Furthermore, the identification of priority areas is crucial in the context of enhancing the development of their own innovations. The data presented herein has the potential to inform the development of systemic solutions that could be integrated into the innovation policy framework within the residential real estate market. This will not only allow developers to develop their own innovations, which, in addition to being implemented in their own activities, can also be sold to other entities. It would allow the Polish economy to rank higher in the innovation ranking of countries. Without our own innovations and by only adapting innovations, we will not become an economy at the forefront of the innovation ranking and thus competitiveness.

References

1. Anthopoulos, L.G. (2015). Understanding the smart city domain: A literature review. In: M.P. Rodríguez‑Bolívar (Ed.), *Transforming city governments for successful smart cities* (pp. 9-21). Springer International Publishing. https://doi.org/10.1007/978-3-319-03167-5_2
2. Bac, M. (2014). W poszukiwaniu innowacji na rynku nieruchomości. *Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie, Vol. 24, Iss. 1.*
3. Bartkowiak, P., Górska, A., Koszel, M., Mazurczak, A., Strączowski, Ł. (2023). *Nowe technologie na rynku nieruchomości – w poszukiwaniu zrównoważonego rozwoju.* Poznań: Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu. Retrieved from: https://wydawnictwo.ue.poznan.pl/book.html?isbn=978-83-8211-155-2
4. Baum, A. (2017). *PropTech 3.0: The future of real estate.* Saïd Business School, University of Oxford. Retrieved from: https://www.sbs.ox.ac.uk/news/property-tech-30-ground-breaking-report-looks-future-real-estate
5. Baum, A., Saull, A., Braesemann, F. (2020). *PropTech 2020: The future of real estate. Future of Real Estate Initiative.* Saïd Business School, University of Oxford. Retrieved from: https://www.sbs.ox.ac.uk/sites/default/files/2020-02/proptech2020.pdf

6. Braesemann, F., Baum, A. (2020). *PropTech: Turning real estate into a data-driven market?* SSRN Working Paper. Retrieved from: http://dx.doi.org/10.2139/ssrn.3607238, 02.10.2024.
7. Brzeziński, M. (Ed.) (2001). *Zarządzanie innowacjami technicznymi i organizacyjnymi.* Warszawa: Difin.
8. COM (2019). *Europejski Zielony Ład. Komunikat Komisji do Parlamentu Europejskiego, Rady, Europejskiego Komitetu Ekonomiczno-Społecznego i Komitetu Regionów*, COM (2019) 640 final. Bruksela.
9. Drucker, P.F. (1992). *Innowacja i przedsiębiorczość. Praktyka i zasady [Innovation and Entrepreneurship]*. Warszawa: PWE.
10. European Commission (2025). *Research and Innovation. Country Profile: Poland*. Retrieved from: https://projects.research-and-innovation.ec.europa.eu/en/statistics/performance-indicators/european-innovation-scoreboard/eis#/eii/countries/PL
11. Eurostat (2018). *Community Innovation Survey*. Retrieved from: https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey
12. Główny Urząd Statystyczny (2012). *Działalność innowacyjna przedsiębiorstw w latach 2009-2011*. Warszawa: Urząd Statystyczny w Szczecinie.
13. Główny Urząd Statystyczny (2024). *Działalność innowacyjna przedsiębiorstw w Polsce w latach 2022-2024.* Retrieved from: https://stat.gov.pl/obszary-tematyczne/nauka-i-technika-spoleczenstwo-informacyjne/nauka-i-technika/dzialalnosc-innowacyjna-przedsiebiorstw-w-polsce-w-latach-2022-2024,14,11.html
14. Killip, G., Owen, A. (2020). The construction industry as agents of energy demand configuration in the existing housing stock. *Energy Policy, No. 47*, 111816.
15. Luque, J. (Ed.) (2021). *PropTech Global Trends 2021: Annual Barometer*. ESCP Business School. Retrieved from: https://escp.eu/sites/default/files/PDF/news-events/proptech-global-trends-2021.pdf
16. Maududy, C.F., Gamal, A. (2019). Literature review: Technologies and property development. *IOP Conference Series: Earth and Environmental Science, Vol. 396, No. 1.* Institute of Physics Publishing. https://doi.org/10.1088/1755-1315/396/1/012020
17. OECD/Eurostat (2008). *Podręcznik Oslo. Zasady gromadzenia i interpretacji danych dotyczących innowacyjności*. Retrieved from: http://www.uwm.edu.pl/citt/wp/content/uploads/2023/10/Podręcznik-Oslo-Manual.pdf, 02.10.2024.
18. OECD/Unia Europejska, GUS (2018). *Podręcznik Oslo 2018. Zalecenia dotyczące pozyskiwania, przetwarzania i wykorzystywania danych z zakresu innowacji*. Warszawa/Szczecin.
19. Piasecki, M. (2022). *Innowacyjność w nowej perspektywie finansowej 2021-2027.* Retrieved from: https://www.mojedotacje.pl/innowacyjnosc-w-nowej-perspektywie-finansowej-2021-2027, 02.10.2024.

20. Porter, L., Fields, D., Landau-Ward, A., Rogers, D., Sadowski, J., Maalsen, S., Kitchin, R., Dawkins, O., Young, G., Bates, L.K. (2019). Digital transformations of housing and planning. *Planning Theory and Practice, 20(4),* 575-603. doi:10.1080/14649357.2019.1651997
21. Porter, M. (1990). *The Competitive Advantage of Nations*. London: Macmillan Press.
22. Prystrom, J. (2012). *Innowacje w procesie rozwoju gospodarczego. Istota i uwarunkowania*. Warszawa: Difin.
23. Rozporządzenie Parlamentu Europejskiego i Rady (UE) (2021). Europejskie prawo o klimacie. Dz.U. L 243, pp. 1-17.
24. Schumpeter, J.A. (1934). *Teoria rozwoju gospodarczego*. Warszawa: PWN.
25. Shaw, J. (2018). Platform real estate: Theory and practice of new urban real estate markets. *Urban Geography, 41(8),* 1-28.
26. Siniak, N., Kauko, T., Shavrov, S., Marina, N. (2020). The impact of PropTech on real estate industry growth. *IOP Conference Series: Materials Science and Engineering, 869,* 062041.
27. Sipa, M., Skibiński, A. (2015). *Innovative strategies of small enterprises in Poland*. Liberec Economic Forum, Proceedings of the 12th International Conference, Technical University of Liberec, pp. 342-352.
28. Sitek, M. (2023). Działalność innowacyjna deweloperów mieszkaniowych w Polsce w kontekście barier i stymulantów implementacji. *Zeszyty Naukowe Wyższej Szkoły Humanitas. Zarządzanie, 24(4),* 175-191.
29. Sitek, M. (2023a). Rola innowacji w strategii deweloperów mieszkaniowych w Polsce. *Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie, No. 185*, 433-453.
30. Sitek, M., Sipa, M. (2024). Innovation in development projects in Poland. In: N. Obermayer, A. Bencsik (Eds.), *Proceedings of the 25th European Conference on Knowledge Management, Vol. 25, No. 1.* Reading: Academic Conferences and Publishing International.
31. Sustainable Development Goals (2015). *Cele zrównoważonego rozwoju*. Warszawa: Ośrodek Informacji ONZ. Retrieved from: https://www.unic.un.org.pl/strony-2011-2015/zrownowazony-rozwoj-i-cele-zrownowazonego-rozwoju/2860
32. Szpringer, W. (2017). *Nowe technologie a sektor finansowy. FinTech jako szansa i zagrożenie.* Warszawa: Poltext.
33. Szymańska, J., Kubacka, M., Woźniak, J., Polaszczyk, J. (2022). Analysis of residential buildings in Poland for potential energy renovation toward zero-emission construction. *Energies, 15*, 9327. doi:10.3390/en15249327
34. Tagliaro, C., Bellintani, S., Ciaramella, G. (2020). R.E. property meets technology: Cross-country comparison and general framework. *Journal of Property Investment & Finance, 39(2),* 125-143. https://doi.org/10.1108/JPIF-09-2019-0126

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CONTEMPORARY DEMOGRAPHIC TRENDS AS DETERMINANTS OF CHANGES IN ORGANIZATIONAL MANAGEMENT APPROACHES – A THEORETICAL FRAMEWORK

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Purpose: The purpose of this paper is to analyze the impact of contemporary demographic trends, such as population aging, generational diversity, and migration, on management practices within organizations, with particular emphasis on Poland and selected Central and Eastern European countries.
Design/methodology/approach: The study combines a narrative literature review with a bibliometric analysis based on the Web of Science and Scopus databases (over 950 publications from 2000 to 2025), using VOSviewer software. The co-occurrence analysis of keywords enabled the identification of thematic clusters, dominant research directions, and existing research gaps.
Findings: The results indicate a deepening process of population aging, especially in Central and Eastern European countries, and its implications for human resource management—particularly in the areas of leadership and knowledge transfer among employees of diverse age and cultural backgrounds. Additionally, the study identified a lack of connections between demographic research and management practice.
Research limitations/implications: The study has a regional scope, focusing on selected countries in the CEE region and utilizing data from the Scopus and Web of Science databases. It is recommended that future research extend the analysis to other regions and include empirical studies.
Originality/value: This paper contributes to the discussion on the relationship between demographic processes and organizational management by combining narrative and bibliometric approaches and by identifying research gaps that are crucial for further in-depth exploration of this topic.
Keywords: organisational management, age management, diversity management, migration, demographic trends.
Category of the paper: Research paper/literature review.

1. Introduction

Contemporary organisations operate in an environment of dynamic socio-economic and technological changes that influence both the labour market and human resource management strategies. In most European countries, and particularly in Poland, a process of deepening population ageing, declining fertility rates, and increasing international migration is underway (Skibiński et al., 2016; Yembi et al., 2021). As a result, a growing diversity in terms of generation, culture, and social background can be observed globally (Eurostat, 2023; Messner, 2025). Consequently, organisations are compelled to adapt their management strategies to new challenges and to fully utilise the potential of diverse employee teams (Shen et al., 2009). Of particular importance is the region of the Visegrad Group countries, characterised by increasing occupational mobility and both internal and cross-border migration. These trends enhance the cultural diversity of teams and necessitate the development of intercultural competencies and effective communication strategies (Tavares, 2020). Demographic changes, therefore, pose new challenges for organisations while simultaneously creating opportunities for growth and increased competitiveness. Hence, understanding the demographic determinants in this region may provide a foundation for designing more effective diversity management policies that support integration and the full utilisation of employees' potential. Table 1 presents a summary of selected dimensions of diversity and their implications for organisational management.

Table 1.
Dimensions of diversity and their implications for management

Dimension of diversity	Focus	Example characteristics	Implications for management processes
Primary	Inherent, immutable individual characteristics	Gender, age, nationality, and physical abilities	Building an inclusive culture, preventing discrimination (Banasik, 2024)
Secondary	Acquired, variable life characteristics	Education, marital status, lifestyle, income	Flexible benefits systems and career paths (Morris, 2007; Banasik, 2024)
Organisational	Work-related structural characteristics	Position, experience, organisational affiliation	Motivation adjustment, mentoring, knowledge transfer (Succession Planning Framework, 2017)

Source: Own elaboration based on (Banasik, 2024; Morris, 2007; Succession Planning Framework, 2017).

An important factor shaping management paradigms is demographic processes, considered at both the global and regional levels. Particular attention should be paid to the ongoing population ageing, changes in the intergenerational composition of the labour market, and the intensification of international labour migration (Chłoń-Domińczak et al., 2017; Rakowska, 2023; Lami et al., 2022). It is worth noting that population ageing is a long-term, structural process that has been observed in Europe, and especially in Poland, for several decades. This process results, among other factors, from the combination of increasing life

expectancy and declining fertility rates, which do not ensure straightforward generational replacement. The aim of this article, based on a synthetic literature review, is to present the impact of contemporary demographic trends on organisational management and to identify research gaps that may inspire more advanced studies in this area.

2. Methods

This study employs a dual-track methodological framework, integrating a narrative literature review with bibliometric mapping. This hybrid approach ensures both theoretical depth and reproducible results, combining qualitative synthesis with quantitative mapping to identify research gaps and interpret the current state of knowledge.

1. Narrative Review

The narrative review evaluated the impact of demographic shifts—population ageing, migration, and generational diversity—on organisational management. High-impact publications in management, demography, organisational sociology, and human resources were examined using the Scopus and Web of Science databases. This phase focused on how demographic factors (age, culture, generational cohorts) relate to organisational outcomes such as leadership effectiveness and performance, providing context for identifying overarching trends and preliminary research gaps.

2. Bibliometric Analysis

A bibliometric analysis was conducted using the Scopus database (Search date: September 2025). Predefined search terms related to demographic trends and organisational management were applied to article titles, abstracts, and author keywords. The dataset was limited to peer-reviewed journal articles published in English between 2000 and 2025, excluding other document types such as conference proceedings or editorials. Approximately 950 publications were included. Data were exported to VOSviewer (version 1.6.18) for keyword co-occurrence mapping and cluster interpretation, enabling the identification of thematic clusters and underexplored research areas.

3. Integration of Approaches

Combining narrative and bibliometric methods provides a comprehensive understanding of the field. Bibliometric mapping offers a macro-level view of research trends, while the narrative review adds theoretical nuance. Together, these approaches support the identification of research gaps and establish a foundation for future empirical studies.

3. Results and discussion

3.1. Contemporary demographic trends in Poland and the V4 countries

To better understand the nature of the challenges facing contemporary organisations in both Poland and the V4 countries, it is necessary to examine the dynamics of demographic change, characterised by an accelerating process of population ageing and the lack of straightforward generational replacement. Considering the median age, according to Maksimowicz (1990), the demographic profile of Poland indicates an advanced stage of population ageing, with the median age surpassing 35 years already before 2010. To illustrate the scale of demographic changes, the authors considered indicators such as the total fertility rate (TFR), the ageing dependency ratio (ADR), and the net migration rate (NMR per 1000 inhabitants). Table 2 presents the dynamics of demographic changes in the V4 countries, including demographic forecasts.

Table 2.
Selected demographic indicators in the V4 countries

Country	Demographic indicators							
	TFR 2023	TFR 2050*	NMR 2023	NMR 2050*	ADR (65+/15-64) 2023	ADR (65+/15-64) 2050*	Total population 2023 [million]	Total population 2050* [million]
Czech. Republic	1,46	**1.56**	+2.70	**+2.00**	34.5	**55.0**	10.5	**10.8**
Poland	1,16	**1.26**	-0.33	**+1.50**	33.5	**57.0**	37.6	**33.2**
Slovakia	1.49	**1.37**	+0.40	**+1.00**	32.0	**59.0**	5.4	**5.0**
Hungary	1.55	**1.70**	+2.50	**+1.80**	33.0	**54.5**	9.6	**8.7**

Note: *Forecast data.

Source: Own elaboration based on data from CSO, Eurostat, OECD, UN World Population Prospects, 2024.

It should be noted that demographic forecasts are subject to uncertainty and scenario-based assumptions; therefore, the indicators presented should be interpreted as indicative long-term trends rather than precise predictions. Analysing the data presented in Table 2, it should be emphasised that the NMR values for Poland (-0.33) and Slovakia (+0.40) in 2023 were statistically underestimated relative to the actual inflow of population, as both countries excluded from their official migration statistics individuals under temporary protection (primarily refugees from Ukraine) (OECD, 2024). On the other hand, the Czech Republic and Hungary show a clearly positive net migration rate, which is significant for maintaining a stable population growth rate (Czech Republic +0.3 million by 2050). The interpretation of the presented demographic indicators allows several specific conclusions. First, total fertility rates (TFR) remain well below the replacement level (2.1), indicating a deepening process of population ageing across all V4 countries, albeit with varying dynamics. For Poland (-4.6 million) and Hungary (-0.9 million), the projected decline in population is the greatest.

In contrast, the Czech Republic appears to be the only V4 country for which a slight population increase is forecast (+0.3 million), which may result from the compensatory effect of migration on natural population change. Analysing the ageing dependency ratio (ADR), which has increased significantly in all V4 countries, indicates an adverse impact on social security systems. Consequently, the sharp rise in ADR alongside fertility rates below the replacement level leads to an ageing and shrinking potential labour force. This process provides the basis for analysing the challenges facing contemporary organisations, particularly in the area of human resource management.

3.2. The Impact of Demographic Trends on Contemporary HR Strategies – Theoretical Perspective

3.2.1. Demographic Aging of the Potential Workforce and Age Management Strategies

The deepening process of population aging across European societies represents a key challenge for both the European labor market and social security systems (European Commission, 2019; Bloom et al., 2010). The systematic decline in the number of people of working age (15-64), combined with the growth of the older, less mobile population (45-64), has led to a contraction of the potential labor force. One response to these demographic challenges is the implementation of the age management model, which has been widely documented in the literature (Liwiński, Sztanderska, 2010). Accordingly, contemporary age management constitutes a strategic concept aimed not only at extending the professional activity of older employees but also at leveraging their valuable experience, knowledge, and potential to benefit organizations. In this context, particular importance is attached to retention strategies, flexible forms of employment, and succession planning, which can help organizations adapt effectively to demographic change while maintaining competitiveness and knowledge continuity.

It is worth emphasizing that organizations seeking to respond to demographic changes effectively must consider implementing age-inclusive human resource management practices. As highlighted by Zacher and Rudolph (2022), the goal of such practices is to create a work environment that supports employees regardless of age and promotes intergenerational collaboration. Research indicates that these practices enhance work motivation and help eliminate ageism within organizations. Therefore, organizations aiming to retain older employees should consider introducing flexible work arrangements, such as flexible working hours, part-time employment, or remote work (telework) options (Farr-Wharton et al., 2023; Lister, Harnish, 2011; Ivasciuc et al., 2022). Studies show that flexibility, including a focus on work–life balance, is an important factor in retaining older workers, while also aligning with the expectations of younger generations (Morris, 2007).

At the same time, introducing greater flexibility into compensation systems and retirement benefits appears essential. In many Western European and Scandinavian countries, the concept of phased retirement has gained popularity, allowing employees to gradually transition out of

the labor market. This solution can be crucial in situations where an employee is not ready for full retirement. However, implementing phased retirement requires revisions to pension schemes, adjustments to healthcare benefits, and the creation of incentives for knowledge transfer (Van Solinge et al., 2023).

In this context, the issues of knowledge transfer and succession planning are fundamental. These tools are regarded as strategic components of risk management and form the foundation for maintaining operational continuity in the face of knowledge drain caused by workforce aging (Government of Alberta, 2012; Rathore et al., 2024). Notably, Iraola and Diez (2024) highlight a persistent gap between the strategic awareness of this issue and the actual operational readiness of organizations (Iraola, Diez, 2024). Therefore, it is necessary to transition from informal methods to systematic knowledge transfer protocols, supported by advanced knowledge management systems and AI-based tools that facilitate effective cataloguing and intergenerational exchange of knowledge (Rathore et al., 2024).

Thus, effective age management integrates two crucial pillars: retention and employment flexibility on the one hand, and knowledge transfer and succession planning on the other. Together, they form a coherent human capital management strategy, particularly relevant in the context of an aging society. Organizations that can more effectively adapt working conditions and manage knowledge transfer are likely to gain a competitive advantage based on experience and intergenerational trust (Farr-Wharton et al., 2023; Radziszewska, 2017).

3.2.2. Generational Diversity in Organizations and the Demographic Context

From a demographic perspective, the simultaneous presence of multiple generations within organizations, often including Generation X, Millennials (also known as Generation Y), and Generation Z, creates a complex dynamic where differing values, work styles, and attitudes intersect.

It is evident that different generations are driven by distinct motivations, which requires a personalized management approach, and understanding these differences is crucial for effective retention and engagement. Generation X tends to focus on maintaining a work–life balance and is motivated by task diversity (Salahuddin, 2010). Generation Y (Millennials) value intellectual challenges, opportunities for development, and equal treatment, while Generation Z emphasizes a sense of purpose, flexible HR policies, and transparent communication. According to recent research, organizations that actively support the mental well-being of their employees significantly increase their sense of purpose at work – by 67% for Generation Z and nearly 72% for Millennials (Deloitte, 2025). These findings highlight that successfully attracting, motivating, and retaining employees from Generations Y and Z requires adapting HR policies with a strong focus on flexibility and a sense of mission (Wijerathna, Rebecca, 2024).

Generational diversity has a significant impact on team performance, particularly in terms of creativity and innovation, as it fosters the generation of new ideas and creative solutions. However, perceptions of these benefits vary across age groups (Banasiak, 2024). For example,

72% of Generation Z respondents recognize creativity-related benefits, compared to 67% of Generation X and 54% of Generation Y. The study by Banasiak (2024) suggests that to fully leverage their creative potential, organizations must actively manage diversity and adapt their organizational culture to the specific characteristics of their teams and sectors. Socio-demographic factors also play an important role in shaping corporate culture. For instance, in the Slovak forestry and wood industry, a clan-type organizational culture is predominant (Lorincova, 2024).

Although generational diversity fosters creativity and innovation, it also introduces both cognitive conflicts, which can enhance innovation, and affective conflicts, which may reduce team performance (Liu, Liu, 2024). Therefore, to effectively harness the positive potential of diversity, organizations should implement shared leadership models, where leadership responsibilities are distributed among team members. This model strengthens the positive impact of cognitive conflicts without increasing affective ones (Liu, Liu, 2024). In practice, this requires reorganizing team hierarchies and roles within multigenerational teams, as well as introducing mechanisms that promote constructive conflict while fostering trust and a collaborative culture. Table 3 presents the characteristics of generations in an organizational context.

Table 3.
Key Characteristics of Generations in Organizations

Generation	Workplace Preferences	Key Motivators and Values	Impact on Organizational Engagement
Generation X	Task diversity, autonomy	Work–life balance, competence, feedback	High motivation when balance is maintained (Huyler et al., 2024; Salahuddin, 2010)
Millennials (Generation Y)	Rapid development, flexibility, meaningful contribution	Purpose, growth, and intellectual challenges	Require a strong sense of meaning and value (Deloitte, 2025; Salahuddin, 2010)
Generation Z	Flexible HR policies, transparent e-communication, preference for collaborative leadership	Value alignment, well-being, innovation, purpose	Retention depends on adaptable HR policies and effective communication (Wijerathna, Rebecca, 2024)

Source: Author's own elaboration based on Wijerathna, Rebecca, 2024; Huyler et al., 2024; Deloitte, 2025; Salahuddin, 2010.

The above table highlights the key values, professional preferences, and the influence of different generations on workplace engagement. The existing intergenerational differences undoubtedly require the adaptation of HR policies and leadership styles to effectively motivate and retain valuable employees within the organization, regardless of their age.

3.2.3. Migration and Cultural Diversity as an Effect of Demographic Change

In today's era of globalization and intensified labor migration, cultural diversity has become a common phenomenon within organizations (Almeida et al., 2024). Migration, as a form of international economic exchange, plays an increasingly significant role by fostering diversity while simultaneously influencing both the labor market and social culture (Grosskopf et al.,

2024). This trend is particularly evident in Polish enterprises, where the proportion of foreign workers in the total workforce continues to increase.

It is essential to note that the collision of diverse values, communication styles, and work approaches can lead to conflicts and reduced efficiency (Memon et al., 2023). Therefore, intercultural competencies, alongside professional qualifications and language proficiency, have become key factors in success. Organizations should thus implement intercultural training programs that enhance awareness, openness, and collaboration efficiency, thereby improving organizational culture (Danko, 2024).

Cultural diversity, on the one hand, offers developmental opportunities by stimulating team creativity and innovation. Yet, on the other hand, it poses challenges related to cultural contamination, which can alter the dynamics of organizational culture (Grosskopf et al., 2024). Consequently, the cultural diversity of employees is gaining strategic importance. Intercultural management should therefore become an integral part of strategic change management, including diversity audits and the implementation of systemic solutions (Abdelhay, 2024).

However, global migration trends also carry the risk of losing qualified personnel. The phenomenon of brain drain, which involves the emigration of highly skilled and talented individuals, results in the loss of key competencies, increased recruitment costs, and decreased productivity for both organizations and the countries of origin (Batista et al., 2025).

In the context of Poland and the Central and Eastern European (CEE) region, a research gap remains regarding organizational readiness for cultural change, despite the growing significance of cultural diversity in Poland. Nonetheless, Polish enterprises are still not fully prepared for these shifts. Addressing these challenges requires a deep understanding of the local labour market and the development of HR policies that actively counter stereotypes while fostering the integration of diverse employee groups.

3.3. Dual Literature Analysis – An Attempt to Identify Key Research Gaps

The conducted literature review, which combined an examination of major demographic trends and their impact on organisational management, innovation, and leadership, with a bibliometric analysis using VOSviewer software, enabled the identification of three main research gaps. Initially, the authors performed a preliminary bibliometric analysis encompassing 953 publications from the Scopus database. Figure 1 presents the keyword co-occurrence map, illustrating the relationships between the dominant research themes.

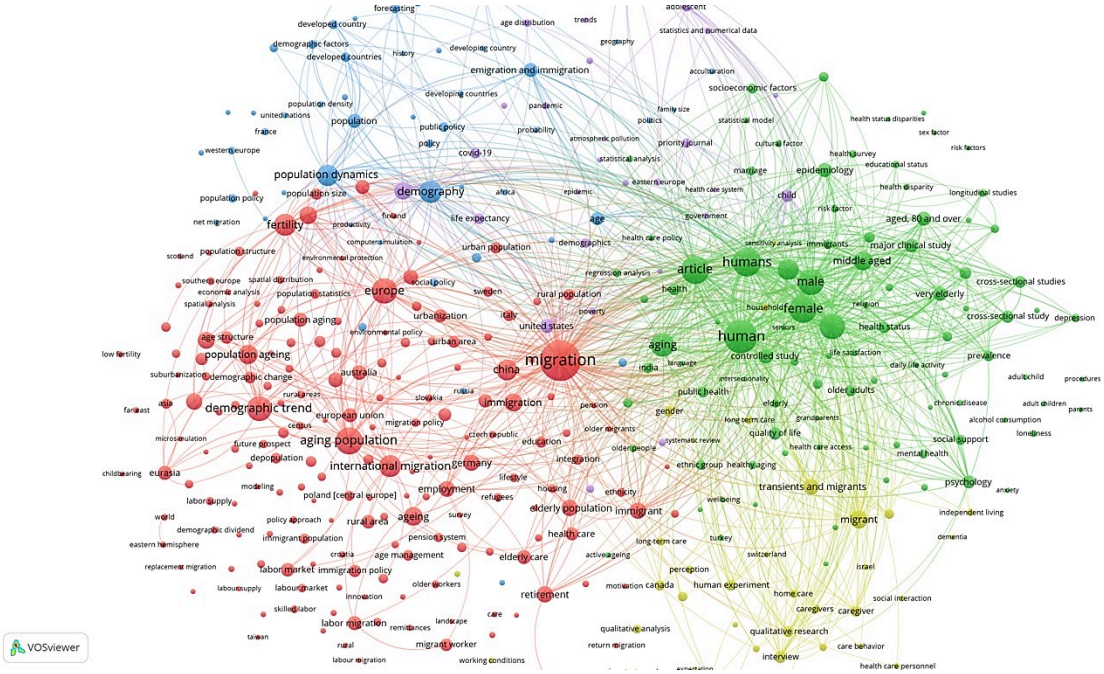


Figure 1. Keyword Co-occurrence Map Generated in VOSviewer.

Source: Author's own elaboration.

From Figure 1, it can be seen that the analysis of the co-occurrence network of keywords revealed four main thematic clusters: demography and migration, population and health, macro-social research, and qualitative studies on migrants. The bibliometric analysis was applied as a complementary tool to identify dominant research streams and thematic structures in the literature. While the keyword co-occurrence mapping provides an overview of the field, the interpretation of results and identification of research gaps are grounded in a qualitative narrative review. Thus, bibliometric findings serve as a contextual background for theory driven discussion rather than as an independent explanatory method. At the same time, it highlighted the peripheral positioning of topics related to human resource management, confirming the existence of a significant gap of an applied or methodological nature. Table 4 presents a synthesis of the key research gaps identified through the narrative literature review and the bibliometric analysis, as visualised in the VOSviewer map.

Table 4.
Synthesis of Key Research Gaps

Type of Research Gap	Problem Description	Link to Demographic Trend	Link to VOSviewer Analysis Results	Suggested Directions for Further Research
Contextual and Geographic	Insufficient applied research on foreigners in Poland and the CEE region; low understanding of employer motivations and the effectiveness of integration programs.	Migration and labor mobility. Increasing scale of labour migration to Poland and the CEE region, with a growing share of foreigners in the labour market.	In the "demography and migration" cluster, and partially in "qualitative research on migrants", terms such as "migration", "HRM", and "organisation performance" are weakly connected; the CEE context is marginally present.	Applied and comparative research (CEE vs. Western Europe); qualitative analyses of professional integration of migrants; impact of cultural diversity on organisational culture.
Methodological	Insufficient number of long-term and quasi-experimental studies evaluating the effectiveness of HR interventions in the context of population ageing and diversity.	Population aging and increasing life expectancy (a rise in the average employee age) necessitate adapting employment policies to meet the needs of non-mobile employees aged 45 and above.	In the "population and health" cluster, there are no links between the terms "evaluation", "HR practices", and "organisational outcomes".	Panel studies on HR program effectiveness; empirical evaluation of ROI for diversity and age management initiatives.
Theoretical and Integrative	Fragmentation of theories connecting age management, migration, and generational diversity; an insufficient number of models integrating macro-level (demography) and micro-level (organisation) perspectives.	Generational and multicultural diversity. Coexistence of multiple generations (X, Y, Z) and cultures in a single work environment; impact on leadership and communication.	In the "demography and migration" and "population and health" clusters, there is low connectivity between the terms "leadership", "organisational culture", and "diversity management".	Development of integrated theoretical models (e.g., linking LMX and diversity theories); studies on the impact of demography on organisational outcomes.

Source: Author's own elaboration.

From the above tabular overview, it can be concluded that human resource management, when considered from a demographic perspective, particularly in the context of migration in Poland and selected Central and Eastern European (CEE) countries, remains an insufficiently explored area. The conducted analysis revealed a specific fragmentation in the literature, reflected in the identification of the main thematic clusters. The most noticeable research gap is contextual and geographic in nature. Consequently, existing applied studies on the employment of foreigners in Poland and the CEE region are somewhat limited, which restricts our understanding of employer motivations and the effectiveness of integration programs (Szaban, 2022; Vasić et al., 2023). In the "demography and migration" cluster, and partially in

"qualitative research on migrants", the terms "migration" and "HR" are weakly connected, while the CEE context is marginally represented.

At the same time, the number of quasi-experimental studies evaluating, for instance, the effectiveness of HR interventions in the context of population ageing and diversity is also insufficient (Mazur, Walczyna, 2020; Igora-Iraola, Diez, 2024). Consequently, a methodological gap appears to be directly linked to this aspect. In the "population and health" cluster, there is a lack of connections between the terms "evaluation", "HR practices", and "organisational outcomes", indicating insufficient evaluation of HR programs and highlighting the need for panel studies and ROI assessments, i.e., the return on investment in HR initiatives related to age management and diversity.

The bibliometric analysis also revealed a theoretical and integrative gap, associated with the fragmented approach to integrating, for example, leadership theories (LMX) with diversity and age management theories in multigenerational teams, particularly in international contexts (Liu, Liu, 2024). In the "demography and migration", "population and health", and "macro-social research" clusters, a low density of links was observed between the terms "leadership", "organisational culture", and "diversity management". As a result, the lack of coherent integrative models may hinder the assessment of the impact of demographic and diversity factors on intra-organisational outcomes. Therefore, there is a clear need for applied, panel, quasi-experimental, and comparative research, which could enable both the identification of effective HR practices and the development of integrated theoretical models connecting demography, cultural context, and HR activities. This research direction is crucial for addressing challenges related to increasing workforce mobility, population aging, and the complexities of multigenerational and multicultural organizational structures. Based on the identified gaps and to provide a framework for future empirical investigation, the following research questions have been formulated:

(RQ1) How do ageing-related HR practices influence organizational effectiveness and innovation capacity within the specific socio-economic context of the CEE region?

(RQ2) In what ways does migration-driven workforce diversity reshape leadership styles and organizational culture in Poland and other V4 countries?

(RQ3) Through what mechanisms can generational and cultural diversity be integrated into coherent and sustainable organizational management models?

4. Summary

The conducted study appears to confirm that contemporary organisational management, both in Poland and other V4 countries, is strongly determined by observable demographic trends such as population ageing, migration, which insufficiently compensates for the overall

population decline, and generational diversity. These trends create a need for changes in management approaches. This is occurring because many organisations have already adopted models that respond to demographic challenges, including age management and diversity management. However, demographic diversity (in terms of age, generation, and culture) is increasingly becoming a key factor that can significantly influence organisational effectiveness, innovation, and cohesion.

This, in turn, requires a redefinition of existing management models, from standardised, hierarchical structures toward more flexible and personalised human resource management systems. Positive outcomes in this area can only emerge when supported by conscious managerial interventions and effective leadership. In light of this, an attempt has been made to identify three main areas of strategic action from the perspective of human resource management practice:

- Diversity audit – Diversity management should be integrated into the core of the business strategy, encompassing formal audits and programs aimed at counteracting stereotypes and cultural biases. In the context of migration, intercultural training may be necessary to enhance team awareness and cohesion within organisations.
- Succession planning and knowledge transfer – In view of the ageing workforce, ensuring leadership continuity becomes a key organisational priority. It is essential to enhance succession systems and knowledge transfer protocols, complemented by flexible employment arrangements tailored to employees aged 45 and above, which can support the retention of competencies.
- Change management – Managers should develop shared leadership skills capable of managing generationally diverse teams. Adapting leadership styles to the values and expectations of different generations present within the organization becomes crucial.

In summary, effective management in organizations, particularly under conditions of dynamic demographic change, requires a holistic approach that integrates inclusion, leadership, and knowledge management. Organizations that consciously implement these elements can gain greater resilience, innovation capacity, and long-term development potential in the face of adverse demographic trends.

References

1. Abdelhay, S. (2024). Impact of diversity management on innovation in organizations: Mediating role of knowledge sharing and moderating effect of inclusive leadership. *Management Paper, 6(2),* 231-245. https://doi.org/10.33545/26648792.2024.v6.i2d.231
2. Banasik, P. (2024). Znaczenie zarządzania różnorodnością w przedsiębiorstwach z perspektywy pracowników różnych pokoleń. *Przegląd Organizacji [Organization Review], 3(1002),* 38-44. https://doi.org/10.33141/po.2024.03.06
3. Batista, C., Han, D., Haushofer, J., Khanna, G., McKenzie, D., Mobarak, A.M., Theoharides, C., Yang, D. (2025). Brain drain or brain gain? Effects of high-skilled international emigration on origin countries. *Science, 369(6509),* 1293-1299. https://doi.org/10.1126/science.adr8861
4. Bloom, D.E., Canning, D., Fink, G. (2010). Implications of population ageing for economic growth. *Oxford Review of Economic Policy, 26(4),* 583-612. https://doi.org/10.1093/oxrep/grq038
5. Chłoń-Domińczak, A., Lewandowski, P., Magda, I., Morawski, L., Myck, M., Najsztub, M., Oczkowska, M., Paukszteło, W. (2017). *Pokolenie 50+ w Polsce na tle Europy: Aktywność, zdrowie i jakość życia. Wyniki na podstawie badania SHARE*. Centrum Analiz Ekonomicznych CenEA. https://share50plus.pl/sites/share50plus.pl/files/2020-07/SHARE_Pokolenie50plus_www_0.pdf
6. Danko, L. (2024). Rethinking the role of knowledge sharing on organizational performance. *Journal of Knowledge Management, 28(3),* 1-20. https://doi.org/10.1007/s13132-024-02354-5
7. Deloitte (2025). *2025 Gen Z and Millennial Survey.* https://www.deloitte.com/global/en/issues/work/genz-millennial-survey.html
8. European Commission (2019). *Ageing Europe — looking at the lives of older people in the EU (Statistical publication No. KS-02-19-681).* Eurostat. https://ec.europa.eu/eurostat/web/products-statistical-books/-/KS-02-19-681
9. Eurostat (2023). *Demography of Europe – 2023 edition*, https://ec.europa.eu/eurostat/web/interactive-publications/demography-2023
10. Farr-Wharton, B., Bentley, T., Onnis, L.-A., Caponecchia, C., Neto, A.D.A., O'Neill, S., Andrew, C. (2023). Older worker-orientated human resource practices, wellbeing and leave intentions: A conservation of resources approach for ageing workforces. *International Journal of Environmental Research and Public Health, 20(3),* 2725. https://doi.org/10.3390/ijerph20032725
11. Government of Alberta (2012). *Succession planning: Retaining skills and knowledge in your workforce.* https://open.alberta.ca/dataset/f0b35827-1a33-4006-9154-

14e36a13bda9/resource/b9fbd149-127c-4044-8235-2fd29fef0bf6/download/6069872-2012-succession-planning-retaining-skills-and-knowlwdge-2012-09.pdf

12. Grosskopf, S., Barmeyer, C., Landes, A. (2024). Organizational integration of highly skilled migrants? Social worlds as multiple cultures dismantling conventional framings. *Journal of Industrial and Business Economics, 51(3),* 691-724. https://doi.org/10.1007/s40812-023-00290-0
13. Huyler, D., Gomez, L., Plakhotnik, M.S. (2024). Leading different generational cohorts in the workplace: Focus on situational and inclusive leadership. *Advances in Developing Human Resources, 37(1)*. https://doi.org/10.1177/19394225241297230
14. Igoa-Iraola, E., Díez, F. (2024). Procedures for transferring organizational knowledge during generational change: A systematic review. *Heliyon, 10(5),* e27092. https://doi.org/10.1016/j.heliyon.2024.e27092
15. Ivasciuc, I.S., Epuran, G., Vuță, D.R., Tescașiu, B. (2022). Telework Implications on Work-Life Balance, Productivity, and Health of Different Generations of Romanian Employees. *Sustainability, 14(23),* 16108. https://doi.org/10.3390/su142316108
16. Lami, B., Tarasenko, I., Shyshova, O., Voropayeva, T., Verhun, A. (2022). International migration of human resources in the conditions of social transformations. *Economies, 10(9),* 1-23. https://doi.org/10.3390/economies10090216
17. Lister, K., Harnish, T. (2011). *The state of telework in the U.S.: How individuals, businesses, and government benefit.* Telework Research Network, https://passages-pro.fr/wp-content/uploads/2020/06/USA-Telework-Trends.pdf
18. Liu, Z., Liu, Q. (2024). Does Leader–Member Exchange (LMX) Ambivalence Influence Employees' Constructive Deviance? *Behavioral Sciences*, *14*(1), 70. https://doi.org/10.3390/bs14010070
19. Liwiński, J., Sztanderska, U. (2010). *Zarządzanie wiekiem w przedsiębiorstwie*. Polska Agencja Rozwoju Przedsiębiorczości. https://www.een.org.pl/storage/publications/pdf/19001zarzadzaniewiekiemd.pdf
20. Lorincová, S. (2024). The Influence of Socio-Demographic Factors on Management Concerning Corporate Culture in the Forest and Wood-Processing Sector. *Forests, 15(10),* 1694. https://doi.org/10.3390/f15101694
21. Maksimowicz-Ajchel, A. (1990). Struktura ludności według wieku w krajach Europy Wschodniej: Tendencje długookresowe. *Studia Demograficzne, 4(102),* 3-24.
22. Mazur, B., Walczyna, A. (2020). Bridging Sustainable Human Resource Management and Corporate Sustainability. *Sustainability, 12(21),* 8987. https://doi.org/10.3390/su12218987
23. Memon, M.A., Maitlo, Q., Lashari, I.A., Ali, S., Junejo, M.A. (2023). How to manage cultural diversity for organizational knowledge sharing. *Migration Letters, 20(S6),* 1307-1321, https://migrationletters.com/index.php/ml/article/view/10579

24. Messner, W. (2025). Quantification of cultural practices and diversity: An empirical experiment with generative artificial intelligence. *Journal of World Business, 60(3),* Article 101622. https://doi.org/10.1016/j.jwb.2025.101622
25. Morris, C. (2007). *Flexible work options [Unpublished research paper]*. Texas State University. https://gato-docs.its.txst.edu/jcr:86d517b9-2fd4-43be-a500-8893ca5d7999/Morris,+Cathy,+research_paper%5B1%5D.pdf
26. OECD (2024). *International migration outlook 2024*. OECD Publishing, https://www.oecd.org/en/publications/2024/11/international-migration-outlook-2024_c6f3e803.html
27. Radziszewska, A. (2017). Dobre praktyki zarządzania wiekiem. In: M. Zając, M. Czerska (eds.), *Zarządzanie zasobami ludzkimi w warunkach starzejącego się społeczeństwa*. Difin, https://bibliotekanauki.pl/chapters/63290516.pdf
28. Rakowska, A. (2023). Kulturowa różnorodność pracowników w czasach nasilonej emigracji. *HRM [ZZL], 150(1),* 10-23. https://doi.org/10.5604/01.3001.0016.2922
29. Rathore, R., Rathore, S.P.S. (2024). Machine learning applications in human resource management: Predicting employee turnover and performance. *International Journal for Global Academic & Scientific Research, 3(2),* 48-59. https://doi.org/10.55938/ijgasr.v3i2.77
30. Salahuddin, M.M. (2010). Generational differences impact on leadership style and organizational success. *Journal of Diversity Management, 5(2),* 1-6. https://doi.org/10.19030/jdm.v5i2.805
31. Shen, J., Chanda, A., D'Netto, B., Monga, M. (2009). Managing diversity through human resource management: An international perspective and conceptual framework. *International Journal of Human Resource Management, 20(2),* 235-251. https://doi.org/10.1080/09585190802670516
32. Skibiński, A., Sipa, M., Gorzeń-Mitka, I. (2016). An intergenerational cooperation in the organization – View from the age perspective. *Procedia - Social and Behavioral Sciences, 235*, 412-419, https://doi.org/10.1016/j.sbspro.2016.11.051
33. *Succession Planning Framework* (2017). ACDS, https://acds.ca/files/Resources/Succession_Planning/Succession_Planning_Framework.pdf
34. Szaban, D. (2022). Ukrainian migrants in the Polish labour market: HRM selected issues. *Journal of Eastern Europe Research in Business and Economics*, https://doi.org/10.5171/2022.813170
35. Tavares, M.F.F. (2020). Across establishments, within firms: worker's mobility, knowledge transfer and survival. *Journal for Labour Market Research, 54(2).* https://doi.org/10.1186/s12651-020-0267-y
36. Van Solinge, H., Vanajan, A., Henkens, K. (2023). Does phased retirement increase vitality in older workers? Findings from a 3-year follow-up panel study. *Journal of Aging & Social Policy, 35(2)*, 221-240. https://doi.org/10.1080/08959420.2022.2029270

37. Vasić, M., Duică, M.C., Berber, N., Enukidze, N., Vasić, S., Weis, L. (2023). Migrant workers and workforce integration: Challenges for managers in European companies. *Strategic Management Journal, 28(2),* 27-43. https://doi.org/10.5937/StraMan2200027V
38. Wijerathna, M.D.T.D., Rebecca, E. (2024). An Introspection of GEN Z's Organizational Commitment and Workplace Behavior. *Educational Administration: Theory and Practice, 30(1),* 01-11. https://doi.org/10.53555/kuey.v30i1.7361
39. Yembi Renault, B., Agumba, J.N., Ansary, N. (2021). Regression analysis of the influence of demographic characteristics using risk management practices within South African small and medium construction enterprises. *Journal of Engineering, Design and Technology, Vol. 19, No. 6,* pp. 1505-1529, https://doi.org/10.1108/JEDT-08-2020-0332
40. Zacher, H., Rudolph, C.W. (Eds.) (2022). *Age and work: Advances in theory, methods, and practice.* Routledge. https://doi.org/10.4324/9781003089674

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INSTITUTIONALIZATION AND AUTOMATION OF ADAPTIVE PROCESSES IN WIKIMEDIA PROJECTS

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Purpose: The aim of the article is to show the variety of forms of deployment of non-professional knowledge workers, in this case: volunteers working on Wikipedia, the most recognisable of the Wikimedia projects. An attempt was made to determine the relationship between Wikipedians' activity and the amount of potential social capital produced by people creating accounts on Wikimedia projects.
Design/methodology/approach: Using publicly available data, the activity of Wikipedians and the number of potential newcomers in the 20 versions of Wikipedia were compared. Two formulated hypotheses were tested using Spearman's rank correlation coefficient. The process of institutionalisation of newcomer adaptation processes in the Polish-language Wikipedia is presented using a netnographic approach.
Findings: A clear correlation was observed between the number of users registering and the number of people actively editing on Wikipedia. In these projects, there are different distances between the 'centre' and the 'periphery' in terms of editing activity, which may be relevant to different strategies for onboarding the newcomers. There are three phases that can be observed in the relationship between communities and newcomers, dominated by spontaneous, institutionalised and automated actions respectively.
Research limitations: The netnographic approach has made it possible to outline more broadly the evolution of changes in attitudes towards newcomers to the Polish-language Wikipedia. A full presentation of the various action strategies in this area would require research in dozens of the largest language versions of Wikipedia.
Social implications: Large free culture projects, of which Wikimedia is one, have a better chance of further community growth if more people are willing to join in mentoring activities. Further identification of the ways in which newcomers are onboarded would optimise the selection of appropriate strategies on a project-by-project basis.
Originality/value: The research conducted identified a framework for the interrelated processes of institutionalisation and automation of the onboarding of newcomers to knowledge-sharing work in the 20 language versions of Wikipedia. Previous research has been limited to descriptions of activities in this area in the various language versions.
Keywords: adaptive processes, knowledge sharing projects, free culture movement, Wikimedia, virtual communities of practice.
Category of the paper: research paper, case study.

1. Introduction

The massive introduction of remote working modes in a global pandemic has necessitated adaptation to a range of new conditions, and has also prompted intensified research on this topic. Although the new generation just entering the labour market is both more accepting of change and operates in a digital environment more naturally, this type of work has limited the possibilities of assimilating organisational culture and thus the relevant rules of operation that are socially accepted in individual organisations (see Pratt, 2023). For generation Z, remote working also prevents direct support from superiors and is problematic for these employees due to higher levels of stress and a disturbed work-life balance (Łukasiński, Wójcik, 2024). The pandemic period was stressful for a number of reasons, some business entities were terminating their operations. During this time, however, online communities focused on knowledge co-creation were becoming more active. In Wikipedia, which is the leading project of the free culture movement and the most recognisable of the Wikimedia projects, not only has the number of edits (activities performed) increased, but also the number of new participants has grown. In addition, communities were more forgiving towards them, which may indicate greater solidarity during the global lockdown (Ruprechter et al., 2021).

The mechanisms developed in virtual communities of practice to improve adaptation processes in cyberspace could potentially be useful for their implementation in other types of communities and organisations. This, however, warrants a notable caveat. In the social sciences, the phenomenon of this online encyclopaedia was noticed quite quickly. Some publications have even postulated that the work organisation and sharing models specific to this online culture could be transferred to commercial ventures (Tapscott, Williams, 2008; Aigrain, P., Aigrain, S., 2012). However, the mechanisms of interaction have not been understood well enough to be implemented outside this particular project. Besides, the value system (openness, freedom to share) would be difficult to implement in ventures where the core of the business is based on gaining a competitive advantage.

Although some researchers note that attitudes towards newcomers may be favourable, other studies have shown a number of adaptation problems, mainly due to the difficulty of adopting a rather complex system of operating rules (Gluza, Turaj, Meier, 2021; Vetter, Sarraf, Woods, 2022). The aim of this article is to present the ways in which volunteers can be onboarded to the co-creation processes and to compare the different forms of co-creation activities in selected language versions of Wikipedia. Communities in the different language versions, noting the problem of poor retention of newcomers, are developing autonomous adaptation systems (Karczewska, 2022, 2023), often introducing mentoring activities.

The remainder of the article reviews the literature, characterises the methodological approach used including both quantitative and qualitative analysis and presents the findings.

2. Literature review

2.1. General issues of socialisation of newcomers in Wikimedia

Some researchers point out that the functioning of open systems requires a constant flow of new users to replace those who leave for various reasons. It is important not only that there is a visible flow of them, but more importantly that a significant proportion of them can move from the 'periphery' of activity to the 'centre' (Morgan et al., 2013). Indeed, in online communities, the phenomenon of the development of distinct centres with the growth of social networks is evident, which is also associated with certain aspects of the concentration of power among a few, outstanding persons (Rijshouwer, Uitermark, de Koster, 2023). In the case of Wikipedia, less than one promille of users are responsible for nearly half of the content produced (see Priedhorsky et al., 2007). Although a significant proportion of the most active users are bots, the disparity in engagement is very large. In contrast, integrating newcomers into the cooperation becomes increasingly difficult over time, as they have to master the adopted policies and guidelines.

By 2008, there were already hundreds of pages describing the rules in the English-language Wikipedia, including help pages, and new ones were being created in subsequent years (Li et al., 2020). In addition to this, it is important to acquire the technical skills associated with the MediaWiki environment, the interface of which is also evolving. Getting started without mastering this knowledge and skill is difficult, and power users involved in content control often become distrustful of newcomers and oppressive rather than supporting when it comes to make edits (see Morgan et al., 2013; Narayan et al., 2017; Li et al., 2020). Active Wikipedians frequently assume that most newcomers will not remain active, so it is not worth investing time in mentoring activities (Konieczny, 2021). It has also been observed that distrust is increasing towards users with the administrator rights (Skolik, Jemielniak, 2011). Furthermore, mentoring initiatives created in the early years of Wikipedia were blocked on the grounds that the project would become 'too social' and that such actions could draw users away from editing articles towards other activities (see Musicant et al., 2011).

Efforts to tie editors to the project have been evident in Wikipedia since 2009, when there was a marked decline in the number of newcomers (Morgan, Halfaker, 2018). Between 2006 and 2010, their retention rate fell from 25% to 5%, which was associated with more frequent negation of their work contribution (Narayan et al., 2017). These problems were also noted earlier. Between 2005 and 2007, on the English-language Wikipedia, the percentage of users who were still active one year after they made their first edition dropped from 40% to 12-15% (Musicant et al., 2011).

Problems with the socialisation of new (registered) Wikipedians as well as of anonymous editors arose from dilemmas relating to openness to collaboration. On the one hand, openness and assumption of goodwill was important to increase the number of editors, but on the other,

active Wikipedians focused on controlling newbies contributions. On the part of the community, it is not easy to assess whether users are striving to act in accordance with the accepted rules, even though they initially make mistakes. Newcomers, on the other hand, find it difficult to assess their own competence in contributing to encyclopaedia resources. Research has shown that new editors tend to act in accordance with norms when these norms are easily identifiable, clearly defined and when users have the opportunity to see examples of pronormative behaviour (Morgan, Filippova, 2018). It can be assumed, according to broken windows theory (Kelling, Wilson, 1982), that the rapid elimination of content created in violation of the rules should result in less exposure to the effects of rule-avoiding activities and also increase the chances of staying in the project. However, quality-oriented measures result in a focus on controlling new content rather than correcting deficiencies in existing articles.

The part of the community that seeks to identify the main barriers to entry can recognise them comprehensively during direct contact with newcomers, which takes place, among other things, during editathons. These are relatively rare meetings arranged with small groups of new users, usually students, where both parties can identify the main difficulties in starting a project activity. Some of these result in publications in the form of case studies (Vetter, Sarraf, Woods, 2022). Inconsistent user interface, lack of quick feedback and lack of guidance and support when editing articles were identified as barriers to entry, among others (Gluza, Turaj, Meier, 2021).

Early measures to support the retention of new users and their adaptation were two-pronged. On the one hand, there was an individual commitment to mentoring some of the active Wikipedians, and on the other, the interface changes were introduced to automate the socialisation process. The latter included templated rule-breaking messages that included hyperlinks to policies and guidelines pages. Their function was primarily to warn against vandalism, but they also acted as a deterrent to newcomers who also received them, although they had no intention of destroying the project's resources (Morgan, Halfaker, 2018). It is fair to say that engaging in empathetic support and technical improvements to provide faster information about rules on Wikipedia were not compatible. A tendency towards schematic behaviour was also observed in mentor role players. This manifested itself, among other things, in the fact that instead of adopting a proactive attitude towards newcomers and pointing out safe fields of action to them, they limited themselves to responsive behaviour, mainly to answering questions posed to them (Musicant et al., 2011). Research indicated that social support was more effective than technical support. The change in the style of support and warning messages has not led to a clear change. 'Early interventions' were more effective, also providing support (Morgan, Halfaker, 2018).

Both forms of support (social and technical) belong to institutional support, which is common in online services. However, large projects based on peer production, of which Wikipedia is an example, are dominated by individualised rather than institutionalised socialisation. New users determine for themselves which areas they want to be active in and

seek appropriate guidance to be able to engage, what leads to a situation, where some of them are not able to meet the requirements (Narayan et al., 2017; Li et al., 2020). Previous research indicates that the provision of an institutionalised, structured socialisation process, together with symbolic rewards not only increases the retention of newcomers, but also their engagement (Warncke-Wang et al., 2023), meaning that they move from the periphery of this social system towards its centre. It has also been pointed out that collaboration between newcomers may yield better results, also in terms of the quality of the content created, in comparison with interaction with committed community members (Li et al., 2020). In contrast, when newcomers are experts, they can expect to quickly find themselves at the centre of the community. However, when they are involved in a debate about the quality of their contributions, they usually have less time than the editors involved, and they also lack knowledge of the rules on Wikipedia. This can result in a relatively quick decision to leave the project (see Konieczny, 2021).

The question of how activity patterns develop over time is often found in the literature. Three stages of user adaptation are indicated: 1) the passive reader, who learns about the possibility of editing Wikipedia, 2) the new editor, focusing on selected topics, and 3) the engaged community member, taking on a broader perspective and administrative roles. People who are committed to the action usually show a very high level of editing at the beginning, and although it decreases later, it still remains high (Antin, Cheshire, Nov, 2012). However, there are cases of return and even intensive editing years after creation of one's account. The moment at which the newcomer decides to act is crucial. Behavioural patterns are assumed to develop at the time of inclusion, during the first edits, which translates into the rapid formation of specific social roles (Narayan et al., 2017).

2.2. Initiatives for the adaptation of new users to the Wikipedia environment

The problems of adapting new users in the Wikimedia environment were complex enough to lead to the establishment of a variety of solutions in this regard. In the early years of these projects, so-called welcoming committees developed in many language versions of Wikipedia. Their task was to inform the rules in this online encyclopaedia, as well as in sister Wikimedia projects. Members of welcoming committees posted personal or, more often, templated welcome messages on the discussion pages of users who made their first edits after registering an account. They included references to pages of rules, help pages, and outlined ways for community members to communicate and cooperate. Due to the template nature of the messages, a significant number of language versions have chosen to have them inserted automatically (by a specially programmed bot). The form and content of these messages depended on the general (ethnic) culture in which the users functioned (Karczewska, 2022).

The shift away from personal communication and its subsequent automation resulted in less emotional involvement in the adaptation process. It led to the need for new initiatives to 'improve' social relations between committed Wikipedians and newcomers, and between the newcomers themselves. Most of them were first tested on the English-language version of

Wikipedia. One of these was a project called Adopt-A-User, launched on the English-language Wikipedia as early as 2006 and developed, among other things, through the involvement of the Wikimedia Foundation (Musicant et al., 2011). Engaged users involved in this program invited newcomers in a personalised way to interact in thematic WikiProjects. However, this personalisation was only possible after the new user had made some edits, so that it could be determined which areas of knowledge they were interested in. Newcomers were therefore individuals who were already able to cope with the barriers to entry and adapt to the system to some extent (Morgan, Halfaker, 2018).

Many more such initiatives were created after 2010. In 2011, The Wikipedia Adventure project was launched. In it, newcomers are invited to perform a series of edits according to scenarios that mimic the activities performed when editing articles (Narayan et al., 2017). A year later, a special Wikipedia: Teahouse page was created, which was a special internal forum for new users of the English-language Wikipedia. Its main purpose is to be able to provide quick assistance to users asking questions. It is important that support appears within the first 24 hours in order to retain a new Wikipedian. In addition, a script has been created that reports info on 'promising newcomers' once a day. At the Teahouse, the socialisation of newcomersis not formalised; instead, they are advised to engage in simple, non-controversial activities. Individuals who participate in this form of socialisation make more edits and stay active longer in the project (Morgan et al., 2013; Warncke-Wang et al., 2023).

Since 2013, the English-language Wikipedia has also been developing a Wiki Education Programme with the support of a specially established organisation called the Wiki Education Foundation. The basis of this programme is institutionalised socialisation via tutorials, training modules and schedules. By 2020, more than 63,000 students had edited close to 83,000 articles, so slightly more than one article per participant. This means that it did not explicitly contribute to the retention of newcomers, but provided an introduction to the Wikipedia environment. The tutorials used were well appreciated by the participants, but did not contribute to increasing their engagement. Only one in five programme participants completed all seven stages of the tutorial. Nevertheless, its participants stayed longer on Wikipedia than those who joined the project in the traditional way (Li et al., 2020). According to Konieczny, this initiative, although effective in the case of students, does not work for experts. This is not so much caused by their discouragement by discussions with amateurs, but rather by the fact that they find editing Wikipedia less attractive than their professional activities (Konieczny, 2021).

The technical support to get involved in improving articles at the start is to provide newcomers with links to problematic articles. A program (SuggestBot) is used in this case, indicating to newcomers the articles in which various types of problems need to be fixed, along with an indication of the degree of difficulty (Warncke-Wang et al., 2023). In addition to locally initiated projects, the WMF Growth Team has been active since 2012 as a special team within the Wikimedia Foundation. Its main aim is to increase the retention of newcomers. However, according to Rijshouwer, Uitermark and de Koster (2023), the Wikimedia Foundation's

commitment to encouraging participation in Wikimedia projects can only be observed from 2014 onwards. Until 2007, there was an expansion of bureaucratic rules and then a professionalisation of the foundation itself and an increase in its influence in the Wikimedia environment under the leadership of a technocratic executive director.

3. Methods

In order to determine the variety of ways in which newcomers are onboarded to collaborate on knowledge sharing in Wikimedia projects, a qualitative and quantitative research was conducted among 20 language versions of Wikipedia in June 2024. The research sample consisted of the language versions with the highest number of active Wikipedians, who could potentially also engage in helping new users: English (en), German (de), French (fr), Russian (ru), Spanish (es), Japanese (ja), Portuguese (pt), Italian (it), Polish (pl), Chinese (zh), Persian (fa), Arabic (ar), Dutch (nl), Hebrew (he), Ukrainian (uk), Turkish (tr), Indonesian (id), Czech (cs), Korean (ko) and Swedish (sv).

In the first stage of the research, the average number of active Wikipedians, the average number of new accounts created in these versions, the average number of edits made by the total number of registered Wikipedians and by the most active members of the community were calculated on the basis of available aggregated statistics on Wikipedian activity (*Wikimedia Statistics*, 2024). An indicator of the number of active Wikipedians was the average number of accounts with at least 1 edit per month for 2023. Also, the number of registered accounts referred to the monthly average in 2023.

The average edit counts of the total registered Wikipedians and the most active ones were examined for three periods: January 2023, July 2023 and January 2024. An indicator of the most active Wikipedians was the number of 20 users who made the most edits in a given month. In this case, monthly averages were not determined, as there may have been different people among the most active in each month. The accumulation of this data allowed two hypotheses to be tested:

H1: There is a clear statistical relationship between the number of active Wikipedians and the number of new users registering their accounts in the largest Wikipedia communities.

H2: There is a relationship between the average number of edits made by a Wikipedian and the average number of edits made by the most active members in the largest language versions of Wikipedia.

A positive verification of H1 would allow to conclude that the size of the potential for new Wikipedians is dependent on the size of the community that contributes to a given Wikimedia project. In contrast, a positive verification of H2 would mean that the distance between the

centre and periphery of activity in Wikimedia projects is similar. It could also mean that the engagement of the most active Wikipedians translates onto the engagement of the general user base, and thus leads to a social facilitation effect.

In the second stage of qualitative research, selected language versions of Wikipedia were compared in terms of initiatives to include and socialise new users. In this respect, it was verified which initiatives were launched in which language versions. Research to date has mainly focused on the English-language version and has only analysed individual programmes for the benefit of the onboarding of the new users. However, an in-depth analysis of all versions would not be possible for organisational reasons. It would require the knowledge of various languages and substantial time necessary to get acquainted with the operation of communities working on the respective language versions. Therefore, in order to present the process of automating the relationship between new and committed users, the analysis focused chiefly on the Polish version, where the author of this article has been conducting participatory observation since 2005. This part of the study was netnographic in nature (Kozinets, 2015) and no research hypotheses were formulated at this stage.

4. Results

4.1. Users activity, power users and new accounts in largest Wikipedias

For 2023, the monthly average of the number of created Wikipedia accounts ranged between 820 in the Swedish version and 99,655 in the English version. The difference between the two extreme positions among the 20 most active Wikipedia communities is as much as two orders of magnitude. Similar disparities could be observed when the numbers of active Wikipedians were compared. The Korean version had the fewest active Wikipedians, with an average of 1850 users making at least one edit per month, while the English version had the most: 120,636 people. Only a small percentage of those who set up accounts uses them for making edits, so the relationships between these variables are not obvious. However, the statistical test showed a statistically significant relationship between the two for $p < 0.05$. Spearman's rho correlation equals 0.864662. Thus, H1 can be accepted. The results on logarithmic scales are shown in Figure 1.

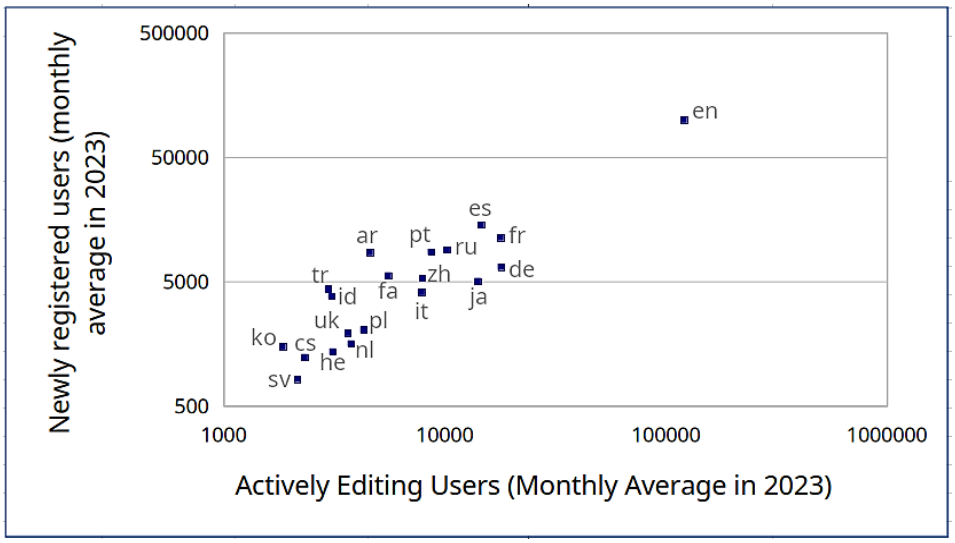


Figure 1. Relationships between the number of active Wikipedians and the number of Wikipedian accounts created per month in the analysed language versions of Wikipedia. Monthly average for 2023.

Source: own work.

The differences between the average number of edits per one registered Wikipedian were relatively small, ranging between 15 and 50 edits across the language versions studied. A greater disparity was observed when comparing the average number of edits made by the most active Wikipedians. These ranged between 1000 and 7000 edits apart from the English-language version, where the average was approx. 20,000 editions. Statistical tests using Spearman's rho correlation equals for $p > 0.05$ showed no relationship between the two variables. This means that the activity of power users (understood as the number of edits performed) does not translate into overall Wikipedians activity and does not contribute to facilitation in this respect. However, it was observed that the ratio between the two quantities was similar across language versions for the data from the three analysed months (Figures 2-4).

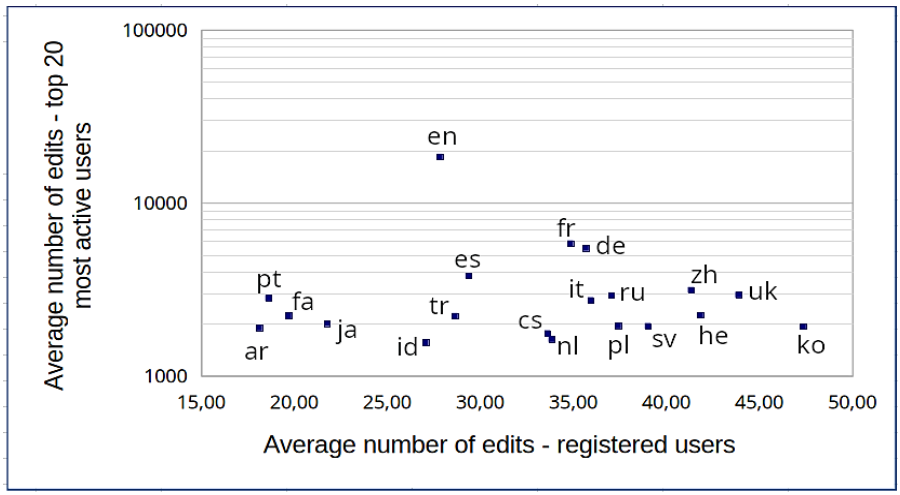


Figure 2. The ratio of the average number of edits by all registered Wikipedians to the average number of edits made by 20 most active users. Data for January 2023.

Source: own work.

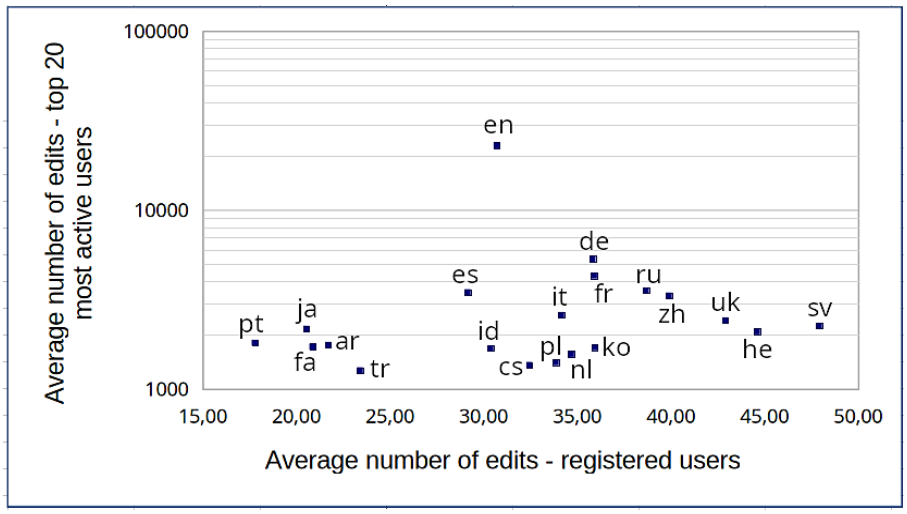


Figure 3. The ratio of the average number of edits by all registered Wikipedians to the average number of edits made by 20 most active users. Data for July 2023.

Source: own work.

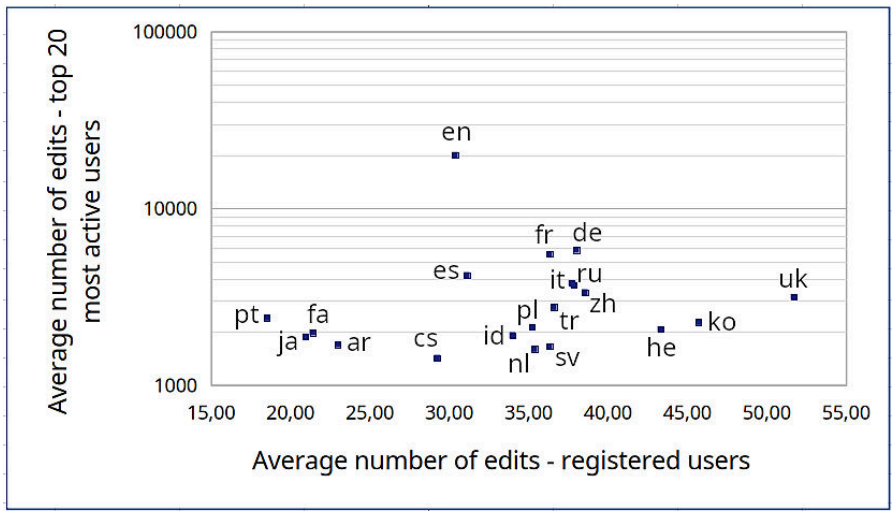


Figure 4. The ratio of the average number of edits by all registered Wikipedians to the average number of edits made by 20 most active users. Data for January 2024.

Source: own work.

Taking into account the overall activity of Wikipedians and the activity of power users (the people with the most edits made at any given time), certain trends can be identified in some language versions. In the English, French, Russian and Spanish versions, which are the largest Wikipedias, power users make more edits than the same category of users in other language versions. At the same time, the number of edits made by Wikipedians in general is close to the middle of the scale. In the Ukrainian, Swedish, Hebrew and Korean versions, power users are less active, with the relatively high activity of registered Wikipedians. These are also versions where the number of active Wikipedians and the number of new accounts created is relatively low. So it can be said that there is a lot of mobilisation in small communities. The Portuguese, Japanese, Arabic and Persian versions, on the other hand, show low activity of both power users and general Wikipedians. They are characterised by relatively large communities –

with numerous active users and a high number of new accounts being created. The size of the community compensates for their lower activity in order to be able to achieve project development in terms of the number of articles and corrections or updates. One can assume that each of these categories faces different relationship problems between the users involved and the Wikipedians joining the project.

4.2. Evolution of the forms of supporting and engaging newcomers

In the early years, the English-language Wikipedia was a model for other language versions. Solutions for supporting newcomers, including help pages, advice, and recommendations and the assumption of goodwill were therefore also copied from it. Hence, a 'system' solution was initially introduced in the form of a help desk page, where questions could be asked about the functioning of this online encyclopaedia. This solution was adopted by all of the language versions studied. Within the first few years of Wikipedia, another initiative emerged in the form of the *Welcoming Committee*. This committee brought together users who devoted part of their time to inserting welcome messages to newcomers. They also agreed on the content and form of these messages in order to communicate the basics of the project activity as effectively as possible.

Although the template messages themselves were adopted in all major versions, committees only functioned in some of them, including English, German, Polish and Japanese, which until 2010 were (not counting the French-language Wikipedia) the versions with the largest number of articles. Subsequent initiatives emerged as a development of these two initial ones. Some of the most popular initiatives are shown in Table 1.

Activity in the *Welcoming Committee*, once the wording of the welcoming messages was established, was usually limited to their insertion into the users' discussion page. There was no expectation of feedback from newcomers and even though the latter were informed of the rules and recommendations, they were often nonetheless breaking the accepted rules. This form of information about the system of adopted standards was therefore not sufficient. Therefore, broader communication with newcomers was advocated on the basis of bilateral relations between mentors and joining users (e.g. the *Adopt-a-User* initiative in English version). Often, however, this was only limited to replies to questions directed at the mentors. Due to the lack of active involvement in the support, the initiative contributed little in comparison with the help desk. Mentoring has been included in the largest language versions, including French, Spanish and Russian. In the Japanese version, as in the Korean and Chinese versions, where *Welcoming Committees* were also formed, this initiative was, however, omitted, possibly due to the cultural differences. Help desk has been developed into forums for newcomers, which include *the Teahouse* on the English-language Wikipedia. Although the initiative has been widely promoted, including in academic publications, it has only been adopted in English, German and Russian versions, and a few more (Arabic, Chinese, Czech and Swedish) have only

been set up with websites for newcomers. However, they were not active, probably due to too few people operating with newcomer status at the same time.

Table 1.
Forms of support and activation of newcomers in the studied language versions of Wikipedia

Language version	Help desk	Welcoming Committee	Traditional mentors (adopters)	Forum for newbies	Automatic welcoming	Semi-automatic mentors	Suggest Bot	Reporting mistakes	Editor Retention
English	+	+	+	+		+	+		+
German	+	+	+	+		+			
French	+		+		+	+	+		+
Spanish	+		+			+		+	+
Japanese	+	+							
Russian	+		+	+	+	+	+	+	+
Portuguese	+				+	+	+	+	
Italian	+				+ every hour	+			
Chinese	+	+		doesn't work	+	+			
Persian	+				+	+	+		
Polish	+	+	+		+	+	+	+	
Arabic	+	+		doesn't work	+	+			
Dutch	+		+			+			
Hebrew	+	+	+			+		+	
Ukrainian	+				+	+			+
Turkish	+					+			
Indonesian	+		+			+			
Czech	+			doesn't work		+			
Korean	+	+			+	+			
Swedish	+			doesn't work		+	+		

A '+' sign indicates the existence of a website with a description of the initiative in question. Note 'doesn't work' in the case of a forum for newcomers means that such a forum has been set up, but newcomers do not participate.

Source: own work.

If it is assumed that the first forms of newcomers' onboarding were spontaneous and schematic, the introduction of forms of mentoring and the creation of forums for newcomers can be seen as a development of institutional support that eliminated spontaneity to a certain extent. In contrast, the aftermath of the schematisation of activities was their automation. Since the welcome message containing information on forms of collaboration on the creation of the encyclopaedia was inserted by users in the same shape, in some language versions it was decided that such actions could be performed by bots. In such cases, users receive welcome messages as soon as they create an account. Where such an automatic device has emerged, it has simultaneously led to the sunsetting of the *Welcoming Committee* initiative.

The process of building relationships between mentors and newcomers itself has also been partly automated. The automation here consisted of assigning a new user to a randomly selected mentor with whom they can interact. The form of communication, which in the case of wiki-type sites is specific and unintuitive for internet users, has also been facilitated in this aspect. This form of partial automation of the communication process was implemented in all language versions of Wikipedia studied. In some of them, newcomers also get information about tasks that are recommended to be relatively easy in the initial phase of the activity. Lists of such tasks are generated by yet another program called SuggestBot. The tasks refer to problem articles, marked with special templates. However, such labelling is done spontaneously, and its purpose is to improve content, not to socialise newcomers. Therefore, suggestions to perform a task can breed frustration.

Table 1 identifies two more initiatives that involve the socialisation of new users. In the Spanish, Portuguese, Russian, Polish and Hebrew versions, readers can use the tab (link) available in the menu to report errors in articles. As editing Wikipedia does not require the creation of an account, much of this is done by unregistered users. For some, this may be their first activity on Wikipedia, and the Wikipedians involved may encourage them to create an account and become more active in correcting articles themselves. The initiative has also become popular in smaller language versions being developed in Eastern Europe and Central Asia. The latest initiative is the in-house *Editor Retention* project, developed in English, Spanish, French, Russian and Ukrainian versions. As with other in-house projects, this is not a single solution, but a working space to discuss ways of retaining newcomers inside projects and increasing their involvement.

Various factors may have influenced decisions to launch initiatives in individual projects. In order to recognise these, it would be necessary to conduct qualitative research on a larger scale, mainly through interviews with long-established Wikipedians who are also involved in the problems of the website operation. The following part of the article outlines the process of ongoing changes in the socialisation of newcomers in the Polish-language Wikipedia. This has been made possible by participatory and non-participatory observation over the past two decades, including activities aimed at engaging new Wikipedians.

4.3. Case Study of the Polish Wikipedia

In the early years of the Polish-language Wikipedia, when the interface was not yet extensive and the community was small, newcomers were greeted by spontaneously typing a few sentences on their user page. The general rules had not yet been codified, and greetings primarily encouraged them to produce more articles. Once the rules were written on the relevant pages, schematic greeting templates began to be created. From 2005 onwards, committed users began to be invited to join *the Welcoming Committee*. During this time, there was a significant growth of the community and a constant increase in the number of newcomers, which required more time for the 'welcoming movement'. Therefore, gamification elements have been

introduced to increase the motivation for this form of activity. A certain image problem was allowing people whose substantive and social competence was questioned to be a part of welcoming committees. People critical of such egalitarianism included those Wikipedians who also insisted that the community should focus on the quality of content rather than the number of articles.

An important issue was to determine what content, in what form and in what order, should be included in the welcome message. It was assumed that too much information and too many links would cause the newcomer to be discouraged from reading them. For this reason, they briefly outlined the essence of the main policies, while pointing to the more extensive assistance pages. During the period of the most intensive use of these messages, six forms were in operation at the same time, each of which was subject to irregular modifications. With the emergence of the institution of the guide (the Polish variant of mentoring), a special message was created so that guides could post it to their 'mentees'. In addition, there were several templates for foreign language users and templates for people editing without creating an account with the request to register with the service. When the community of the Polish version of Wikipedia decided that the welcome message should be posted by a bot, another content modification took place. However, it then occurred that it was much more common for such messages to be inserted to people whose intention was to commit acts of vandalism or to troll. Some Wikipedians involved in detecting such deviant actions have even advocated the abandonment of the automatic greeting. Consequently, the word 'welcome' was dropped and the use of a colour scheme that was intended to bring a positive emotional charge was abandoned. In addition, an streamlined iconography was used.

The dominance of the typographic approach over the iconographic one was also evident on the page presenting the guides (mentors). In the initial stage, people joining this group were encouraged to briefly describe on a special page what they could help with and to include a photo or possibly an avatar of themselves. This approach was intended to 'humanise' the forms of contact and to point out to the newcomers that different people can help them, and that they can make a choice in this regard. As of 2024, the old version of the guides page has been replaced by a new form, linked to the *Growth* tool, which gives newcomers easier tips on how to act and communicate with the guides. In this system also dispensed with colour, including colour iconography.

Some tools are often sunset by general changes to the Wikimedia interface. The author of this text co-authored a special message which, together with motivational images, was displayed to account-creating Wikipedians and encouraged them to include a set of useful links by clicking on one of the selected options. his tool was deactivated with the redesign of the interface and the deactivation of the information about account creation confirmation (system message *Welcomecreation*). An earlier attempt to introduce it in an English-language version was also unsuccessful. Although it met with the approval of power users, it was not consulted with the community and was consequently rejected.

5. Discussion

Positive verification of H1 means that the larger the communities, the more opportunities there are to incentivize new users before they make their first edits. Continued growth of the community is potentially possible if more of the active Wikipedians are persuaded to spend more time playing the role of mentors (guides) for newcomers. In some language versions, however, there may have been a situation typical of the Polish-language Wikipedia, where the same people have been the guides for years. If such users engage in more difficult administrative situations and conflict resolution, this may also project their emotional response towards other users, including newcomers. This is because the greater the involvement in a project, the greater the willingness to intervene in problematic situations. However, a positive aspect of such multilateral engagement may be that newcomers perceive that their mentors are working towards quality. This in turn means that they may witness pronormative actions, as pointed out by Morgan and Filippova (2018).

The differences in activity between power users and general Wikipedians could perhaps be linked to the relationship of the community to experts. Konieczny (2021) indicated that experts with novice status do not want to spend too much time familiarising themselves with internal (often heavily bureaucratic) policies and procedures. The qualitative changes that take place in a project are very often initiated by experts who have chosen to actively participate for many years. This also applies to changes in the policies themselves. In contrast, the implementers of these policies treat them less critically and more literally, and are often the ones patrolling the changes made by newcomers. Persuading experts to stay in the project would therefore rather require intensive dialogue with other experts. While institutional support is beneficial (Warncke-Wang et al., 2023), forms of individualised support should still be used with newcomers who could become power users.

The tendency towards routine and schematic thinking in interactions with newcomers, evident in Wikimedia projects, reduced overall proactive engagement (Musicant et al., 2011). The result was the creation of warnings that were more discouraging to newcomers acting in good faith than to those with destructive intentions (Morgan, Halfaker, 2018). The automation of interactions was supposed to free up social capital and channel the energy of Wikipedians into forms of proactive implementation of new users. While such a shift in activity was evident in the insertion of welcome messages, further activity in this area led to further problems. The inclusion of SuggestBot to present newcomers with articles in need of improvement was linked to the fact that the choices made by this program were not directly controlled by the communities. In the Polish language version, for example, the suggestions for improvement included entries with multiple issues existing at the same time. Attempts to improve such entries can sometimes even lead to a discussion concerning the removal of such article due to other, more serious problems. The situation is similar with automatic suggestions for translating

articles or adding hyperlinks and illustrations, as newcomers are often not familiar with the recommendations made for such actions beforehand.

6. Summary

The collapse of the trend of continuous growth of the number of newcomers to Wikimedia projects prior to 2010 prompted a search for solutions that would facilitate growth of the community. Earlier research conducted mainly in the English-language Wikipedia led to some solutions, some of which were also implemented in other language versions. Some solutions introduced by the communities were only provisional and over time they were replaced by other forms, more institutionalised and automated. Previous studies have overlooked local conditions and the different ways in which new volunteers cope with adaptation to knowledge-sharing activities. This article outlines a framework for linking the institutionalisation and automation processes of new user onboarding that can be complemented by qualitative research.

Further research would require a broader, qualitative comparison of the strategies for attracting new community members developed in many language versions of Wikipedia and in other Wikimedia projects. Such research, however, would require the involvement of several teams working inside these projects. At the level of implementation, attention should also be paid to the fact that solutions created on the basis of experiments limited to one or a few language versions may create distrust among members of the wider community. This, in turn, may reduce the motivation to participate in the postulated programmes.

References

1. Aigrain, P., Aigrain, S. (2012). *Dzielenie się: Kultura i gospodarka epoki internetu*. Warszawa: Fundacja Nowoczesna Polska.
2. Antin, J., Cheshire, C., Nov, O. (2012). Technology-mediated contributions: Editing behaviors among new wikipedians. *Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work*, CSCW '12, pp. 373-382. doi: 10.1145/2145204.2145264
3. Gluza, W., Turaj, I., Meier, F. (2021). Wikipedia Edit-a-thons and Editor Experience: Lessons from a Participatory Observation. *Proceedings of the 17th International Symposium on Open Collaboration*, OpenSym '21, pp. 1-9. doi: 10.1145/3479986.3479994
4. Karczewska, A. (2022). Forms of Adaptation of Newcomers in Wikipedia as Online Sharing Knowledge Project. *European Conference on Knowledge Management*, *Vol. 23, Iss. 1*, pp. 593-600, DOI: 10.34190/eckm.23.1.568

5. Karczewska, A. (2023). GLAM Wikiprojects as a Form of Organization of Cooperation Between Wikipedia and Cultural Institutions. *European Conference on Knowledge Management*, *Vol. 24, Iss. 1*, pp. 619-627, doi: 10.34190/eckm.24.1.1374
6. Kelling, G.L., Wilson, J.Q. (1982). Broken Windows. *The Atlantic*. Retrieved from: https://www.theatlantic.com/magazine/archive/1982/03/broken-windows/304465, 30.10.2025.
7. Konieczny, P. (2021). The Case for Institutional Support: It's High Time for Governments and University Administration to Actively Support Wikipedia. *She Ji: The Journal of Design, Economics, and Innovation*, *Vol. 7, Iss. 2*, pp. 187-196. doi: 10.1016/j.sheji.2021.05.002
8. Kozinets, R.V. (2015). *Netnography: Redefined*. London: SAGE Publications Ltd.
9. Li, A., Yao, Z., Yang, D., Kulkarni, C., Farzan, R., Kraut, R.E. (2020). Successful Online Socialization: Lessons from the Wikipedia Education Program. *Proceedings of the ACM on Human-Computer Interaction*, *Vol. 4, Iss. 50*, pp. 1-24, doi: 10.1145/3392857
10. Łukasiński, W., Wójcik, M. (2024). Wady pracy zdalnej w opinii przedstawicieli pokolenia Z w Polsce. *Przegląd Organizacji*, *Vol. 2*, pp. 41-51, doi: 10.33141/po.2024.2.5
11. Morgan, J.T., Bouterse, S., Walls, H., Stierch, S. (2013). Tea and sympathy: Crafting positive new user experiences on wikipedia. *Proceedings of the 2013 Conference on Computer Supported Cooperative Work*, *CSCW '13*, pp. 839-848. doi: 10.1145/2441776.2441871
12. Morgan, J.T., Filippova, A. (2018). 'Welcome' Changes? Descriptive and Injunctive Norms in a Wikipedia Sub-Community. *Proceedings of the ACM on Human-Computer Interaction*, *Vol. 2 (CSCW)*, pp. 52:1-52:26, doi: 10.1145/3274321
13. Morgan, J.T., Halfaker, A. (2018). Evaluating the impact of the Wikipedia Teahouse on newcomer socialization and retention. *Proceedings of the 14th International Symposium on Open Collaboration*, *OpenSym '18*, pp. 1-7, doi: 10.1145/3233391.3233544
14. Musicant, D.R., Ren, Y., Johnson, J.A., Riedl, J. (2011). Mentoring in Wikipedia: A clash of cultures. *Proceedings of the 7th International Symposium on Wikis and Open Collaboration*, *WikiSym '11*, pp. 173-182, doi: 10.1145/2038558.2038586
15. Narayan, S., Orlowitz, J., Morgan, J., Hill, B.M., Shaw, A. (2017). The Wikipedia Adventure: Field Evaluation of an Interactive Tutorial for New Users. *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing*, *CSCW '17*, pp. 1785-1799, doi: 10.1145/2998181.2998307
16. Pratt, O. (2023). Procesy wdrażania pracowników w Polsce w obowiązki zawodowe i kulturę organizacyjną w warunkach pracy zdalnej na przykładzie sektora prywatnego. Badania własne z użyciem indywidualnych wywiadów pogłębionych. *Zoon Politikon*, *Vol. 14, Iss. 14*, pp. 1-57.
17. Priedhorsky, R., Chen, J., Lam, S. (Tony) K., Panciera, K., Terveen, L., Riedl, J. (2007). Creating, destroying, and restoring value in wikipedia. *Proceedings of the 2007 ACM*

International Conference on Supporting Group Work, *GROUP '07*, pp. 259-268, doi: 10.1145/1316624.1316663

18. Rijshouwer, E., Uitermark, J., de Koster, W. (2023). Wikipedia: A self-organizing bureaucracy. *Information, Communication & Society*, *Vol. 26, Iss. 7*, pp. 1285-1302, doi: 10.1080/1369118X.2021.1994633
19. Ruprechter, T., Horta Ribeiro, M., Santos, T., Lemmerich, F., Strohmaier, M., West, R., Helic, D. (2021). Volunteer contributions to Wikipedia increased during COVID-19 mobility restrictions. *Scientific Reports*, *Vol. 11, Iss. 1*, pp. 1-12, doi: 10.1038/s41598-021-00789-3
20. Skolik, S., Jemielniak, D. (2011). Otwartość i zaufanie w organizacji opartej na wolnych licencjach na przykładzie Wikipedii. In: P. Sochaczewski (Ed.), *W kierunku zrównoważonej gospodarki opartej na wiedzy w Polsce* (pp. 92-104). Białystok: Wyższa Szkoła Ekonomiczna w Białymstoku.
21. Tapscott, D., Williams, A.D. (2008). *Wikinomia: O globalnej współpracy, która zmienia wszystko*. Warszawa: Wydawnictwa Akademickie i Profesjonalne.
22. Vetter, M.A., Sarraf, K.S., Woods, E. (2022). Assessing the Art + feminism Edit-a-thon for Wikipedia literacy, learning outcomes, and critical thinking. *Interactive Learning Environments*, *Vol. 30, Iss. 6,* pp. 1155-1167, doi: 10.1080/10494820.2020.1805772
23. Warncke-Wang, M., Ho, R., Miller, M., Johnson, I. (2023). Increasing Participation in Peer Production Communities with the Newcomer Homepage. *Proceedings of the ACM on Human-Computer Interaction*, *Vol. 7(CSCW2)*, pp. 280:1-280:26. doi: 10.1145/3610071
24. *Wikimedia Statistics* (2024). Retrieved 8 November 2025, Retrieved from: https://stats.wikimedia.org/#/all-projects, 30.10.2025.

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INTEGRATED MANAGEMENT SYSTEM AND ITS RELATIONSHIP WITH THE IMPLEMENTATION OF THE HOSPITAL STRATEGY – INTRODUCTION TO RESEARCH

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Purpose: The main purpose of this article is to introduce the issues related to the use of integrated management systems in healthcare facilities and their linkage to strategy. Due to the breadth of the topic, this article serves only as a theoretical introduction to a further, more detailed series of publications encompassing research assumptions.
Design/methodology/approach: The article is based on theoretical analysis and literature review.
Findings: The article describes the theoretical assumptions regarding integrated management systems, their premises and possibilities of application in medical facilities, defining the directions of further research.
Research limitations/implications: The presented content constitutes an outline of further research area.
Practical implications: The presented considerations and references to theories constitute the basis for further research, which will enable the identification of a possible impact on improving the management and quality of health services provided in medical facilities.
Social implications: Undertaking research based on the theoretical assumptions described should improve the management of medical facilities and more rational use of resources in order to improve the access to services and their quality and safety.
Originality/value: The article is addressed primarily to health care managers, as well as economists and public administration employees dealing with the issues of management in health care and public health.
Keywords: Healthcare system, management control, Integrated Management Systems, quality, accreditation, ISO.
Category of the paper: General review.

1. Introduction

The development of healthcare systems in Poland and worldwide is occurring in two fundamental directions. The dynamic growth of medical knowledge and technological advancements are resulting in growing specialization within both medical professions and the organization of healthcare services. This allows for the provision of medical services based on the latest available diagnostic and therapeutic technologies, but also requires the costly maintenance of complex organizational structures and multidisciplinary human resources. The emphasis on digitization and the integration of management systems for these healthcare entities is playing an increasingly important role in this process. Integrated management systems, which have been in use in other industries for years, play a significant and supportive role in this process.

The concept of continuous improvement, developed primarily by E. Deming, has found widespread practical application. Most contemporary enterprises see no prospects for continued market operation without the need to continually adapt to changing environmental conditions and sustainably improve the quality of their products and services. Product quality and quality management are becoming increasingly important, as the results of activities undertaken in this area directly or indirectly impact the implementation of healthcare facilities' strategies and goals (Ejdys, Kobylińska Lulewicz-Sas, 2012). Currently, the primary goal of most healthcare facilities – especially those governed by local governments – is survival in a turbulent environment and chronic underfunding. This goal is typically achieved by improving organizational efficiency. One way to improve organizational efficiency is to implement an integrated management system, which may include quality, environmental, occupational health and safety, and other management systems. It should be emphasized that a crucial factor that enterprises should consider when deciding on system integration is the identification of common elements across all these systems. What is important here is the fact that the structure of the existing standards is very similar, which allows organizations to implement these systems simultaneously or to adapt the newly implemented ones to the existing ones, while taking into account the key principles applicable to all management systems, such as (Wysokińska-Senkus, Wyrębek, 2011):

- policy and planning process,
- implementation and operation, defining the responsibilities, duties and powers of individual employees within the planned and implemented elements, as well as methods of communication between individual organizational units,
- evaluation of results in terms of comparing intentions with implemented activities,
- review of the system in terms of policy implementation and its effectiveness.

Currently, there are many documents regarding various aspects of management (in terms of quality, environment, occupational health and safety, information). They are commonly referred to as standardized or formalized management systems (Borys, Rogala, 2007), although the literature also identifies other types of management systems, such as "integrated" or "specialized" (Ejdys, Kobylińska Lulewicz-Sas, 2012).

Standardization is an increasingly frequently used tool for implementing integrated management systems, widely applicable in all areas of socio-economic life. The European standard PN-EN 45020: 2009 defines standardization as an activity aimed at achieving the optimal level of order within a given scope, under given circumstances, by establishing provisions intended for common and repeated use, addressing existing or potential problems (PN-EN 45020: 2009). The subject of standardization in a broad sense can be a product, process, or service, including any material, component, equipment, procedure, method, management system, or area of activity (Łańcucki, 2010). The skillful and widespread use of standardization achievements contributes to civilizational progress by promoting best solutions and fostering their dissemination and application. Standardized management systems are one of the tools that can be used in the process of managing an organization. These systems facilitate the establishment of a necessary, minimum set of requirements, the fulfillment of which should enable the achievement of planned, consistent goals.

The primary goal of management system integration is to streamline and optimize processes within an organization and ensure interoperability between individual management systems, including external processes implemented by suppliers and subcontractors (Matuszak-Flejszman, 2010). The decision to integrate management systems should be a strategic decision of management. The goals, expectations, results, and planned costs of the project should be determined before the decision to implement the system is made. It is worth emphasizing that the literature emphasizes two types of integration (Węgrzyn, 2007):

- unification, adaptation of analogous systems, taking advantage of the similarity of standards (norms) in relation to the structure of the system: the purpose of such unification is primarily to reduce administrative costs and audit costs,
- full integration of all procedures and instructions, based on the application of the total quality management (TQM) approach, focused on employees and customers and continuous improvement.

In turn, the implementation of management systems for various areas can be carried out according to one of the following schemes (Matuszak-Flejszman, 2007):

- building an integrated management system from scratch,
- building a single management system and gradual integration,
- expansion of the system with new elements,
- construction of autonomous management systems.

Among the key factors contributing to the integration of management systems are the similar philosophy and requirements of the individual systems' standards. Also important are the ability to simplify documentation by combining similar procedures, the use of experience and applied good management practices by those coordinating management systems, and the intertwining of environmental and quality issues in the management of individual processes within the enterprise.

The chosen topic is becoming extremely important. Topics such as "Integrated Management Systems", "Quality", "TQM", "ISO", and "Strategy" are very well described and defined in the literature. There are numerous publications and studies on the impact of these systems on quality improvement and economic aspects. However, there is a research gap regarding healthcare facilities, resulting from new legal regulations that impose specific requirements that these entities must meet.

The article is divided into the following sections: introduction, literature review, methods, accreditation as an element of an integrated management system in a healthcare facility, computerization of healthcare facilities, and summary.

2. Review of literature

The operation of medical facilities in Poland is regulated by a number of legal acts that address both organizational issues and the principles of medical examinations. Regulations regarding organizational standards, personnel qualifications, diagnostic equipment, and personal data protection are of key importance. Key regulations and guidelines include, in particular:

- Act of 15 April 2011 on medical activity, specifying the principles of conducting medical activity, including the functioning of laboratories as medical entities or their organizational units.
- Act of 5 December 1996 on the professions of physician and dentist, specifying the rules and conditions for practicing the professions of physician and dentist in Poland.
- Act of 6 November 2008 on patients' rights and the Patient Rights Ombudsman, which in turn regulates, among other things, the principles of providing access to medical records and the obligations of entities providing health services related to patients' rights.
- Act of 27 August 2004 on health care services financed from public funds, specifying – among other things – the conditions for providing and the scope of health care services.

While the issues of quality and standardization are very well known and developed, there is a significant gap in healthcare entities regarding quality, standards, and management system integration. A significant area of research in this area could be an adaptive approach to

developing a standardized systems integration template, which could serve as a guide for management staff and owners of these entities.

In Polish literature, the topic of "quality management" is well known and well-developed. Many authors have been dealing with this issue for years, resulting in numerous works. For a general overview of the topic, examples include:

- Blikle, A. *Doktryna jakości. Rzecz o skutecznym zarządzaniu*.
- Iwasiewicz, A. *Zarządzanie jakością*.
- Jazdon, A. *Doskonalenie zarządzania jakością*.
- Krzakiewicz, K., Cyfert, Sz. (eds.). *Metodologiczne aspekty nauk o zarządzaniu*.
- Kalinowski, T. *Innowacyjność przedsiębiorstw a systemy zarządzania jakością*.
- Łunarski, J. *Zarządzanie jakością: standardy i zasady*.
- Łunarski, J. *Normalizacja i standaryzacja*.
- Skrzypek, E., Skrzypek, A. *Jakość 4.0 w warunkach czwartej rewolucji przemysłowej*.
- Nowicki, P., Kafel, P. *Wybrane zagadnienia zarządzania jakością: dokumentacja i audyt systemów zarządzania jakością*.
- Skrzypek, E. *Zarządzanie jakością*.

However, strictly in the field of quality management in healthcare, the following examples can be mentioned:

- Celej, P. (ed.). *Zarządzanie jakością w podmiotach ochrony zdrowia*.
- Dobska, M., Dobski, P. *Zarządzanie jakością w podmiotach leczniczych*.
- Lisiecka, K. (ed.). *Zarządzanie jakością usług zdrowotnych*.

When considering an adaptive approach to systems integration, it is important to recognize the inextricable link between broadly understood quality issues and quality standards – particularly ISO (International Organization for Standardization) standards. From a theoretical perspective, this topic is also widely discussed. Examples include authors such as:

- Bugdol, M. System zarządzania jakością według normy ISO 9001:2015,
- Lewandowski, M. (ed.), *System Zarządzania Jakością według ISO 9001:2008: wdrażanie i organizacja*.
- Lewandowski, M., Ochyra, I., Konkolewska, D. *Audit wewnętrzny według norm ISO – planowanie, realizacja, dokumentowanie i ocean*.
- Michalski, R., Mytych, J. *Przewodnik po akredytacji laboratoriów badawczych według normy PN-EN ISO/IEC 17025*.
- Pacana, A., Stadnicka, D. *Nowoczesne systemy zarządzania jakością zgodne z ISO 9001:2015*.
- Sokołowicz, W., Srzednicki, A. *ISO – system zarządzania jakością oraz inne systemy oparte na normach*.
- Trela, A. *Zarządzanie jakością w działalności leczniczej: nowe wymagania systemów zarządzania – norma ISO i standardy akredytacyjne*.

From the point of view of digitalization, it is also worth mentioning the following publications:

- Bartkiewicz, W., Czerwonka, P., Pamuła, A. *Współczesne narzędzia cyfryzacji organizacji*.
- Gałaj-Emiliańczyk, K. *Wdrożenie systemu zarządzania bezpieczeństwem informacji zgodnie z normą ISO/IEC 27001:2019*.
- Glen, P., Koralewski, M., Lipka, M., Nosowski, M., Sarna, M., Lewańska, E., Brzozowska-Pasieka, M., Mizur, A. *RODO w sieci: 20 pytań i odpowiedzi dotyczących ochrony danych przetwarzanych cyfrowo*.

ISO standards, as we know, are international technical standards developed to harmonize requirements for products, services, and management systems. ISO standards are classified based on various criteria, such as their application, topic, sector, or function. For the proper management of a pathology laboratory, the following categories should be identified:

- ISO 9001 – classifying requirements for quality management systems, including: introducing supervision over documentation and records, involving management in building a quality management system, systematizing resource management, establishing product implementation processes, and making systematic measurements (of customer satisfaction, products, processes).
- ISO 14001 – describes environmental management systems and confirms the consistent implementation of all elements aimed at minimizing the negative impact of the organization on the environment.
- ISO 27001 – regulates broadly understood information security management: it helps organisations manage and protect information assets so that they remain secure, and it also helps to continuously review and improve their methods of operation, not only for today but also for the future.
- ISO 15189 – concerns requirements for medical laboratories and aims to ensure high quality and competence of medical laboratories that provide diagnostic services and conduct research on human material in order to provide information for diagnostics in medical processes or for preventive purposes in the assessment of the patient's health, and the results of a laboratory accredited for compliance with ISO 15189 are indisputable, while a laboratory with an accreditation certificate is perceived as a facility with the highest quality of research services provided.

It's important to emphasize that ISO standards – specifically those related to healthcare – are designed to enhance patient safety, streamline supply chains, and support innovation in digital health and sustainable healthcare. Given the multitude of standards mentioned above, additional, selected scopes can be identified for adaptation to the needs of healthcare facilities. These include, in particular, ISO 13402, 13485, 15223-1, and 14971.

3. Methods

The mandatory application of management control standards on the one hand, and the desire and obligation to improve the quality of services provided on the other, often mean that healthcare entities are faced with a multitude of solutions. Without integration, these solutions often duplicate requirements for management and employees and lead to an accumulation of administrative and bureaucratic responsibilities. Integration therefore seems necessary to improve the effectiveness of quality and risk management systems, and identifying the areas subject to this process is a proper introduction to action in this area.

Due to its specific nature, the provision of medical services should be covered by appropriate tools that support quality and mitigate risk. In addition to legal regulations that must be met by entities providing such services, systemic solutions are emerging and being implemented by a growing number of healthcare providers. In terms of quality management, it is worth mentioning the possibility of implementing quality management systems according to the ISO standard and accreditation standards, the correct application of which is verified by the Quality Monitoring Center (CMJ). In the context of management system integration, it is worth conducting an analysis to answer the question of whether CMJ accreditation and the quality management system according to the ISO 9001 standard are two different systems that determine the level of quality in a healthcare facility. It is increasingly common for a healthcare facility with accredited hospital status to decide to implement the ISO 9001 standard, and vice versa. A certain degree of competition then begins to emerge between the ISO standard and CMJ accreditation, and in principle, these systems should work together in the same direction, as implementing both should lead to greater benefits than using only one selected system (Głód, Głód, 2017).

The quality and safety of medical services play an extremely important role in modern medicine. Management systems are increasingly becoming a strategic goal for every entity, as they improve the quality and safety of medical services, as well as ensure greater predictability and stability of implemented processes, standardize operations, and eliminate the causes of errors. They are increasingly moving towards proactive measures aimed at counteracting the risk of threats. Technological advancements in recent years, the development of medical knowledge, and new types of medications allow medical facilities to increasingly meet patient expectations. The level of quality offered by medical facilities results from (Białas, Krakowiak, Włodarczyk, Rzeźnicki, Stelmach, 2016):

- expectations that the environment formulates towards them (individual approach, standardization of work, predictability, stability, safety of care and faster access to health services),

- shaping a strategy by healthcare managers focused on quality as one of the advantages of medical facilities, allowing them to retain and acquire new patients and ensure an appropriate standard of medical services.

In healthcare facilities where integrated management systems are implemented and operational, processes are identified and their course and sequencing are defined based on the scope of their operations. To ensure the effective and efficient operation of these systems, tools and indicators are established to monitor the progress of ongoing processes, ensuring the necessary resources for their implementation are directly supervised by those managing them. Ensuring compliance with the requirements of existing management systems compliant with ISO and/or CMJ accreditation standards can be used as effective tools in defining programs, goals, and tasks, ensuring compliance with adopted procedures, schemes, and standards of conduct, which form the basis of the facility's management process and thus improve its performance. Functioning quality management systems, often combined with risk management, are a very effective tool for minimizing threats affecting patient safety. Additionally, they translate into reduced costs for error correction and reduced compensation claims from patients (Czerw, 2012).

Considering the above management trends and the ever-increasing number of tasks aimed at continuous improvement in healthcare quality, there is a noticeable lack of uniform procedures that would enable and, above all, facilitate healthcare providers' compliance with a range of legal requirements and imposed norms and standards. Furthermore, with the current healthcare system in Poland generating requirements from multiple sources, often ambiguously formulated, inconsistent, and requiring the implementation of the same or similar actions multiple times, as well as frequent modifications and corrections, establishing a stable quality management policy in healthcare facilities becomes virtually impossible, and even requires the deployment of additional resources, which does not always translate into improved quality or increased patient safety (Kaniecka, Białas, Szrajber, Timler, Sobczak, 2018).

This article provides an introduction to theoretical issues related to the potential for integrating management systems, with particular emphasis on quality management, risk management, and management control, for use in medical facilities and other healthcare entities. At this stage, it is proposed that further research be undertaken to determine the degree of integration of management systems used in medical facilities, taking into account the following areas:

- Electronic Medical Records,
- cybersecurity,
- management control,
- certification,
- accreditation,
- ISO.

In each area, groups of factors to be assessed should be identified, including in particular:

- professional competences,
- organizational structure,
- monitoring and evaluation of the implementation of strategies, goals and tasks,
- resource security,
- risk identification, analysis and response,
- current information, internal and external communication,
- system monitoring.

This matrix will serve as the basis for conducting survey research, primarily aimed at assessing the level of preparation and advancement of the implementation process for specific legal requirements, accreditation, and other quality standards in subordinate healthcare units, as well as proposing a universal approach to implementing and integrating individual systems. The research should also consider the impact of external stakeholders (cultural, social, political, legal, regulatory, financial, technological, economic, natural, and competitive environments, key factors and trends influencing the organization's goals, and relationships with external stakeholders) and internal stakeholders (organizational governance, organizational structure, roles, policies, goals, and strategies for achieving them, resources and knowledge, information systems and decision-making processes, relationships with internal stakeholders).

4. Accreditation as an element of an integrated management system in a healthcare facility

Accreditation, as an external quality assessment method, is used for entities providing healthcare services under the Act of November 6, 2008, on Accreditation in Healthcare. Given that accreditation is intended to distinguish healthcare providers in the healthcare services market, each provider may apply for an accreditation certificate to confirm compliance with specific quality standards. This can have a positive impact on their financial situation. Possession of a certificate is one of the criteria assessed in the process of concluding contracts for healthcare services by the National Health Fund (NFZ), which may consequently translate into the inclusion of the services offered in the contract (by awarding additional points to assess their quality). It should be emphasized that the accreditation procedure described in the Accreditation Act assumes voluntary submission to a review conducted by inspectors from the accreditation center. The assessment procedure is based on a review of the healthcare provider's compliance with accreditation standards. The Accreditation Act provides a basis for assuming that accreditation in the healthcare system constitutes a significant element of statutory oversight of such an entity's activities, which include the provision of healthcare services. It is worth noting, however, that the Supreme Audit Office (NIK) pointed out significant

shortcomings of the healthcare entity accreditation system in terms of improving the quality of healthcare services and patient safety in its 2019 Audit Report (187/2019/P/19/095/LPO). The NIK noted, among other things, that the current accreditation system does not ensure the sustainability of pro-quality solutions, reports do not reflect the way healthcare entities operate, standards require significant changes, etc. It should be added, however, that having an accreditation certificate, which can be treated as a quality management system document, impacts a healthcare entity's operations in the competitive healthcare services market (Lipowski, 2022).

5. Computerization of medical facilities

Access to information is essential for effective decision-making within an organization. Information management is a strategic, multi-faceted process essential to enterprise planning and development. Today's market needs and ubiquitous competitiveness make information systems essential for a properly functioning organization, not only to meet these demands but also, often, as a condition for the company's very existence.

The basic legal act regulating the computerization of medical facilities is the Regulation of the Minister of Health of September 19, 2007, on the types and scope of medical documentation in health care facilities and the method of its processing. Based on Article 18, Section 9 of the Act of August 30, 1991, on health care facilities, a definition of the term "medical documentation" was introduced. The Regulation divides documentation into (Sawicki, 2014):

- individual documentation relating to individual patients using health care services at a health care facility, both internal and external; individual documentation is kept for individual patients using health care services, in the form of forms or printed forms, and in particularly justified cases in another form,
- collective documentation relating to all patients using the facility's health services or specific groups of these patients", collective documentation is kept in the form of books, registers, forms or files.

Documentation must be maintained in electronic form, unless other circumstances prevent this. This raises the question of how to reconcile printed and electronic formats. According to the regulation, sets of information covered by documentation may be prepared and recorded on electronic media, provided:

- maintaining selectivity of access to the information set,
- securing the information collection against access by unauthorized persons,
- securing the information collection against destruction,
- preparing a set of information to the extent allowing for the maintenance of individual documentation in the manner specified in §2, section 2 of the Act.

Today, advanced IT systems allow for the collection, integration, and interconnection of virtually any type of information. It's important to note that the systems required for a medical facility are fundamental, essential for its ongoing operation, such as the operating system (patient care, reports), accounting, and financial systems. Additional systems include, for example, a sales system (reporting to the National Health Fund), a complaints and notification system, a call center system, an external communication system (website, portal), and an HR system.

It's also worth considering the characteristics of a good IT system. These include functionality, dynamism, simplicity, reliability, and price, as well as modular design – in which case its individual modules are linked to separate operational processes. Advantages of a modular design include: the ability to better tailor the IT solution to the needs of a given entity, spreading the computerization process over time, improved project management efficiency thanks to the ability to divide it into stages, reduced project launch costs – planning for future budgets, implementing a new module without migrating previously collected data or losing it, and the ability to interrupt the implementation process without losing existing benefits. Basic medical system modules: registration, cash module, online registration, occupational medicine, doctor's office, treatment and vaccination room, dental office, diagnostics room, integration with diagnostic imaging, PACS – image archiving and transmission system, RIS – Radiology Image Processing System. Additional medical system modules: prescription, settlements with the National Health Fund, integration with the laboratory, HL7 (Health Level Seven) protocol – a standard for electronic information exchange in medical environments (includes messages regarding: data access, data download, data transfer, control, results download and clinical observations), integration with the financial and accounting system, sales, remuneration and human resources management module, IT system users, etc.

6. Summary

Integrating management systems can address the current challenges facing the Polish healthcare system. It will not only improve the quality of patient care but also increase its efficiency. Currently, there is no single, unified system, and the multitude of systems available on the market, combined with centrally imposed obligations regarding quality, cybersecurity, management control, accreditation, and ISO standards, often leads to duplication of various activities and expenditures on similar functionalities. Of course, implementing a unified model for an integrated management system faces numerous challenges that may hinder its implementation or discourage further integration. By definition, an integrated management system is a coherent system for the simultaneous management of multiple aspects by establishing and implementing policies and the resulting goals for specific aspects of an entity's

operations. However, when describing the rationale for implementing an integrated management system, it is important to mention the measurable effects of integration. The most significant factor is that the integrated management system guarantees the fulfillment of all the requirements of the individual systems. A unified system guarantees stable and repeatable processes. In turn, only repeatable and stable processes can ensure the safety and quality of healthcare services in their broadest sense. Moreover, a unified management system can contribute to a greater focus on organizational goals, reduce business risk, clearly define roles and responsibilities to maintain an integrated management system, and ultimately reduce documentation. Furthermore, a unified, integrated management system can contribute to a reduction in resources devoted to system management, a simpler reporting structure, and encourage employee skill development.

The issues described above constitute an introduction to the problem and further research into the implementation of solutions aimed at identifying the possibilities and benefits of implementing an integrated management system in medical facilities and their connection with the implementation of the strategy.

References

1. Bartkiewicz, W., Czerwonka, P., Pamuła, A. (2020). *Współczesne narzędzia cyfryzacji organizacji*. Łódź: Wydawnictwo Uniwersytetu Łódzkiego.
2. Białas, M., Krakowiak, J., Włodarczyk, B., Rzeźnicki, A., Stelmach, W. (2016). Zmiany zachodzące w opiniach pacjentów na temat jakości udzielania świadczeń medycznych po wdrożeniu Zintegrowanego Systemu Zarządzania w Instytucie Hematologii i Transfuzjologii. *Przedsiębiorczość i Zarządzanie, Tom XVII, Zeszyt 10, Część 3*. Wydawnictwo SAN, ISSN 1733-2486.
3. Blikle, A. (2014). *Doktryna jakości. Rzecz o skutecznym zarządzaniu* Gliwice: Onepress.
4. Borys, T., Rogala, P. (eds.) (2007). *Systemy zarządzania jakością i zarządzania środowiskiem.* Wrocław: Wydawnictwo Akademii Ekonomicznej.
5. Bugdol, M. (2018). *System zarządzania jakością według normy ISO 9001:2015*. Gliwice: Helion-Onepress.
6. Celej, P. (ed.) (2018). *Zarządzanie jakością w podmiotach ochrony zdrowia.* Gliwice: Wyższa Szkoła Humanitas.
7. Czerw, A., Religioni, U. Systemy oceny jakości w ochronie zdrowia. *Problemy Zarzadzania, vol. 10, no. 2(37).* Wydział Zarządzania UW.
8. Dobska, M., Dobski, P. (2012). *Zarządzanie jakością w podmiotach leczniczych.* Warszawa: ABC a Wolers Kluwer business.

9. Ejdys, J., Kobylińska, U., Lulewicz-Sas, A. (2012). *Zintegrowane systemy zarządzania jakością, środowiskiem i bezpieczeństwem pracy*. Białystok: Oficyna Wydawnicza Politechniki Białostockiej.
10. Gałaj-Emiliańczyk, K. (2021). *Wdrożenie systemu zarządzania bezpieczeństwem informacji zgodnie z normą ISO/IEC 27001:2019.* Gdańsk: ODDK.
11. Glen, P., Koralewski, M., Lipka, M., Nosowski, M., Sarna, M., Lewańska, E., Brzozowska-Pasieka, M., Mizur, A. (2024). *RODO w sieci: 20 pytań i odpowiedzi dotyczących ochrony danych przetwarzanych cyfrowo.* Warszawa: Wydawnictwo Wiedza i Praktyka.
12. Głód, G., Głód, W. (2017). W kierunku integracji systemów zarządzania jakością i ryzykiem w publicznych jednostkach ochrony zdrowia. Studia Ekonomiczne. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach, Nr 316,* p. 83. ISSN 2083-8611.
13. *Informacja o wynikach kontroli: Akredytacja podmiotów leczniczych, nr ewid. 187/2019/P/19/095/LPO*.
14. Iwasiewicz, A. (1999). *Zarządzanie jakością.* Warszawa: PWN.
15. Jazdon, A. (2002). *Doskonalenie zarządzania jakością.* Bydgoszcz: Oficyna Wydawnicza Ośrodka Postępu Organizacyjnego.
16. Kalinowski, T. (2010). *Innowacyjność przedsiębiorstw a systemy zarządzania jakością*. Warszawa: Oficyna a Wolters Kluwer business.
17. Kaniecka, E., Białas, M., Szrajber, W., Timler, D., Sobczak, J. (2018). Ocena stopnia przygotowania i zaawansowania procesu wdrożenia poszczególnych wymagań prawnych, akredytacji i innych standardów jakości w jednostkach ochrony zdrowia podległych samorządowi województwa łódzkiego. *Przedsiębiorczość i Zarządzanie, Tom XIX, Zeszyt 12, Część 3.* Wydawnictwo SAN, ISSN 2543-8190.
18. Krzakiewicz, K., Cyfert, Sz. (eds.) (2012). *Metodologiczne aspekty nauk o zarządzaniu.* Poznań: Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu.
19. Lewandowski, M. (ed.) (2010). *System Zarządzania Jakością według ISO 9001:2008: wdrażanie i organizacja.* Warszawa: Wydawnictwo Wiedza i Praktyka.
20. Lewandowski, M., Ochyra, I., Konkolewska, D. (2011). *Audit wewnętrzny według norm ISO – planowanie, realizacja, dokumentowanie i ocena.* Warszawa: Wydawnictwo Wiedza i Praktyka.
21. Lipowski, P. (2022). Akredytacja podmiotów leczniczych. *Kontrola i audyt, Nr 2(marzec-kwiecień).*
22. Lisiecka, K. (ed.) (2003). *Zarządzanie jakością usług zdrowotnych: praca zbiorowa*. Warszawa: Instytut Przedsiębiorczości i Samorządności.
23. Łańcucki, J. (2010). Trzy filary zrównoważonego rozwoju. Metrologia, ocena zgodności, normalizacji. In: J. Łańcucki (ed.), *Znormalizowane systemy zarządzania*. Poznań: *Wydawnictwo Uniwersytetu Ekonomicznego*.

24. Łunarski, J. (2014). *Normalizacja i standaryzacja*. Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej.
25. Łunarski, J. (2008). *Zarządzanie jakością: standardy i zasady*. Warszawa: WNT.
26. Matuszak-Flejszman, A. (2010). Integracja systemów zarządzania. In: J. Łańcucki (ed.), *Znormalizowane systemy zarządzania*. Poznań: Wydawnictwo Uniwersytetu Ekonomicznego.
27. Matuszak-Flejszman, A. (2007). *System zarządzania środowiskowego w organizacji*. Poznań: Wydawnictwo Akademii Ekonomicznej.
28. Michalski, R., Mytych, J. (2011). *Przewodnik po akredytacji laboratoriów badawczych według normy PN-EN ISO/IEC 17025*. Katowice: Elamed.
29. Nowicki, P., Kafel, P. (2020). *Wybrane zagadnienia zarządzania jakością: dokumentacja i audyt systemów zarządzania jakością*. Kraków: Wydawnictwo Uniwersytetu Ekonomicznego w Krakowie.
30. Pacana, A., Stadnicka, D. (2017). *Nowoczesne systemy zarządzania jakością zgodne z ISO 9001:2015*. Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej.
31. PN-EN 45020 (2009). *Normalizacja i dziedziny związane. Terminologia ogólna*. Warszawa: PKN.
32. Rozporządzenie ministra zdrowia z dnia 19 września 2007 r. *w sprawie rodzajów i zakresu dokumentacji medycznej w zakładach opieki zdrowotnej oraz sposobu jej przetwarzania*.
33. Sawicki, J. (2014). Systemy informacyjne wspomagające zarządzanie w podmiotach leczniczych. In: M. Jarosiński, S. Winch (eds.), *Zarządzanie podmiotami leczniczymi przekształcanymi w spółki prawa handlowego*. Warszawa: Oficyna Wydawnicza Szkoła Główna Handlowa w Warszawie.
34. Skrzypek, E., Skrzypek, A. (2023). *Jakość 4.0 w warunkach czwartej rewolucji przemysłowej*. Lublin: Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej.
35. Skrzypek, E. (2023). *Zarządzanie jakością.* Lublin: Wydawnictwo UMCS.
36. Sokołowicz, W., Srzednicki, A. (2006). *ISO – system zarządzania jakością oraz inne systemy oparte na normach.* Warszawa: C.H. Beck.
37. Trela, A. (2016). *Zarządzanie jakością w działalności leczniczej: nowe wymagania systemów zarządzania – norma ISO i standardy akredytacyjne.* Warszawa: Wydawnictwo Wiedza i Praktyka.
38. Ustawa z dnia 15 kwietnia 2011 r. *o działalności leczniczej*.
39. Ustawa z dnia 27 sierpnia 2004 r. *o świadczeniach opieki zdrowotnej finansowanych ze środków publicznych*.
40. Ustawa z dnia 5 grudnia 1996 r. *o zawodach lekarza i lekarza dentysty*.
41. Ustawa z dnia 6 listopada 2008 r. *o akredytacji w ochronie zdrowia*.
42. Ustawa z dnia 6 listopada 2008 r. *o prawach pacjenta i Rzeczniku Praw Pacjenta*.
43. Ustawa z dnia 30 sierpnia 1991 r. *o zakładach opieki zdrowotnej*.

44. Węgrzyn, B. (2007). Zintegrowany system zarządzania etapem kształtowania w przedsiębiorstwie. Zarządzania przez jakość (TQM). *Przegląd Organizacji, nr 6*.
45. Wysokińska-Senkus, A., Wyrębek, H. (2011). Zintegrowane systemy zarządzania. Zalety i wady oraz trudności i porady podczas wdrażania. *Journal of Agribusiness and Rural Development, 3(21)*.

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CREATIVE-INNOVATIVE RELATIONS IN ENTERPRISE ACTIVITIES

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Purpose: The aim of this article is to present creative–innovative relations in the context of enterprises' creative activities. Indicating creativity as an imperative of enterprises' creative actions required consideration of both the factors that foster and those that hinder creativity. In the article author tries to interpret the empirical findings obtained in the study within the broader context of existing research on creativity, innovation, and enterprise development.
Design/methodology/approach: The essence of the problem was identified in the impact of creativity on innovation, the result of which are decision-making relationships. An ontological approach to these relations justified the need to emphasize the destructive–creative dimension of innovation in enterprises.
Findings: Its practical reflection is an analysis of innovation activity through expenditures and effects of innovations in Poland in the years 2020-2022. The results of the research indicate positive changes in innovation activities of enterprises in Poland. An increase in expenses on innovation is clear and also the number of large enterprises that introduce innovation is growing. Innovations play crucial role in developing Polish enterprises.
Originality/value: This type of activity – creative-innovative and destructive at the same time- is distinguished in the interpretation of innovation as an adaptation of anything new in the enterprise. This study has different implications for innovation researchers. It argues for increased attention to creative-destruction relations in enterprises in the context of innovation.
Keywords: creative relations in enterprises, creative activities, innovations in enterprises.
Category of the paper: Research paper.

1. Introduction

In the science of management and quality, various decision-making issues undertaken by enterprises are taken into account. Assuming that the essence of an enterprise's functioning is determined by its development, it is justified to identify areas of pro-developmental inspiration. One of the significant areas is the creativity of an enterprise, which determines the current and future directions of economic activity (Brzóska, Knop, 2020) The literature emphasizes the

phenomenon of creativity as an operational concept, highlighting moreover the integrative nature of creative initiatives initiated by individual employees and the activities of managerial teams aimed at ensuring the enterprise's development. Development requires a creative attitude from the management staff, characterized by openness, inventiveness, preference for individualism, and visionary abilities regarding the company's operations, based on creative–innovative relations. A visionary attitude of both the management and the enterprise indicates the necessity of increasing production potential, which enables the creation of new products. (Sousa et al., 2019). Their inspiration lies in creative attitudes focused on implementing innovations (Sopińska, Dziurski, 2020).

The idea of innovation in the context of creativity is based on an approach that integrates the imperative of creative actions with Schumpeter's concept of creative destruction. Its foundation lies in innovations identified as instruments of destabilization within enterprises. Through destabilization, the enterprise enhances its potential by implementing innovations that arise from creative destruction and subsequently stabilize its operations. The relationship between creativity and innovativeness is thus the result of a creative behavior of the enterprise striving to achieve benefits from implemented innovations.

2. Creativity as an Imperative of an Organization's Creative Activities

The concept of creativity constitutes a significant area within the discipline of management and quality sciences. Its idea is concentrated in the decision-making processes undertaken in organizations. The essence of the problem can be defined by considering various definitions of creativity.

The starting point is the definition of creativity as a process of combining knowledge from different disciplines in order to generate new and original concepts of a non-conventional nature (Ilha Villanova, Pina e Cunha, 2021). The essence of creativity can also be described as "a set of traits possessed by an individual that enables constant searching for new solutions" (Wojtaszek, 2014).

New concepts of creativity thus refer to the reorganization of creative potential in a given area in order to obtain an analytical view of its essence (Wojtaszek, 2014).

Considering this approach, it is useful to present a definition that emphasizes its creative nature. Creativity is identified as "…the ability of creative thinking, combining various ideas in an original and unique way, adopting new assumptions, viewing things from a new perspective, generating ideas, doing something new or doing the same thing in a better way, as well as the unusual association of different thoughts and views" (Brzeziński, 2009).

The essence of creativity can also be related to a set of elements of lateral marketing, identified with organized efforts to search for new market areas and new partners for cooperation (Strużycki, 2017).

In such cooperation, the importance of the phenomenon of creativity is emphasized - evolving from forms of individual activity to organized teams, which together create a foundation for enterprise development (Suszyński, 2018).

In this context, an often-cited definition states that "creativity transcends the boundaries of ordinary knowledge and proficiency; it requires the ability not only to solve but also to perceive problems, which is something more than simply relying on established patterns" (Simonton, 2014). Creativity thus becomes a course of action for employees and organizations, enabling economic development (Bialas, 2022). The creative character of an organization's activity is of particular significance in relation to creativity itself.

In the literature, attention has been given to analyzing the identity of the terms creative and innovative (Olszak, 2017). Although these terms are sometimes differentiated, it is possible to indicate features they share. The material of creativity is made up of ideas distinguished by novelty and usefulness. Equally important is the processual approach, which generates new concepts integrating creativity with innovativeness. As a consequence, it becomes possible to implement new, creative ideas within an enterprise (Olszak, 2017).

The context of creativity may also be considered in relation to the "creative class" - a distinct part of society identified with the creative and educational attitudes of individuals forming a social collective (Patson et al., 2021). The task of this distinguished class is creativity, based on openness to diverse ideas of development and a preference for individualism. Equally important is the autonomy of concepts, a high level of specialized competence, and visionary skills in solving problems of enterprises and clients.

Within the competences of the creative class, one may distinguish the ability to generate original products and services of market value, ensuring profits for the enterprise. Achieving economic results requires the creative class to continuously improve their skills (Spałek, Zdonek, 2018).

When distinguishing the characteristics of creativity, it is important to highlight: general intellectual efficiency and effectiveness, possession of knowledge, competences, and creative predispositions. These features make it possible to implement a creative style of thinking based on self-confidence and a willingness to take risks (Ulfah, Syahrudin, 2024).

The analysis of creativity factors is also of great importance. Factors that foster creativity include (Mroczko, 2014):

- openness and tolerance,
- ability to accept criticism,
- sensitivity in relationships involving various problems,
- propensity for risk,

- quick responsiveness in undertaking actions combined with flexibility and originality of initiatives,
- demonstration of courage, curiosity, and initiative,
- sensitivity regarding one's own visions,
- generation of potential in the area of network cooperation.

These factors indicate the essence of creativity in terms of what it is and what it is not (Hee Kim, 2019). To seek answers, it is also allowed to point to the limitations of creativity. The factors limiting creative potential include (Kamińska, 2020):

- lack of ability to make high-risk decisions and fear of making mistakes or encountering conflict situations,
- avoidance of change,
- excessive reliance on consultants' opinions,
- unwillingness to engage in discussions on important issues due to lack of courage,
- limited motivation, flexibility, and initiative.

The above factors constitute barriers to creativity and innovations (Kamińska, 2020). Their consequences relate to the threats facing creativity itself.

Among the threats to creativity, attention is drawn to the priorities of individuals and groups. Their essence focuses on the goals of freedom and equality, which question the problem of restricting individual freedom in relation to the goals of the enterprise striving to achieve profit (Winch, 2018).

Considering the previous deliberations and future research perspectives, creativity is identified with a paradigm that indicates the need to verify existing knowledge in order to respond to current market challenges. The research problems is that creativity constitutes an imperative of enterprise activity and a determinant of innovation processes, demonstrating the central role of creative activity in innovation implementation.

In the processes of creativity, actions related to stimulation and development are crucial, as they result in achieving additional organizational potential. Their aim is to inspire and prepare new innovative concepts oriented toward producing new, original products or services and implementing modern technologies. Such initiatives form the basis for recognizing innovation as a direction for enterprise development (Cheng, 2021).

3. The Creative–Destructive Dimension of Innovation in Enterprises

The issues of creativity addressed above indicate the substantive complexity and diversity of conditions, as well as concepts based on the creative actions of organizations.

Taking into account the presented concepts, it is justified to point to a plane of reflection that integrates the imperative of creative actions with Schumpeter's concept of creative destruction, the consequence of which is innovation.

The reference to Schumpeter's creative destruction results from its very nature—as a process reflecting market mechanisms, primarily concerning the competitiveness of economic entities. From the standpoint of this paper's subject, it is justified to emphasize the link between the creative–destructive process and the changes it brings to the existing mechanisms of enterprise and market functioning through the use of creativity directed toward innovation.

Therefore, innovative activities are the consequence of the endogenous potential of enterprises that emphasize creativity oriented toward innovation and a creative approach to problem-solving. Creativity, based on innovativeness, indicates development perspectives for enterprises (Ciborowski, 2014).

In a comparable context, innovation is also identified as an instrument of destabilization of economic entities (Koźmiński et al., 2014). However, destabilization further leads to the process of improving enterprises through the use of innovations that move them from a state of threat to a state of security.

It is significant to emphasize the cyclical nature of these states, as subsequent innovations transfer enterprises from periods of destabilization toward stabilization. In this way, a new cycle of integration through innovation is realized, allowing for the growth of an enterprise's potential (Woźniak, 2014). It can thus be concluded that the increase in enterprise potential is a consequence of implementing innovations resulting from the creative destruction of transformation processes within the area of economic activity (Dachs et al., 2017).

Transformation processes enable the implementation of innovations (Poznańska, 2022). Innovative activity, based on its creative character, displays spatial diversity (Mierzejewska, 2018).

The processes of creating innovations, within this approach, concentrate on three areas:

1. Developing the concept of innovation.
2. Transforming the idea into a specific innovative project.
3. Implementing the project.

The premises for creating innovation concepts may include customer needs identified in the market and the results of R&D activities (Sopińska, 2017). Achieving these contributes to creative cooperation, providing benefits to the collaborating enterprises (Zakrzewska-Bielawska, 2018).

An integrative approach to cooperation is reflected in the relationship between creativity and innovativeness, which enables creative behavior in organizations focused on achieving tangible results (Ingram, 2016).

Within this context, the decision-making process aimed at innovation (Głód, Wronka-Pośpiech, 2018) can be associated with the notion of transformational leadership. Its idea is identified with a process of social influence through which managers foster innovativeness. Transformational leadership ensures the integration of creativity with innovation (Szozda, 2022).

In summary, when analyzing innovation in its various but always specific dimensions, it is important to emphasize the significance of introducing new products, services, or technologies within enterprises (Hisrich, Ramadani, 2017). Innovations constitute the result of their creative-destructive dimension.

The purpose of innovation is to achieve economic outcomes (Nesterak et al., 2022) However, for innovative activities to be carried out, expenditures are indispensable, they determine the creative–destructive processes within this area of enterprise operations.

4. Methodology of the research

The study adopts a mixed methodological approach, integrating qualitative theoretical analysis with quantitative empirical examination. The qualitative component is based on a critical review of selected literature in the fields of management, creativity, and innovation. This review serves to conceptualize creativity and innovation, identify their interdependencies, and justify the adoption of an ontological perspective emphasizing the creative–destructive nature of innovation processes.

From an ontological standpoint, creativity and innovation are treated as interrelated but distinct phenomena embedded in organizational reality. Creativity is understood as a generative capability that enables the creation of new ideas and concepts, while innovation represents the implementation of these ideas in practice, often involving the disruption of existing organizational arrangements. This perspective provides the theoretical foundation for analysing innovation as a cyclical process of destruction and reconstruction.

The quantitative component of the study is based on secondary data analysis using official statistics published by the Central Statistical Office of Poland (GUS). The empirical analysis focuses on innovation activity indicators, including:

- the share of innovative enterprises by size class (number of employees),
- the structure of product and process innovations,
- expenditures on innovative activities in industrial and service enterprises,
- observed effects of implemented innovations.

Descriptive statistical methods are applied to identify trends, structural relationships, and patterns in innovation activity. The analysis does not aim to establish causal relationships but rather to illustrate the manifestation of creative–innovative relations in enterprise practice.

The activities of enterprises operating in the market, within their decision-making processes, largely focus on creative–innovative relations. Their creative dimension engages the enterprise's potential, oriented toward development that is ensured by both creativity and innovation. Appropriate relationships in this area create managerial challenges centred on making decisions regarding the creation of innovations and their subsequent implementation.

The realization of such activity requires a measurable assessment of innovative performance. The assessment parameters include expenditures on innovative activities and the effects achieved through their implementation.

The primary aim of this study is to identify and analyse creative–innovative relations in enterprise activities, with a particular focus on the role of creativity as an imperative of innovation and the creative–destructive character of innovation processes. The study seeks to explain how creativity translates into innovation activity and how innovation, in turn, affects enterprise development through both destabilization and stabilization mechanisms.

To achieve this aim, the study addresses the following research questions:

1. How is creativity conceptualized as an imperative of enterprise activity in management and quality sciences?
2. What is the nature of the relationship between creativity and innovation when innovation is interpreted through the lens of creative destruction?
3. How do innovation inputs (expenditures) and innovation effects reflect creative–innovative relations in enterprises?
4. Does enterprise size, measured by the number of employees, influence the intensity of innovative activity and its outcomes?

These questions are answered indirectly through the synthesis of literature insights and the examination of statistical data on innovation activity.

The analysis is based on data from the Central Statistical Office of Poland (GUS) — Signal Information, October 30, 2023.

An important issue is the structure of innovative enterprises according to the number of employees (Table 1).

Table 1.
Innovative enterprises in 2020-2022 by number of employees

Items	Enterprises, which introduced innovations	
	Product innovations (in %)	Innovations in business processes (in %)
Industrial enterprises	15.2	28.1
Number of employees		
10-49	9,4	21.4
50-249	26.2	40.6
250 and more	47.5	65.1

Cont. table 1.

Service enterprises	8.2	30.1
Number of employees		
10-49	6.5	27.4
50-249	13.6	37.8
250 and more	23.8	59.9

Source: www.stat.gov.pl, Działalność innowacyjna przedsiębiorstw w latach 2020-2022 (2023). Warszawa/Szczecin: GUS.

Innovation in enterprises is determined by size, as defined by the number of employees (Table 1). In terms of the number of employees, organizations with 250 or more employees accounted for the largest share of the total number of enterprises introducing innovations. In both industry and services, enterprises in this size class most often introduced business process innovations (65.1% and 59.9%, respectively). An integral problem of innovation is expenditure on innovative activities (Table 2).

Table 2.
Expenditure on innovative activities

Item	**Head in uppercase letters**		
	2020	**2021**	**2022**
Industrial enterprises	20378.2	19041.5	26011.7
Service enterprises	18399.2	22348.6	29689.1

Source: www.stat.gov.pl, Działalność innowacyjna przedsiębiorstw w latach 2020-2022 (2023). Warszawa/Szczecin: GUS.

Expenditure on innovation in industrial enterprises in 2022 amounted to PLN 26,011.7 million (36.6% more than in the previous year), while in service enterprises it amounted to PLN 29,689.1 million (32.8% more). The growth rate of expenditure in 2022 compared to 2020 is also noticeable.

Both in industrial and service enterprises, expenditure on research and development dominated (accounting for 49.2% and 55.4% of all expenditure on innovation, respectively); expenditure on investments in fixed assets and intangible assets also accounted for a significant share (39.8% and 21.8%, respectively).

When assessing the innovative activity of enterprises in Poland in the period 2020-2022, the following observations can be made:

The above data confirm the thesis that the larger the enterprise—according to the criterion of the number of employees; the greater its tendency to invest in innovation. Financial expenditures allocated to innovative activities increase proportionally to the size of the enterprise. A similar relationship occurs with regard to the effects achieved from implemented innovations.

When evaluating the period 2020-2022, it should be noted that 2021, due to the pandemic crisis, exhibited a declining trend in the field of innovation and other related indicators. However, positive changes in innovative activity already appeared in 2022, which justifies the conclusion about the creative–destructive nature of innovation in enterprises.

Furthermore, the group distinguished by the highest level of innovative activity consisted of large enterprises during the analysed period. Highlighting large enterprises as the key innovators in the economy reflects the importance of creative and innovative potential, which should form an essential element of a creative business strategy.

Innovativeness, as an aspect of a creative strategy, points to the direction of future research.

5. Research Limitations

Despite its contributions, the study is subject to several limitations that should be acknowledged. First, the analysis relies exclusively on secondary data from official statistics, which limits the possibility of capturing qualitative aspects of creativity and innovation processes, such as organizational culture or leadership styles. Second, the use of aggregated data restricts the ability to identify causal relationships between creativity, innovation expenditures, and innovation outcomes.

Another limitation concerns the geographical scope of the study, which is confined to Poland. While this focus allows for in-depth national analysis, it limits the generalizability of the findings to other economic contexts. Furthermore, the study does not differentiate between sectors beyond the basic distinction between industry and services, which may obscure sector-specific innovation dynamics.

Finally, the research period, although analytically valuable due to the pandemic context, remains relatively short. Longitudinal studies covering longer time horizons could provide deeper insight into the durability of creative–innovative relations.

6. Implications

From a theoretical perspective, the study contributes to the literature by reinforcing the interpretation of innovation as a creative–destructive process rooted in organizational creativity. It advances the understanding of how creativity operates not only as a source of novelty but also as a catalyst for structural transformation within enterprises. This perspective encourages a shift from static to dynamic models of innovation analysis.

Practically, the findings underline the importance of fostering creative capabilities at the organizational level, particularly in large enterprises that act as key innovation drivers in the economy. Managers should recognize that temporary destabilization caused by innovation is not necessarily detrimental but may serve as a prerequisite for long-term development. Policies

supporting innovation should therefore focus not only on increasing expenditures but also on creating conditions conducive to creative experimentation and learning.

The results may also inform public innovation policy by highlighting the need to support small and medium-sized enterprises, which demonstrate lower innovation intensity due to resource constraints. Tailored support mechanisms could help reduce this gap and enhance overall economic innovativeness.

7. Directions for Future Research

Future research should aim to extend the present study by incorporating primary data, such as surveys or case studies, to capture the micro-level mechanisms of creative–innovative relations. Comparative international studies could further verify whether the observed patterns hold in different institutional and economic contexts.

Additionally, future studies could explore sector-specific innovation dynamics or examine the role of leadership and organizational culture in mediating the creative–destructive effects of innovation. Longitudinal analyses covering longer periods would also contribute to understanding the sustainability of creative–innovative strategies.

To sum up, the discussion demonstrates that the results of this study not only confirm existing knowledge but also extend it by offering a dynamic interpretation of creativity and innovation in enterprise activities. By explicitly integrating creative destruction into the analysis of innovation processes, the study provides both theoretical enrichment and practical guidance for enterprises and policymakers. The conclusions are clearly grounded in empirical findings and highlight the enduring relevance of creativity as a driving force of innovation and enterprise development.

8. Conclusions

The perspective of creative–innovative relations in the creative activity of enterprises was analyzed in relation to their innovation activity. The concreteness of such activity was assessed primarily through the inputs and effects of innovation in economic entities during the years 2020-2022.

Based on the available data, it can be concluded that 36.1% of industrial enterprises and 34.2% of service enterprises demonstrated innovative activity in the years 2020-2022. The amount of expenditures on innovative activity in industrial enterprises reached 26,011.7 million PLN, while service enterprises allocated 296,898.1 million PLN to innovation in 2022.

These expenditures enabled enterprises to achieve tangible results from implemented innovations. Among the most significant effects were:

- the overall development of the enterprise,
- improvement in the quality of products and services,
- increase in labor productivity,
- improvement in working conditions, and
- growth in sales and market share.

An interesting issue is the relationship between the level of innovation expenditures and the size of the enterprise, determined by the number of employees. The analysis shows that the larger the enterprise, the higher the investment outlays on innovation. In the research processes, the main investors were enterprises employing more than 250 workers.

The empirical analysis of innovation activity in Polish enterprises during the period 2020-2022 confirms that creativity constitutes a fundamental driver of innovation processes. This finding is consistent with earlier studies emphasizing creativity as a prerequisite for innovation and organizational development (Brzeziński, 2009; Olszak, 2017). The results support the view that creativity should not be treated as an isolated or purely individual phenomenon, but rather as an organizational capability embedded in decision-making processes.

The study demonstrates that enterprises with greater organizational resources - measured by the number of employees - exhibit a higher propensity to engage in innovative activity. This observation aligns with previous empirical evidence indicating that large enterprises possess stronger absorptive capacity, greater access to financial resources, and more developed R&D infrastructure, which facilitate innovation (Dachs et al., 2017; Mierzejewska, 2018). However, the present study extends this knowledge by explicitly linking enterprise size with the creative–destructive nature of innovation processes, rather than merely with innovation output.

The results further reveal that innovation activity intensified in 2022 following a decline in 2021 caused by the COVID-19 pandemic. This pattern supports Schumpeter's concept of creative destruction, according to which periods of crisis and destabilization are followed by renewal and restructuring through innovation (Ciborowski, 2014; Koźmiński et al., 2014). In this sense, the findings provide empirical confirmation that innovation acts both as a destabilizing force and as a mechanism of recovery and stabilization.

Generalizing these findings, it is justified to conclude that large enterprises in Poland exhibit the highest innovative activity. The level of activity observed during the analyzed period forms the basis for the conclusion that Polish enterprises demonstrate a moderate degree of engagement in innovative activities.

In conclusion, it is possible to underline the results of this study not only confirm existing knowledge but also extend it by offering a dynamic interpretation of creativity and innovation in enterprise activities. By explicitly integrating creative destruction into the analysis of

innovation processes, the study provides both theoretical enrichment and practical guidance for enterprises and policymakers. The conclusions are clearly grounded in empirical findings and highlight the enduring relevance of creativity as a driving force of innovation and enterprise development.

References

1. Bialas, B.R. (2022). The Dynamic Interplay of Business Competition, Innovation, and Consumer Behaviour. In: J. Nesterak, B. Ziębicki (eds.), *Knowledge – Economy – Society Business Challenges And Transformations In The Digital Age.* Warsaw: Institute of Economics Polish Academy of Science.
2. Brzeziński, M. (2009). *Organizacja kreatywna.* Warszawa: PWN.
3. Brzóska, J., Knop, L. (2020). Business Model Change in the Presence of Challenges Brought by Industry 4.0. In: P. Buła, B. Nogalski (eds.), *The Future of Management. Industry 4.0.* Cracow: Jagiellonian University Press.
4. Cheng, M. (2021). Product Differentiation and Financial Statement Comparability. *Journal of Corporate Accounting and Finance*, *32*.
5. Ciborowski, R. (2014). Schumpeterowska twórcza destrukcja a dryf ładu społeczno-gospodarczego. In: P. Pysz, A. Grabska, M. Moszyński (eds.), *Spontaniczne i stanowione elementy ładu gospodarczego w procesie transformacji. Dryf ładu czy jego doskonalenie?* Warszawa: PTE.
6. Dachs, B., Hud, M., Koehler, C., Peters, B. (2017). Innovation, creative destruction and structural change: firm-level evidence from European countries. *Industry and Innovation*, *24(4)*.
7. Głód, W., Wronka-Pośpiech, M. (2018). Zależności pomiędzy wartościami organizacyjnymi a innowacyjnym stylem przywództwa. Perspektywa firm rodzinnych. *Przegląd Organizacji, 3*.
8. Hee Kim, K. (2019). Demystifying Creativity: What Creativity Isn't or Is? *Roeper Review.*
9. Hisrich, R.D., Ramadani, V. (2017). *Foundation of Entrepreneurial Management. Effective Entrepreneurial Management: Strategy, Planning, Risk Management, and Organization*. Springer Publishing.
10. Ilha Villanova, A.L., Pina e Cunha, M. (2021). Everyday creativity: A systematic literature review. *The Journal of Creative Behavior*, *55(3).*
11. Ingram, T. (2016). *Zarządzanie talentami i pracownikami w dojrzałym wieku w kontekście wpływu na wyniki przedsiębiorstwa*. *Prace Naukowe.* Uniwersytet Ekonomiczny w Katowicach.

12. Kamińska, A. (2020). Regionalne przeszkody działalności innowacyjnej. In: L. Bohdanowicz, P. Dziurski (eds.), *Innowacje i marketing we współczesnych organizacjach - wybrane zagadnienia.* Warszawa: Oficyna Wydawnicza SGH.
13. Koźmiński, A., Jemielniak, D., Latusek-Jurczak, D. (2014). *Zasady zarządzania.* Warszawa: Wolters Kluwer.
14. Mierzejewska, W. (2018). Innovative Performance of Transnational Corporations. *Journal of Management and Financial Sciences*, *31*.
15. Mroczko, F. (2014). Istota i uwarunkowania kreatywności w procesie innowacji. In: L. Kowalczyk, F. Mroczko (eds.), *Kreatywność. Innowacyjność. Przedsiębiorczość. Zarządzanie operacyjne w teorii i praktyce organizacji biznesowych, publicznych u pozarządowych*. *Prace WWSZiP, t. 30*.
16. Nesterak, J., Wodecka-Hyjek, A., Bąchor, E. (2022). Lean Management Implementation Support Tools in the Enterprise – Own Research. In: J. Nesterak, B. Ziębicki (eds.), *Business Challenges and Transformations in the Digital Age*, Warszawa: INE PAN.
17. Olszak, C. (2017). *Twórcza organizacja. Komputerowe wspomaganie twórczości organizacyjnej.* Warszawa: CH Beck.
18. Patson, T., Kaufman, J.C., Cropley, A.J., Marrone, R. (2021). What is Creativity in Education? A qualitative Study of International Curricula. *Journal of Advanced Academics, 32(2).*
19. Poznańska, K. (2022). Innowacje jako czynnik sukcesu przedsiębiorstwa. In: E. Bojar (ed.), *Recepty na sukces w zarządzaniu. Refleksje przedstawicieli nauk o zarządzaniu i praktyków*. Toruń: Dom Organizatora.
20. Simonton, D.K. (2014). Creative performance, expertise acquisition, individual differences, and developmental antecedents: An integrative research agenda. *Intelligence*, *4.*
21. Sopińska, A., Dziurski, P. (2020). Motives for Creating Open Innovation in Enterprises Operating in Poland. In: P. Buła, B. Nogalski (eds.), *The Future of Management. Industry 4.0.* Cracow: Jagiellonian University Press.
22. Sopińska, A. (2017). Zarządzanie zasobami wiedzy w otwartym modelu tworzenia innowacji. In: Z. Dworzecki, G. Leśniak-Łebkowska (eds.), *Księga Jubileuszowa dla Profesor Marii Romanowskiej.* Warszawa: Oficyna Wydawnicza SGH.
23. Sousa, F.C., Nunes, F., Monteiro, I. (2019). Managers' attitudes to creativity and innovation practices in the creative industries. *Tourism & Management Studies*, *15(1SI).*
24. Spałek, S., Zdonek, J. (2018). Implikacje eksternalizacji wiedzy przedstawicieli twórczych specjalistów. In: P. Wachowiak, S. Gregorczyk (eds.), *Organizacja kreatywna. Teoria i praktyka*. Warszawa: Oficyna Wydawnicza SGH.
25. Strużycki, M. (2017). Strategiczne aspekty konkurencji i kooperacji w zarządzaniu regionalnym. In: A. Sopińska, P. Wachowiak (eds.), *Wyzwania współczesnego zarządzania strategicznego.* Warszawa: Oficyna Wydawnicza SGH.

26. Suszyński, C. (2018). Kreatywność jako imperatyw i atrybut współczesnego przedsiębiorstwa. *Przegląd Organizacji, nr 5*.
27. Szozda, N. (2022). *Zarządzanie produktem w łańcuchu dostaw w dobie transformacji cyfrowej*. Wrocław: Uniwersytet Ekonomicznego we Wrocławiu.
28. Ulfah, M., Syahrudin, H. (2024). The impact of self-confidence and creativity on entrepreneurial intentions: The mediating role of risk-taking. *Jurnal Ekonomi Pendidikan dan Kewirausahaan*, *12(2),* 327-346.
29. Winch, S. (2018). Konserwatyzm przedsiębiorstw jako warunek ich kreatywności. In: P. Wachowiak, S. Gregorczyk (eds.), *Organizacja kreatywna. Teoria i praktyka*. Warszawa: Oficyna Wydawnicza SGH.
30. Wojtaszek, K. (2014). Wpływ kreatywności zasobów ludzkich w przedsiębiorstwie na jego konkurencyjność. In: L. Kowalczyk, F. Mroczko (eds.), *Kreatywność Innowacyjność Przedsiębiorczość Zarządzanie operacyjne w teorii i praktyce organizacji biznesowych, publicznych i pozarządowych. Prace Naukowe Wałbrzyskiej Wyższej Szkoły Zarządzania i Przedsiębiorczości, t. 30(5)*.
31. Woźniak, J. (2014). Kryterium innowacyjności w projektowaniu organizacji gospodarczej: ujęcie systemowe. In: L. Kowalczyk, F. Mroczko (eds.), *Kreatywność Innowacyjność Przedsiębiorczość Zarządzanie operacyjne w teorii i praktyce organizacji biznesowych, publicznych i pozarządowych. Prace Naukowe Wałbrzyskiej Wyższej Szkoły Zarządzania i Przedsiębiorczości, t. 30(5)*.
32. www.stat.gov.pl. *Działalność innowacyjna przedsiębiorstw w latach 2020-2022* (2023). Warszawa/Szczecin: GUS.
33. Zakrzewska-Bielawska, A. (2018). Kreatywna współpraca jako atrybut relacyjnej strategii przedsiębiorstwa. *Przegląd Organizacji, 3*.

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VIRTUAL REALITY IN AVIATION: APPLICATION AREAS AND SWOT ANALYSIS

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Purpose: The main objective of the research is to identify and analyze areas of application of virtual reality in aviation. The specific objectives includes: (1) the assessment of the usefulness of virtual reality in pilot training, (2) conducting a SWOT analysis for pilot training, (3) the assessment of the potential of VR as a tool supporting the development of aviation personnel competencies and improving operational safety.
Design/methodology/approach: The research uses the literature analysis method, the survey method and the SWOT analysis. To assess the perceived usefulness of virtual reality in pilot training, a survey was conducted among 30 individuals at various stages of their aviation careers (from ATPL(A) to First Officer) training. Authors used internet questionnaire survey. SWOT analysis was carried out also for pilot training area.
Findings: Respondents closely related to pilot training (from ATPL(A) to First Officer) showed great interest in virtual reality. The study shows the potential of using virtual reality in supporting pilot training.
Practical implications: The results presented in the article can be treated as an introduction to larger studies and a broader discussion on the potential of using virtual reality in pilot training. The survey results indicate a positive interest of respondents in the use of virtual reality in aviation. This topic should be researched more extensively and practical actions should be taken in this direction.
Originality/value: As shown in the section on literature analysis, the topic of using virtual reality in aviation is not yet exploited. Hence the article shows an area that has great potential both in terms of research and application. Survey research were conducted on respondents closely related to pilot training (from ATPL(A) to First Officer). Based on the SWOT analysis, the article presents a view on the use of virtual reality in pilot training from various perspectives.
Keywords: virtual reality (VR), VR training, aviation, pilot training, survey.
Category of the paper: Research paper.

1. Introduction

The development of the Industry 4.0 concept has initiated changes in the way modern organizations operate. These changes apply to both the manufacturing and service sectors. A significant portion of these changes involves digitalization, which affects processes, services, and the entire economy. Enterprises are increasingly using IT solutions, e-services, and information and communication technologies (ICT). One of the key elements of digital transformation and Industry 4.0 is immersive technologies. These include virtual reality (VR) and augmented reality (AR). Of course, they can be used in entertainment (Epp et al., 2021; Stecuła, 2022), relaxation (Fagernäs et al., 2021), and culture (Jung et al., 2016; Kontogiorgakis et al., 2024), but they also have significant potential for application in other areas of human life. They find applications in medicine (Yeung et al., 2021), education (Stecuła, Pradela, 2024), industry (Henriques, Winkler, 2021; Van Wyk, De Villiers, 2009), etc. They enable the use of interactive environments, simulations, and training. The potential for application is enormous, especially as these technologies are currently developing. In industry, they can be used to increase the effectiveness of company training (Norris et al., 2019), shorten task completion times (Kangas et al., 2022), increase work safety (Haj-Bolouri et al., 2024) and many other purposes.

Aviation is among the many sectors that could benefit from the development of immersive technologies. It is characterized by a high degree of complexity, requiring precise training, rapid response to non-standard situations, and adherence to the highest safety standards. Due to the nature of air operations, their cost, and the limited availability of real-world crisis scenarios, virtual reality represents an area of exceptional potential. VR offers the ability to replicate dynamic, challenging, or dangerous situations. Such scenarios can be repeated without significant expense. Scenario rehearsal is conducted in a safe and controlled manner. VR has the potential to improve the quality of training, streamline decision-making processes, and develop the practical competencies of aviation personnel.

This article addresses the application of virtual reality in aviation. Based on a literature review and the authors' own experiences, the areas of aviation where VR has the potential and potential for application have been identified. The authors identify these areas and then conduct a SWOT analysis to assess their strengths, weaknesses, opportunities, and threats. The results can serve as a basis for formulating recommendations regarding VR implementation in the aviation sector, particularly in the context of training and improving personnel competencies.

2. Literature review

The authors examined the number of articles that deal with the topic of virtual reality in aviation. For this purpose, using the search engine in the Scopus database, they performed a quantitative analysis of the literature. Authors focused on articles that have both keywords "virtual reality" and "aviation". The search formula was written as follows – formula (1):

$$KEY\ ("virtual\ reality")\ AND\ KEY\ ("aviation") \quad (1)$$

An analysis of scientific achievements collected in the Scopus database indicates that between 1991 and 2025, a total of 347 papers on the application of virtual reality in aviation were published. Although the first publications appeared in the early 1990s, for nearly two decades the number of studies was very limited, indicating a low interest in this topic. Only after 2015 was a significant increase in the number of publications observed, and a particularly dynamic increase was recorded after 2018, when the number of papers systematically increased, reaching over 20 articles per year since 2020. This trend confirms that VR research in aviation is still a developing niche – an area with significant exploratory potential that is only just beginning to be recognized by the scientific community. Research activity to date remains low compared to other sectors. This confirms the need for further in-depth analyses and the organization of knowledge in this area. Figure 1 shows the discussed data.

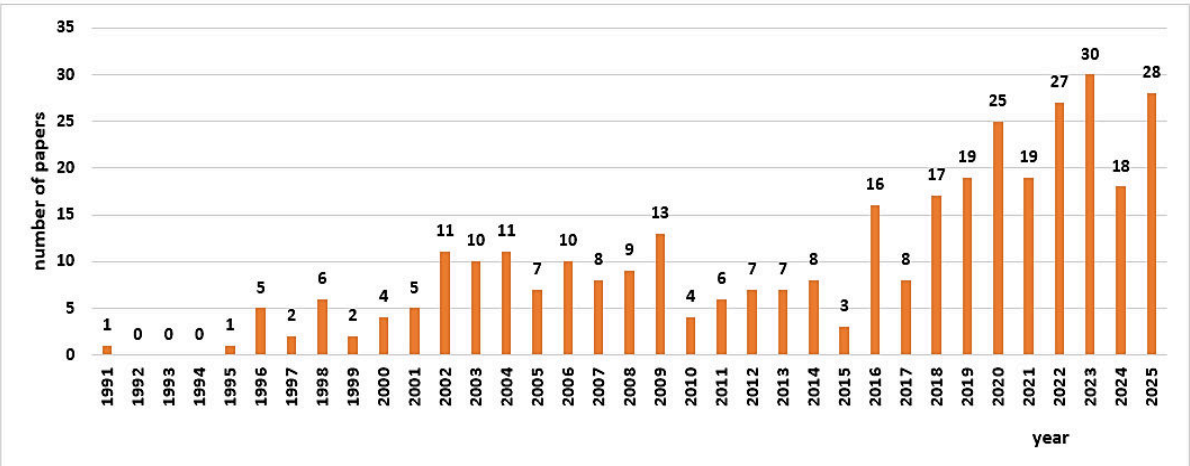


Figure 1. Number of papers in the Scopus database with the keywords „virtual reality" and „aviation" published by year; n = 347 (data state on November 15, 2025).

In the next step, the authors analyzed the structure of publications by subject area, based on data obtained from the Scopus database. The analysis shows that the application of virtual reality in aviation is clearly dominated by technical fields. The largest number of publications were assigned to Engineering (203 documents, almost one-third of all publications) and Computer Science (129 documents), confirming that research on VR in aviation focuses primarily on technological, design, and simulation aspects. Social Sciences (75) and Mathematics (55) also have a high representation, reflecting the interest in training processes,

behavioral analysis, and modeling. A significant, though smaller, group of publications comes from the areas of Medicine (43), Psychology (19), and Neuroscience (15), indicating a growing interest in the impact of immersive environments on perception, stress, cognitive responses, and the safety of VR users. The fields of Physics and Astronomy (23) and Materials Science (19) encompass studies on modeling physical environments, human-machine interaction, and device technology. However, fields such as Business, Management and Accounting (6) and Economics (4) are marginally represented, demonstrating that economic, organizational, and managerial analyses of VR in aviation remain underdeveloped. Figure 2 shows the mentioned data in details.

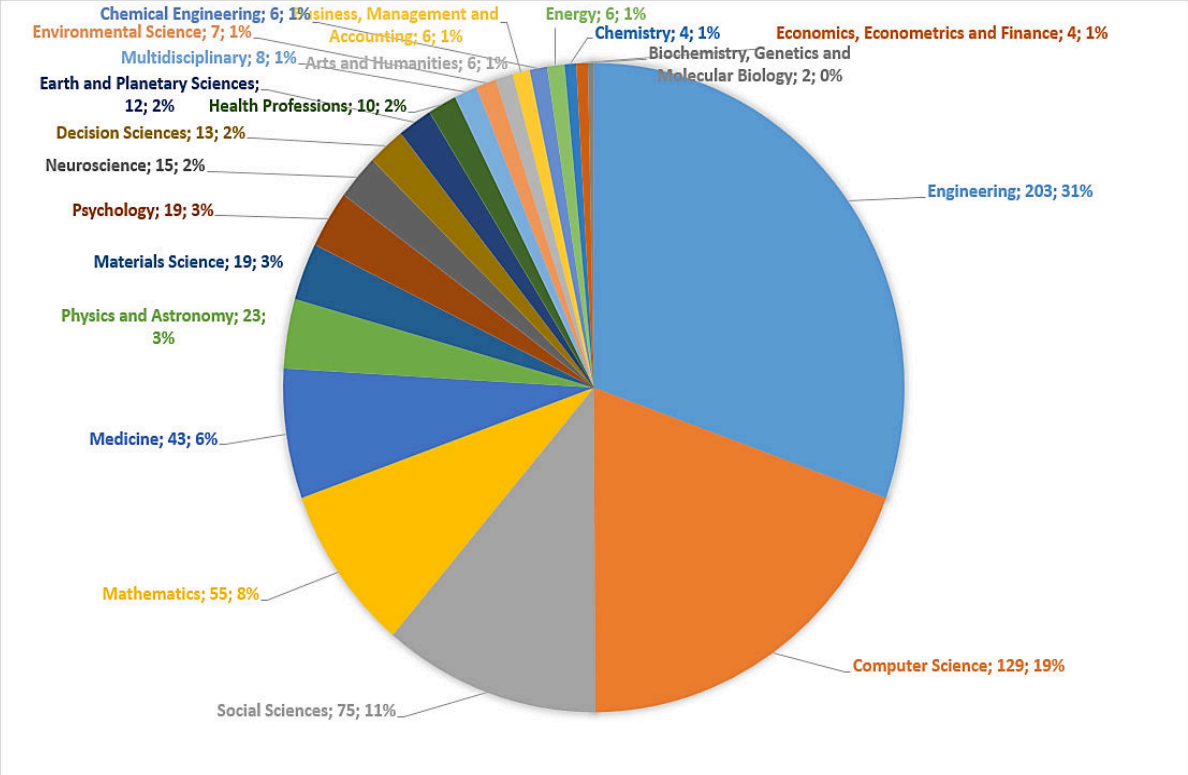


Figure 2. Number of papers in the Scopus database with the keywords „virtual reality" and „aviation" ordered by subject area; n = 347 (data state on November 15, 2025).

The results of the analysis confirm that the literature on VR in aviation is clearly interdisciplinary in nature, but the distribution of publications indicates a dominance of technical research over social or organizational research. At the same time, areas such as management, education, ergonomics, and cost-effectiveness remain underexplored, creating room for further research and representing a scientific niche with significant development potential.

Among papers that were published in 2025-2024, there are different topics and perspectives of research. There are articles on general training and simulation in aviation which uses virtual reality or its elements (Bayro et al., 2025; Larkin et al., 2025; Malmquist et al., 2025; McCullins et al., 2025). Some of the papers discuss and examined the topic of pilot flight simulator training (Kimura et al., 2024; Somerville et al., 2025). Another paper refers generally to immersive

technologies in aviation (Wild et al., 2025). Other authors present and study VR and AR interaction modes in airport control towers (Bagassi et al., 2024). More technological paper (Thijssen et al., 2025), explores the integration of live, virtual, and constructive environments in fighter pilot training through Link-16. Another paper develops methodology for enablement of human digital twins for quality assurance in the aerospace manufacturing domain (Colaw et al., 2025). Digital twins in the context of VR are also discussed in other papers (Jayasree et al., 2025; Ren et al., 2024). There is also a paper which presents research on development and validation of spatial disorientation scenarios using virtual reality and motion simulator (Kim et al., 2025). Other authors presents an iterative design method for advancing air traffic control and management training through immersive VFR 3D map visualization (Patrick et al., 2025). There is also a paper on effects of a VR-based procedure trainer on vision and cybersickness in senior airline pilots (Collet et al., 2025). Mental health and readiness for professions within aviation is also examined (Ćosić et al., 2025). Another group of papers are those on work safety and education about aviation safety (Dodoo et al., 2025; Scorgie et al., 2024; Zhu, 2025).

A literature review shows that the topic of VR research in aviation is very diverse and covers many areas – from general training and simulation, through work on pilots, to research on technical personnel, security services, and psychological issues. The range of publications indicates that this area is still developing rapidly, with immersive technologies gradually being implemented in increasingly new operational contexts. Despite growing interest, many topics remain under-researched, highlighting the significant potential and need for further scientific analysis.

3. Materials and methods

The research uses the literature analysis method, the survey method and the SWOT analysis. To assess the perceived usefulness of virtual reality in pilot training, a survey was conducted among 30 individuals at various stages of their aviation careers (from ATPL(A) to First Officer) training. The survey covered six thematic areas, allowing for the assessment of VR's potential in practical flight training. The authors used an online survey, Google Forms, the survey was sent via email, the results were collected and then the authors analyzed the results and presented them in the next chapter. Participants assessed, among other things:

- experience using VR,
- training areas where VR is most useful,
- training stages where VR could support learning,
- subjective assessment of VR's usefulness in pilot training, and
- possibility of formally incorporating VR as a preparation element for simulator sessions or training flights.

The obtained results enabled the identification of key VR applications and an assessment of the perceived value and limitations of this technology from the perspective of future pilots.

The main objective of the research is:

- to identify and analyze areas of application of virtual reality in aviation,

The specific objectives of the research are set as follows:

- assessment of the usefulness of virtual reality in pilot training,
- conduct a SWOT analysis for a selected area – pilot training,
- assess the potential of VR as a tool supporting the development of aviation personnel competencies and improving operational safety.

The collected responses allowed us to identify key areas of VR application in aviation training and formed the basis for further analysis presented in the Results section.

4. Results

Virtual reality technology is one of the dynamically developing tools supporting the training process in aviation. It enables the creation of immersive environments in which the user can perform activities identical or similar to real aviation operations, while maintaining complete safety and very low costs compared to traditional training. VR is currently being used in an increasing number of areas, and its implementation is supported by both the rapid development of hardware (VR goggles, controllers, motion tracking) and software that enables realistic reproduction of the cockpit, passenger cabin, airport infrastructure and emergency situations.

This study has identified six key areas where VR has particular potential in the context of civil aviation:

- pilot training – cockpit, procedures, emergency situations,
- cabin crew training – evacuation, critical situations, passenger service,
- air traffic controller training – visualization of traffic and unusual situations,
- safety management – crisis scenarios and incident analysis,
- academic education – support for aviation students and trainees,
- maintenance and technical service – training for mechanics and technicians.

Of the areas mentioned, pilot training proved to be the most important, both in terms of research and practice. It is here that the most important stages of acquiring procedural skills are concentrated, and the learning process itself requires both repetition and access to specialized equipment, such as FNPT II, FTD or FFS simulators. For this reason, the analysis of the survey results has been fully integrated into the segment concerning pilot training, where VR found the greatest support among respondents.

4.1. Pilot training

Pilot training is an area where the use of VR technology is most natural and most frequently discussed in literature. This is due to the fact that a large part of the pilot training process is based not on flight dynamics alone, but on procedural skills, knowledge of the cockpit layout and automation of flight operations. Pilots must not only gain the necessary flight time, but also demonstrate precise responses to checklists, flows, emergency situations and operating procedures. Often, these elements are more demanding than the actual piloting of the aircraft. VR fits perfectly into this model of skill acquisition – it allows for multiple, unlimited repetitions of activities, work in a 1:1 cockpit scale, and the performance of procedures in a manner consistent with natural hand movements. This is particularly important prior to training on expensive, certified FSTD devices, where each hour is limited and costly.

In the first part of the survey, participants were asked about the stage of their aviation career. The results are presented in the chart below (Figure 1).

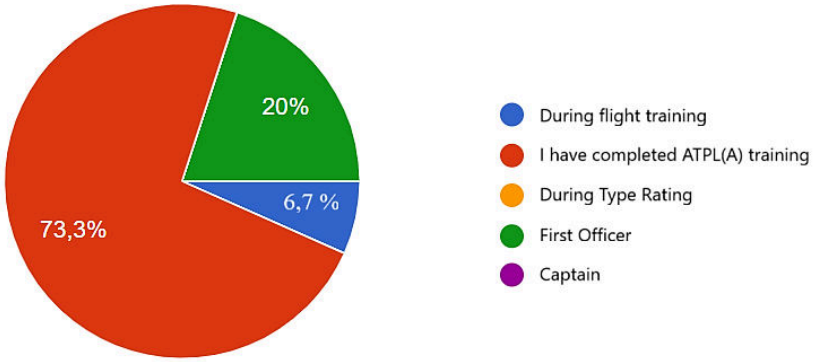


Figure 1. Responses to the question "What stage of your aviation career are you currently at (single-choice question)?" (n = 30).

The interpretation of the data shows that the study was dominated by pilots who had completed ATPL(A) training (73.3%) and active First Officers (20%). Only 6.7% were trainees undergoing basic training. This means that the vast majority of respondents had undergone theoretical and simulator training, so their opinions on VR are based on real experience of practising procedures and working in the cockpit. The high level of experience of the group increases the reliability of the results.

In the second question, respondents were asked about their experience with virtual reality. Among the 30 people, only one person had never used VR. The question concerned not only the use of virtual reality in aviation but also the general experience with this technology. Figure 2 shows the results.

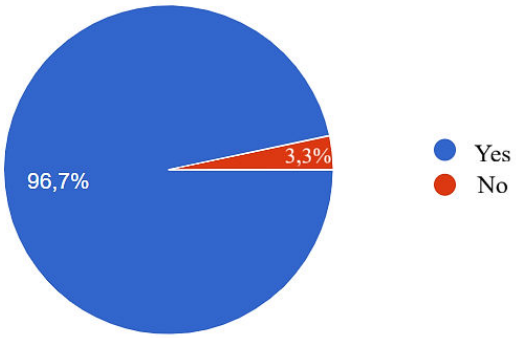


Figure 2. Responses to the question "Have you ever used VR (not just for aviation purposes; multiple choice question)?" (n = 30).

Then, pilots were asked which elements of training could benefit most from the use of VR. The results are presented in the chart below (Figure 3).

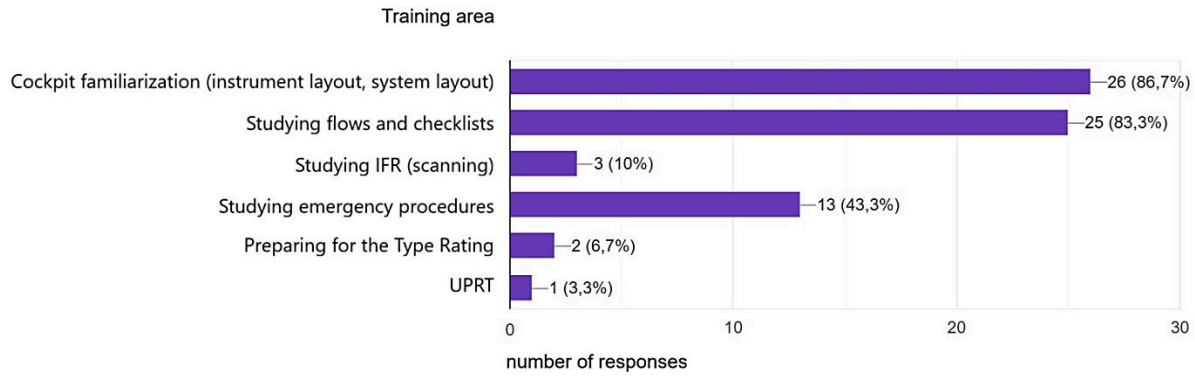


Figure 3. Responses to the question "In what areas of pilot training could VR be most useful (multiple choice question)?" (n = 30).

The analysis of the results shows three main areas:

- Familiarisation with the cockpit – 86.7% – this is the highest-rated element. VR allows you to learn the location of switches, instruments, panels and the logic of the cockpit layout. Respondents emphasised that during their first sessions in FNPT or FFS simulators, the greatest difficulty was finding the right cockpit elements and understanding their layout. VR largely eliminates this problem.
- Learning flows and checklists – 83.3% – the second most frequently mentioned area is learning procedures. VR allows the user to perform sequences of actions in accordance with the logic of the aircraft, repeat them multiple times, and build motor automation. Many pilots emphasised that VR would allow them to prepare much better for their first sessions in FSTD simulators.
- Emergency procedures – 43.3% – in emergency situations, pilots perform procedures according to checklists and procedural memory. VR allows them to train for rare scenarios in a safe environment. Respondent indicated this element as a valuable addition to traditional training.

Lower percentages in other areas (IFR – 10%, preparation for Type Rating – 6.7%, UPRT – 3.3%) do not mean a lack of value, but rather that VR is perceived primarily as a procedural tool and only secondarily as a tool for learning complex situational awareness.

In the next survey question, pilots assessed at which stage of training they believed VR technology could bring the greatest benefits. The results are presented in the chart (Figure 4).

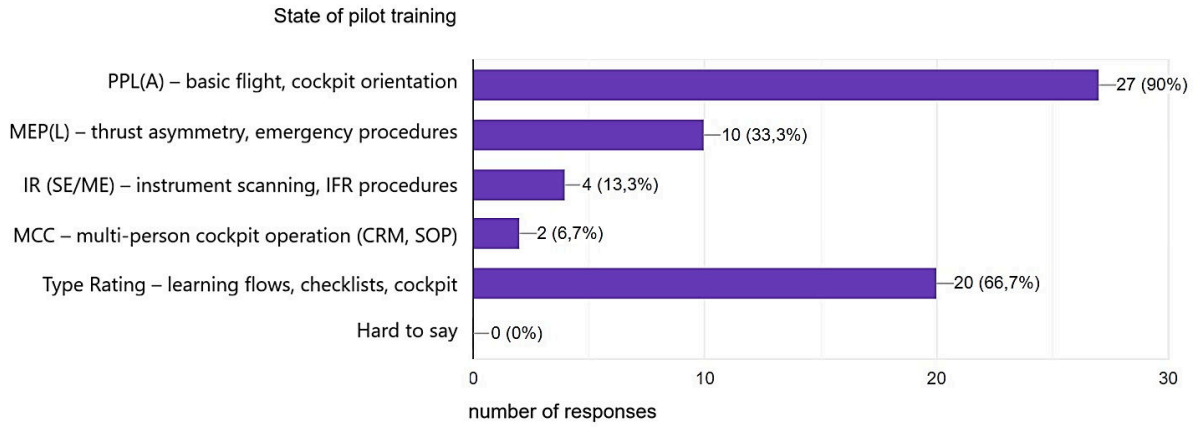


Figure 4. Responses to the question "At what stage of pilot training do you think VR technology could be most useful (multiple choice question)?" (n = 30).

Interpretation of results are as follows:

- PPL(A) – 90% of responses – this stage covers the basics of flying and the first encounter with the cockpit. Respondents felt that VR would be extremely valuable here, as it allows them to freely explore the cabin layout, learn checklists and practise basic procedures without time or cost pressures.
- Type Rating – 66.7% of responses – the second most important stage according to the respondents. Pilots beginning training on a given type of aircraft must learn a huge number of procedures in a short period of time. VR could improve the learning of flows, panel layout and intensive procedural training before entering the FFS simulator.
- MEP(L) – 33.3% of responses – this stage includes assistance in flying multi-engine aircraft and learning emergency procedures related to thrust asymmetry. VR could support checklist response training and build automation of actions in emergency situations.
- IR (SE/ME) – 13.3% of responses – the lower value is due to the fact that IFR training is largely based on working with instruments and precision piloting, which fully requires certified simulators. VR, on the other hand, can support procedural elements – e.g. pre-take-off sequences, aircraft configuration, briefing.
- MCC – 6.7% of responses – this stage is mainly based on crew communication and cooperation. VR can simulate the cockpit environment, but it does not replace the dynamics of two pilots working together in a simulator.

In the next question, respondents were asked to mark on a scale from 1 to 5 to what extent virtual reality can be useful in pilot training. The most frequently chosen rating was 4 points, 80% of respondents chose this answer. The average rating was 3,9. three-person teams took 5 points, while 1, 2 and 3 points were chosen by exactly one person each. Figure 5 shows the results.

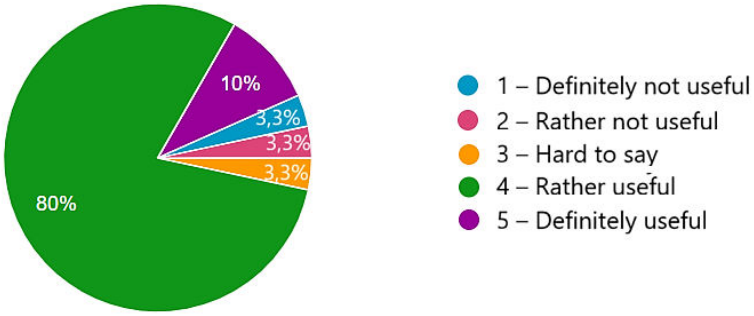


Figure 5. Responses to the question "To what extent could VR be useful in pilot training?" (n = 30).

In the last question, respondents were asked whether, in their opinion, virtual reality should be a formal element of pilot training. 96.7% of people chose the answer “yes, but only as an optional tool”. Only one person answered “no” to this question. Nobody selected the answer “yes”, and “hard to say”. This means that virtual reality is met with interest and future pilots see its potential for use in flight training, although none of the respondents stated that virtual reality should be incorporated as a tool for everyone during training. Figure 6 shows the results. An illustrative example of a person undergoing virtual reality flight training is presented in Figure 7.

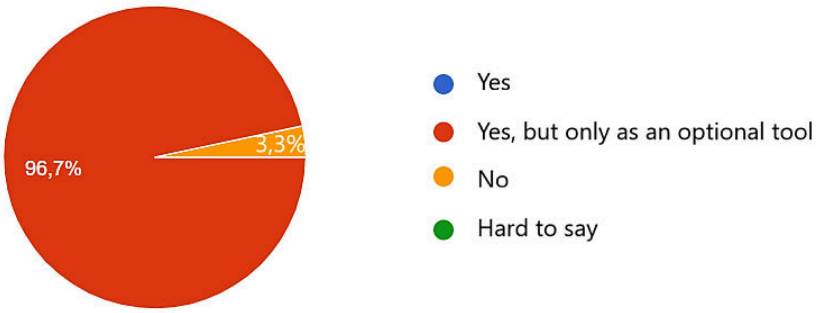


Figure 6. Responses to the question "In your opinion, could VR be incorporated as a formal element of preparation for simulator sessions or training flights in an aircraft?" (n = 30).



Figure 7. An illustrative example of a person undergoing virtual reality flight training (authors' own work).

4.2. Cabin crew training

VR enables realistic simulation of emergency situations such as fire, smoke, decompression or aircraft evacuation. Training for these situations usually takes place in an infrastructure-limited environment, and conducting a full simulation can be costly or difficult to organize. VR enables these events to be safely replayed multiple times, developing the ability to act under pressure, work as a team and communicate with passengers in stressful conditions. This is particularly important because a large part of the cabin crew's duties relate to rare and emergency situations that cannot be practiced in real conditions.

4.3. Training for air traffic controllers

In the area of air traffic control, VR can reproduce both typical and rare operational situations. Controllers can observe aircraft movement in three-dimensional space, simulate unusual situations, transponder malfunctions, airspace violations or incorrect pilot maneuvers. In addition, VR allows for training scenarios involving sudden increases in traffic or radio communication disruptions. VR training can significantly increase an air traffic controller's situational awareness and improve decision-making.

4.4. Security management

VR allows for realistic recreation of crisis situations, such as aviation incidents, system failures, rescue operations, and mass-casualty events. As a result, it can support the safety management system (SMS) through training simulations and corrective action exercises in a risk-free environment. In addition, it is possible to reconstruct aviation accidents in a three-dimensional environment, which facilitates the analysis of causes and the promotion of a safety culture.

4.5. Academic education

VR enables aviation students to learn the basics of aerodynamics, flight mechanics, navigation, meteorology and on-board systems in an interactive and engaging way. Students can analyse the operation of electrical, hydraulic and fuel systems in an aircraft, manipulate virtual structural elements and perform experiments that would be impossible in a traditional lecture hall. VR also supports theoretical courses by enabling the observation of aviation phenomena in a three-dimensional environment.

4.6. Maintenance and technical service

VR is increasingly used in aircraft mechanic training. Technicians can learn maintenance, diagnostic and repair procedures on virtual aircraft models without the risk of damaging structural components. They can perform inspections, learn about system design and practise step-by-step procedures, which speeds up their adaptation to the work environment and reduces training costs.

5. SWOT analysis

This chapter shows the SWOT analysis carried out for the selected area among the mentioned. This area is pilot training. Table 1 presents the analyzed strengths, weaknesses, opportunities, and threats of the use of virtual reality for pilot training.

Table 1.
SWOT analysis of VR application in pilot training

The area of SWOT analysis	The most important elements in the given area
Strengths	• Modern and interactive tool for learning procedures (flows, checklists). • Ability to repeat activities multiple times. • Progress monitoring (quick feedback). • Realistic 3D cockpit representation. • High level of immersion. • Training availability regardless of weather conditions. • Safe emergency procedures training. • Support for building situational awareness.
Weaknesses	• Lack of physical sensations and feelings from the cockpit. • Contraindications to VR use. • Side effects experienced by some individuals (e.g., dizziness, nausea, etc.) while using VR. • Variable quality of equipment and cockpit representation. • Limited operation in a multi-person cockpit. • Lack of formal EASA certification.

Cont. table 1.

Opportunities	• Incorporating VR training as preparation for simulators. • Support prior to Type Rating training. • Development of remote and home training. • Possibility of standardizing learning flows and checklists. • Reducing procedural training costs. • Introducing VR as a tool for self-preparation before flight.
Threats	• Lack of formal regulations and EASA recognition of VR. • Risk of developing bad habits due to poor-quality models. • Rapid obsolescence of VR equipment and the need for frequent updates. • Training effectiveness depends on the quality of hardware and software. • Possible instructor reluctance to adopt new methods. • Risk of over-reliance on simulation at the expense of real-world experience.

An analysis of its strengths indicates that virtual reality can be a modern and interactive tool supporting pilot training. It enables realistic representations of the cockpit, procedures, and checklists. VR also allows a user to repeat tasks many times in safe conditions. Users can practice various scenarios without the risk of an aircraft accident. This allows pilots to practice both basic procedures and complex emergency scenarios. Such VR sessions are without risk. The high level of immersion increases trainee engagement. VR offer also progress monitoring and instant feedback. Such elements enhance the quality of the learning process. VR is also becoming a tool independent of weather, aircraft availability, or training center schedules.

The weaknesses of VR indicate the need for careful implementation of this technology in pilot training. The most significant limitation is the lack of a realistic representation of kinesthetic sensations (which play a crucial role in aviation). VR can help with scenario practice, but the technology isn't yet developed enough to fully replicate all the technical requirements and realistic sensations – equal to a real flight. Furthermore, VR can cause side effects for some people. These include nausea, dizziness, eye strain, disorientation, headaches, and many others. This limits the user base. The varying quality of available hardware and software also poses a challenge. Different headsets and applications can have different quality and level of realism. Crew synchronization issues may arise in multi-person training sessions. Also, the lack of formal EASA certification for VR means this technology cannot yet replace traditional training methods.

VR development in aviation is also an opportunity. Virtual reality can serve as a preparatory stage before training on advanced simulators or before starting a Type Rating course. This allows for a more balanced knowledge level among students and accelerates the learning process. The technology also facilitates the development of remote learning options. VR applications can be played even at home. This can reduce training costs. Another significant opportunity is the possibility of standardizing the learning of procedures, checklists, and flows, which will facilitate the alignment of competencies between different training centers. VR could become a popular tool for self-preparation before a flight, increasing pilots' efficiency.

Using VR is pose also many risks. The risks associated with the use of VR stem primarily from formal and technological issues. The first one is the lack of official regulations and EASA recognition of VR. This currently prevents this technology from playing a full role in the training process. Lack of recognition its potential limits its wide-scale implementation. There is also the risk of developing inappropriate habits if VR models or procedures are inaccurate or outdated. Rapid technological advances mean that equipment can quickly become outdated. This technology (including, first of all, VR applications' quality) requires frequent upgrades. Furthermore, the effectiveness of training depends on the quality of the software, and the reluctance of some instructors to use new methods may delay the adoption of this technology. Overreliance on VR could also reduce the emphasis on gaining experience in real-world conditions, which remains crucial to a pilot's work.

6. Discussion

The results obtained in the above study show that virtual reality technology is perceived by the aviation community as a tool supporting procedural training. Pilot training clearly stands out among the applications of virtual reality. The results show consistency with pilot training procedures, which are mostly based on procedural knowledge, familiarity with the cockpit layout, and standard and non-standard operating procedures. These elements can be effectively utilized by an artificial training environment based on VR technology.

The helpful application of VR is confirmed by a high percentage of respondents who perceive virtual reality as a tool for familiarizing themselves with the cockpit, procedures and checklists, rather than as a replacement for a certified simulator or a real aircraft.

The VR analysis shows the greatest interest among respondents in the early stages of training, such as PPL(A) and Type Rating. During these stages of training, pilots must acquire as much knowledge as possible in the shortest possible time, often before entering the cockpit. Analyzing the respondents' answers, it can be concluded that VR seems to fill the gap by providing an unlimited number of repetitions in an environment that replicates the real cockpit.

Lower ratings for IFR, MCC and UPRT training do not indicate that VR is not useful in these areas. Instrument Flight Rules training requires precise interpretation of instruments and high fidelity flight dynamics, which are best provided by certified simulators. MCC training, on the other hand, is based primarily on real-time crew cooperation between two pilots. These results only emphasize that VR can currently be used as a supplement to training rather than a tool that completely replaces traditional flight training.

Compared to existing literature on the subject, an important contribution of this study is the clear distinction between training stages and training objectives. Most studies present VR as a training innovation. In our research, we demonstrate the application of this technology,

especially for selected training stages. The strong preference for VR in the PPL(A) and Type Rating stages indicates that VR may be most effective when used to build basic procedural competencies rather than advanced operational decision-making skills.

From a practical point of view, the results suggest several important conclusions for training centers. Firstly, VR can become a key tool in preparing for simulator sessions. In this way, the technology can ensure that trainees arrive at FNPT, FTD or FFS sessions with a higher level of procedural readiness. This solution can reduce training time and the costs associated with extended training. The use of VR can also standardize the initial knowledge level of students.

The SWOT analysis further confirms these conclusions, highlighting the strengths of VR. These include cost-effectiveness, flexibility and security. Weaknesses include aspects related to technological limitations and lack of certification. Opportunities include the potential for rapid development of VR equipment and growing acceptance in the aviation community, while threats include regulatory constraints. These factors should be carefully considered when planning the implementation of VR-based training solutions.

The research conducted for the article has its limitations. The survey was conducted among a relatively small group of 30 respondents. In addition, the sample consisted mainly of pilots who had completed ATPL training and active first officers, which may affect the perception of the usefulness of VR compared to student pilots or instructors. The study was also based on the opinions reported by the respondents themselves rather than on objective measurements of results, which means that the results reflect the perceived rather than the measured effectiveness of the training.

Future research should focus on larger and more diverse groups of respondents. It should include instructors, examiners, and training managers. Experimental studies comparing groups of students who have undergone training using VR technology and those who have not would also be an important analysis. In addition, research on multi-user VR environments could help overcome barriers at training stages such as MCC.

Overall, the discussion confirms that virtual reality has significant potential as an auxiliary training tool. Combining this technology with current training methods can significantly improve procedural readiness and contribute to a more effective learning process.

7. Summary

This article discusses the topic of the use of virtual reality in aviation. The article presents the areas in which virtual reality has the potential to be used. The focus is especially on the area of pilot training. Survey research and a SWOT analysis were conducted for this area. The identified areas of VR application demonstrate the wide range of possibilities offered by this technology in aviation. A key area remains pilot training, where VR allows for safe and

repeatable practice of procedures, increased cockpit awareness, and preparation for advanced simulator sessions. Analysis of the surveys confirms that this technology is viewed positively by the aviation community and that its implementation can bring educational and operational benefits.

The survey results confirm that pilots perceive VR as a valuable tool supporting the learning of procedures and cockpit familiarization. VR provides the greatest benefit during the preparation phase for practical training and simulator sessions, particularly in the areas of flows and checklists. Respondents also indicated VR's high usefulness in practicing basic emergency scenarios. Although VR will not replace certified simulators in the near future, it can significantly improve pilot preparation and reduce the costs of procedural training.

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References

1. Bagassi, S., Corsi, M., De Crescenzio, F., Santarelli, R., Simonetti, A., Moens, L., Terenzi, M. (2024). Virtual/augmented reality-based human–machine interface and interaction modes in airport control towers. *Sci. Rep., 14*.
2. Bayro, A., McGarry, S., Nesmith, R., Coyne, J.T., Jeong, H. (2025). *ASANA: A VR-Based Simulation for Assessing Spatial Ability and Situational Awareness in Naval Aviation*. Proceedings - 2025 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops, VRW 2025. pp. 1095-1100.
3. Colaw, C.L., Madison, G., Tseng, B., Griser, G.M., Truelson, G., Gallo, A., Hurmuzlu, Y. (2025). Methodology for Enablement of Human Digital Twins for Quality Assurance in the Aerospace Manufacturing Domain. *Sensors, 25*.
4. Collet, A.-C., Drouot, S., Nemmi, F., Aujeu, E., Buratto, F., Bach, C. (2025). Effects of a VR-based procedure trainer on vision and cybersickness in senior airline pilots. *Cogn. Technol. Work*.
5. Ćosić, K., Kopilaš, V., Jovanović, T. (2025). Importance of mental readiness in highly stressful professions. *Psychiatr. Danub., 37*, 132-140.
6. Dodoo, J.E., Al-Samarraie, H., Alzahrani, A.I., Tang, T. (2025). XR and Workers' safety

in High-Risk Industries: A comprehensive review. *Saf. Sci., 185*.

7. Epp, R., Lin, D., Bezemer, C.-P. (2021). An empirical study of trends of popular virtual reality games and their complaints. *IEEE Trans. Games 13*, 275-286.
8. Fagernäs, S., Hamilton, W., Espinoza, N., Miloff, A., Carlbring, P., Lindner, P. (2021). What do users think about Virtual Reality relaxation applications? A mixed methods study of online user reviews using natural language processing. *Internet Interv., 24*, 100370.
9. Haj-Bolouri, A., Katende, J., Rossi, M. (2024). Gamified immersive safety training in virtual reality: a mixed methods approach. *J. Work. Learn*.
10. Henriques, A.C., Winkler, I. (2021). The Advancement of Virtual Reality in Automotive Market Research: Challenges and Opportunities. *Appl. Sci*.
11. Jayasree, A., Gayatri, T., Vaishnavi, L., Anjana Jyothi, N.V.S.K., Pujitha, M., Siddique Ibrahim, S.P. (2025). *Investing in the Virtual World: Why Digital Twins Are the Next Big Opportunity*. Proceedings of 2025 International Conference on Emerging Technologies in Computing and Communication, ETCC 2025.
12. Jung, T., tom Dieck, M.C., Lee, H., Chung, N. (2016). *Effects of virtual reality and augmented reality on visitor experiences in museum*. Information and Communication Technologies in Tourism 2016: Proceedings of the International Conference in Bilbao, Spain, February 2-5, 2016. Springer, pp. 621-635.
13. Kangas, J., Kumar, S.K., Mehtonen, H., Järnstedt, J., Raisamo, R. (2022). Trade-off between task accuracy, task completion time and naturalness for direct object manipulation in virtual reality. *Multimodal Technol. Interact., 6*, 6.
14. Kim, S., Kang, Y., Lazaro, M.J. (2025). Development and validation of spatial disorientation scenarios using virtual reality and motion simulator. *Appl. Ergon., 125*.
15. Kimura, S., Zintl, M., Hammann, C., Holzapfel, F. (2024). *Simulator-based Mixed Reality eVTOL Pilot Training: The Instructor Operator Station*. Conference on Human Factors in Computing Systems - Proceedings.
16. Kontogiorgakis, E., Zidianakis, E., Kontaki, E., Partarakis, N., Manoli, C., Ntoa, S., Stephanidis, C. (2024). Gamified VR Storytelling for Cultural Tourism Using 3D Reconstructions, Virtual Humans, and 360° Videos. *Technologies*.
17. Larkin, E., Van Benthem, K., Bierlaire, A., Othman, R., Herdman, C.M. (2025). A Comparison of Pilot Situation Awareness in Virtual Reality Flight Simulation and an Online Cognitive Health Screening Tool. *Communications in Computer and Information Science,* pp. 35-45.
18. Malmquist, S., Vincenzi, D.A., Pruchnicki, S., Lemos, K.A. (2025). *Training and Simulation: Processes, Challenges and Solutions, Training and Simulation: Processes, Challenges and Solutions*.
19. McCullins, M.E., Hampton, S., Fussell, S.G., Kiernan, K., Thropp, J. (2025). The effectiveness of using virtual reality training environments for procedural training in fourth-generation airliners. *Aeronaut. J.*

20. Norris, M.W., Spicer, K., Byrd, T. (2019). Virtual reality: the new pathway for effective safety training. *Prof. Saf., 64,* 36-39.
21. Patrick, R.N.C., Lee, T., Desmit, Z., Carter, N. (2025). An Iterative Design Method for Advancing Air Traffic Control and Management Training Through Immersive VFR 3D Map Visualization. *IISE Trans. Occup. Ergon. Hum. Factors, 13*, 109-121.
22. Ren, B., Gao, Y., Gu, Z., Liu, P., Xiong, J. (2024). *Intelligent Equipment Scenario for Aviation Maintenance VR System based on Digital Twin Model*. Proceedings - 2024 5th International Conference on Mobile Computing and Sustainable Informatics, ICMCSI 2024. pp. 427-433.
23. Scorgie, D., Feng, Z., Paes, D., Parisi, F., Yiu, T.W., Lovreglio, R. (2024). Virtual reality for safety training: A systematic literature review and meta-analysis. *Saf. Sci., 171*.
24. Somerville, A., Joiner, K., Lynar, T., Wild, G. (2025). Applications of extended reality in pilot flight simulator training: a systematic review with meta-analysis. *Vis. Comput. Ind. Biomed. Art 8*.
25. Stecuła, K. (2022). Virtual Reality Applications Market Analysis—On the Example of Steam Digital Platform. *Informatics, 9*, 100.
26. Stecuła, K., Pradela, J. (2024). Virtual Reality in language education in the context of technology development. *Lang. Technol. Humanit. Soc. 5.0, 11,* 205.
27. Thijssen, D., van Pelt, D., van Benthem, G.J., Zwaan, S., Petermeijer, B., van der Pal, J. (2025). Exploring the integration of live, virtual, and constructive environments in fighter pilot training through Link-16: lessons learned regarding training aspects. *J. Def. Model. Simul., 22*, 529-542.
28. Van Wyk, E., De Villiers, R. (2009). *Virtual reality training applications for the mining industry*. Proceedings of the 6th International Conference on Computer Graphics, Virtual Reality, Visualisation and Interaction in Africa, pp. 53-63.
29. Wild, G., Nanyonga, A., Iqbal, A., Bano, S., Somerville, A., Pollock, L. (2025). Lightweight and mobile artificial intelligence and immersive technologies in aviation. *Vis. Comput. Ind. Biomed., Art 8*.
30. Yeung, A.W.K., Tosevska, A., Klager, E., Eibensteiner, F., Laxar, D., Stoyanov, J., Glisic, M., Zeiner, S., Kulnik, S.T., Crutzen, R. (2021). Virtual and augmented reality applications in medicine: analysis of the scientific literature. *J. Med. Internet Res., 23*, e25499.
31. Zhu, H. (2025). *Innovative visualizations in aviation safety training leveraging artificial data for educational advancement.* Proceedings of SPIE - The International Society for Optical Engineering.

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MANAGEMENT OF ENERGY TECHNOLOGY SELECTION FOR STRENGTHENING POLAND'S ENERGY SECURITY

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Purpose: The objective of the present paper is to evaluate the energy technologies available and planned for implementation in Poland. This evaluation is conducted in the context of ensuring energy security (in the terminology used in the power sector: security of supply), the resilience of the power system, and compliance with political requirements.
Design/methodology/approach: The research methods employed encompass statistical data analysis, technological parameter assessment, cost analysis, emission indicators, installation lifetime, and energy transition scenarios. The presentation included an exposition of technological and political risk models, alongside comparative analyses of their various iterations.
Findings: The most significant element in enhancing Poland's energy security is to preserve the current technological mix and to incorporate high-power nuclear energy into it. The analysis demonstrated that the predominance of a particular technological approach was associated with an escalation in energy risk.
Research limitations/implications: The study is constrained by the long-term uncertainty of the regulatory environment, the absence of comprehensive data for new technologies, and the significant influence of political decisions.
Practical implications: The findings of the study have the potential to inform national energy policy, operator strategies, infrastructure development planning, enhanced decision-making processes by energy companies, and the formulation of national research and development programs.
Social implications: The energy transition is effecting profound changes to the structure of the energy sector, with consequences for the labor market and the development of local communities. It is imperative to furnish the public with reliable information regarding the planned changes and their effects on energy prices.
Originality/value: The paper integrates the results of technical analysis with strategic assessment and long-term energy development scenarios. The consideration of system resilience and political risks is also a factor in the overall assessment.
Keywords: security of supply, generation mix, generation technologies, energy transition, power sector management.
Category of the paper: Research paper.

1. Introduction

Energy security is a pivotal aspect of the functioning of industrialized countries, serving as a cornerstone of economic and social stability. In contemporary terms, this concept is not limited solely to ensuring the continuity of electricity supply, but also includes the resilience of energy infrastructure to geopolitical, economic, technological, and environmental disruptions. The extant literature on the subject increasingly emphasizes that energy security should be analyzed in systemic terms, taking into account both the supply and demand sides of the energy market (Schmitz et al., 2025).

In recent years, the definition of energy security has expanded significantly. In addition to the traditionally understood security of supply, key categories now include the system's resilience to various types of disruptions and physical and cyber attacks, flexibility of its operation in conditions of demand volatility and the use of weather-dependent sources, and adaptive capacity, i.e. the ability to respond to technological, regulatory and market changes. In the power sector, resilience is understood as an element of security of supply alongside power system reliability, consisting of grid and generation adequacy and operational security. The issue of diversifying domestic fuel and energy sources, and reducing dependence on imports of energy raw materials, such as gas, is also of particular importance. In the context of geopolitical tensions, this issue should become one of the priorities of state policy (Brown et al., 2018).

The present status of energy policy in Poland is such that the nation is undergoing a transformation of its energy sector. It is evident that the execution of this process has been undertaken in close conjunction with the European Union's energy and climate policy framework. The legislative package entitled "Fit for 55", the European Green Deal, and the reform of the emissions trading system (EU ETS) impose a number of political obligations on member states. These obligations include the requirement to systematically reduce CO_2 emissions and to develop so-called low- and zero-emission technologies. These requirements have a substantial impact on energy costs for the economy and municipal consumers (IEA, 2024).

Concurrently, global trends pertaining to the digitalization of the economy, the electrification of transport, and the automation of industrial processes are precipitating a systematic increase in electricity demand. These phenomena indicate that energy security is acquiring a strategic dimension, and investment decisions in the energy sector have long-term consequences for the competitiveness of the economy and the stability of the state (Schmitz et al., 2025).

The Polish power system continues to rely heavily on hard coal and lignite, which in recent years accounted for approximately two-thirds of domestic electricity production. This model guarantees stability of supply; however, it does not align with the directives and decisions of

EU climate policy. Concurrently, there has been uncontrolled development of renewable energy sources (RES), in particular photovoltaic including-prosumer photovoltaic sources and wind energy, with the observability and controllability of these sources not meeting the current standards in the commercial energy sector (Mrozowska et al., 2021).

Despite the rapid growth of RES, the share of stable, low-emission energy sources remains limited. The inherent variability of wind and solar energy production introduces additional challenges to the balancing of the power system, emphasizing the necessity to develop dispatchable sources, energy storage facilities, and modern grid infrastructure. In this context, the planned development of nuclear energy and technologies supporting system flexibility is of particular importance (Aldeman et al., 2023).

A pivotal component of energy security pertains to the effective management of technology within the energy sector. This concept encompasses the systematic planning, implementation, operation, and gradual phasing out of generation technologies over an extended timeframe. The energy sector is distinguished by the notably protracted life cycle of technical assets, which can span from several decades to even eighty years. Consequently, investment decisions must be made with consideration for not only the present market conditions, but also the future implications of regulatory, technological, and social developments. The management of energy technologies therefore requires a systemic approach that integrates engineering, economic, and strategic aspects (Musango, 2024).

In the context of the energy transition, it is imperative to coordinate the development of stable technologies, such as nuclear energy and high-efficiency coal-fired power plants, with the rapid development of renewable technologies and energy storage systems. Effective technology management also includes the assessment of technological and raw material risks, the ability to adapt network infrastructure, and the use of analytical tools to support decision-making, such as scenario analysis, technology life cycle assessment, and multi-criteria models. In this context, technology management has emerged as a pivotal instrument for implementing national energy policy, facilitating a compromise between security of supply, economic efficiency, and environmental objectives (Saini et al., 2025).

In the context of the aforementioned information, the impetus for this study is the necessity to revise the prevailing energy production model in Poland in the face of evolving geopolitical conditions, including the security crisis in Central and Eastern Europe, and increasingly stringent climate regulations. The decisions currently being made regarding the selection of energy technologies will determine the country's energy security for decades to come (Bani et al., 2025).

The objective of the present study is to preliminarily identify and evaluate energy technologies with the potential to form the future foundation of the Polish power system. In undertaking this task, the following criteria will be given due consideration: system adequacy, investment and operating costs, environmental impact, compliance with European Union policy, and technological and raw material risks. The paper constitutes an element of

a prevailing tendency within research in the domain of engineering management and strategic analysis, with a particular emphasis on the optimal selection of technologies in the context of the resilience of critical national infrastructure.

The subsequent chapters are dedicated to the description of the research methods and techniques utilized (Chapter 2), the presentation of the quantitative and qualitative results obtained (Chapter 3), the discussion of these results (Chapter 4), and the summary of the results and the indication of directions for further research (Chapter 5).

2. Methods

The proprietary research methodology applied in this study is interdisciplinary in nature and was developed to enable a comprehensive assessment of energy technologies with regard to their suitability for ensuring Poland's long-term energy security. The methodology integrates relevant elements presented in the subject literature. The research was based on a combination of qualitative and quantitative methods, which made it possible to account for technical and economic aspects as well as strategic, regulatory, and environmental conditions.

The subsequent steps of the research methodology were as follows:

1. Identification of the research problem.
2. Classification of energy technologies.
3. Selection of technology assessment criteria.
4. Comparative analysis of energy technologies.
5. Scenario analysis of the energy mix development.
6. Synthesis of the obtained results.

The first stage of the methodology involved the identification of the research problem, consisting of defining the concept of energy security from a systemic perspective and identifying the key challenges faced by the Polish power sector. At this stage, geopolitical, regulatory, and technological conditions influencing the need for transformation of the energy mix were taken into account. The research problem was formulated as the need to select such energy technologies that ensure a balance between supply reliability, economic efficiency, and the reduction of environmental impact (Cherp et al., 2014).

In the next step, the identification and classification of energy technologies applicable to the Polish power system were conducted. The analysis covered conventional, low-emission, and renewable technologies, as well as supporting technologies such as energy storage systems. The classification was carried out with regard to the level of commercial technological maturity, the operational characteristics (fully dispatchable and non-dispatchable sources), and the potential role in the power system (IEA, 2023).

Subsequently, a set of criteria for the assessment of energy technologies was developed, encompassing four main areas: technical, economic, environmental, and energy security-related aspects. The selection of criteria was based on a review of the literature and recommendations of international institutions. This approach enabled a multidimensional evaluation of technologies, extending beyond traditional cost-based analyses (Musango, 2017).

The next stage consisted of a comparative analysis of energy technologies based on the previously defined criteria. The analysis considered, among others, investment and operational costs, emission intensity, dispatchability, and the impact on system adequacy. The comparative analysis made it possible to identify the strengths and weaknesses of individual technologies and to assess their suitability in the context of national system conditions (Lund et al., 2017).

An important element of the methodology was scenario analysis, aimed at identifying possible pathways for the development of the energy mix over the long term. The scenarios accounted for different rates of development of renewable energy sources, nuclear power, and energy storage technologies, as well as the variability of CO_2 emission allowance prices and technology costs. Scenario analysis enabled the assessment of the power system's resilience to uncertainty and external risks (Bogdanov et al., 2019).

The final stage of the methodology involved the synthesis of the obtained results and the formulation of observations of both cognitive and practical relevance. Based on the conducted analyses, the technologies that contribute most significantly to enhancing Poland's energy security were identified. This stage allowed for the integration of partial results into coherent aggregated findings (Markard et al., 2012).

3. Results

3.1. Identification of the research problem

The starting point of the research was a multifaceted analysis of the current state of the Polish power sector, which is presently at a critical tipping point. Empirical data confirms that Poland remains one of the few European Union member states that still rely heavily on fossil fuels – specifically hard coal and lignite – for their generation base. These resources, which are domestic in origin, are primarily utilized in large-scale system power plants and combined heat and power (CHP) plants. Consequently, the National Power System (NPS) is characterized by high sensitivity to the volatility of CO_2 emission allowance prices (EU ETS), the long-term dynamics of which are determined by political decisions at the European Union level.

Simultaneously, Poland is experiencing a dynamic expansion of distributed renewable energy sources (RES), with a particular emphasis on photovoltaic installations and onshore wind power. At the same time, strategic projects involving offshore wind farms, low-emission

gas-fired sources, and large-scale electricity storage systems are in the early stages of development. A key component of the future generation structure is the construction of Poland's first nuclear power plant, which is currently in the preparatory phase. However, it must be emphasized that the evolution of the generation base necessitates a radical expansion of the national transmission and distribution networks.

The research problem was identified as the imperative to balance the so-called energy trilemma, which involves simultaneously ensuring security of supply, maintaining the cost competitiveness of electricity, and achieving policy-driven carbon emission reductions. In accordance with the updated National Energy and Climate Plan (NECP, 2024), Poland aims to achieve a high, several dozen percent share of RES in the energy mix by 2040. The analysis demonstrated that the technological barrier is no longer the primary inhibiting factor. Currently, the critical challenge lies in the pace of implementation and the integration of new capacities into the power system. This requires an advanced expansion of both the grid and the Information and Communication Technology (ICT) layers – specifically smart grid systems – necessary to manage distributed and highly weather-dependent energy sources.

Realizing such an ambitious transformation vision requires unprecedented capital expenditures (CAPEX). These cover not only the construction of new RES units but, above all, the costly redevelopment of grid infrastructure. The research shows that energy storage technologies, despite their crucial role in system stabilization, currently remain high-unit-cost solutions, which significantly impacts the total costs of the systemic transformation. Due to the high capital intensity and limited scalability of modern storage systems, it is considered essential to maintain, modernize, and further develop large-scale (centralized) power generation.

Large-scale generation units, including the planned nuclear power plants, will play a fundamental role as system stabilizers, guaranteeing continuity and reliability of supply during periods of reduced generation from renewable sources. This approach allows for the preservation of national energy security from a systemic perspective (Prochacka, 2025). Additional significant research challenges are associated with the decarbonization of the district heating sector and the need to adapt the grid to the dynamically increasing demand generated by electromobility.

3.2. Classification of energy technologies

In the second stage of the research, a detailed inventory and classification of available generation technologies were conducted. The analysis also incorporates the state's capacity to independently secure energy generation and delivery processes to end-users. For this reason, energy technologies can be categorized into two groups (Prochacka, 2025):

1. Technological solutions for which Poland possesses its own raw materials or fuel resources, namely: hard coal, lignite, and RES – primarily solar and wind energy (onshore and offshore).

2. Technologies requiring Poland to import raw materials, specifically: gas-fired power and nuclear energy.

Based on fuel types, according to the methodology proposed in this work, the technologies were divided into three main groups:

1. Conventional technologies (fossil fuels): hard coal and lignite power plants (the current baseload of the system) and combined-cycle gas units, serving as dispatchable (regulatory) sources.
2. Renewable technologies: onshore and offshore wind power, photovoltaics (PV), and, to a significantly lesser extent, hydropower, geothermal, and biomass energy.
3. Nuclear technology: traditional large-scale units – classified as zero-emission sources with high availability, remaining a prospective technology in the Polish context, and Small Modular Reactor (SMR) technologies, which have been under development for an extended period.

The classification accounted for the level of commercial technological maturity. Most technologies in use are at the highest level – commercial application is feasible (coal, gas, large scale nuclear, PV, onshore, and offshore wind). Technologies such as large-scale energy storage or SMRs are treated in the Polish context as implementation-stage technologies of potential strategic importance. Differences in commercial availability and construction lead times for individual technologies determine the possible dynamics of changes in the energy mix.

3.3. Selection of technology assessment criteria

To ensure the objectivity of the analysis, a multi-criteria evaluation model was adopted. The selection of criteria was based on a literature review and operational indicators crucial for the transmission system operator. The main areas of evaluation include:

1. Economic criteria.
2. Technical and operational criteria.
3. Environmental criteria.
4. Security and social criteria.

The basic stages of the life cycle of power generation sources are design, construction, operation, and decommissioning. Each of these stages is associated with a corresponding supply chain. In the energy sector, expenditures on so-called "hard infrastructure" dominate (CAPEX). These include outlays for land acquisition for construction, purchase of equipment, construction and assembly costs, and grid connection costs. On the other hand, operating expenditures (OPEX) in energy consist of fuel costs, service and maintenance, repairs, technical inspections, parts replacement, wages, taxes, and fees. An additional quasi-tax is the cost of CO_2 emission allowances. The indicator that provides the basis for comparing different technologies is the LCOE (Levelized Cost of Electricity). LCOE is the total cost of building and operating an energy installation, calculated for each unit of energy produced (typically 1 MWh) over its

entire life cycle. However, LCOE does not take into account system management costs, including balancing and ancillary services or the costs of expanding the power grid.

An essential element of the evaluation was the analysis of technical parameters that determine the stability and reliability of the power system's operation, specifically the technical and operational criteria. A key indicator is the net efficiency, which defines the effectiveness of converting primary energy (fuel) into electricity delivered to the grid. An equally important parameter is the Capacity Factor, reflecting the real degree of unit utilization throughout the year. In an era of increasing shares of unstable RES, the flexibility of units – defined as the ability to rapidly increase or decrease generated power in response to fluctuations in demand and supply – becomes of critical importance.

Environmental criteria, which directly result from the European Union's climate policy goals, can also be utilized in the process of evaluating energy technologies. The primary indicator analyzed is the specific CO_2 intensity. Environmental criteria also include emissions of other pollutants, such as sulfur oxides (SO_2), nitrogen oxides (NO_X), and particulate matter, which significantly affect local air quality. An important, though often overlooked, aspect is land use requirements and the impact on ecosystems – in this context, RES technologies, such as wind or solar farms, require significantly larger areas per unit of installed capacity than centralized nuclear or coal units.

The final group consists of system security criteria and social conditions, which, in the Polish context, determine the feasibility of implementing specific technologies. Key importance was attributed to the dispatchability of supply, understood as the unit's ability to operate independently of external factors. Equally significant is the level of social acceptance, which is becoming a critical barrier for many investments. In this case, attention should be paid to the so-called NIMBY (Not In My Backyard) effect, particularly regarding onshore wind farms and the planned locations for nuclear power plants.

3.4. Comparative analysis of energy technologies

In the fourth step, a direct comparison of the selected technologies was conducted based on the chosen indicators. Within the economic criteria, this was the LCOE. The comparison results for the main technologies are presented in Table 1.

Table 1.
Selected economic parameters

No.	Technology	LCOE [USD/MWh] with CO_2 costs	LCOE [USD/MWh] without CO_2 costs
1.	Coal power plants	90-140	45-85
2.	Gas power plants	80-120	50-80
3.	Nuclear power plants	N/A	70-130
4.	Hydroelectric power plants	N/A	100-160
5.	Solar power plants	N/A	35-55
6.	Onshore wind farms	N/A	30-45
7.	Offshore wind farms	N/A	75-95

Source: authors' own elaboration based on (IRENA, 2025; NREL, 2024).

Unit costs for conventional power plants assume high capacity utilization (baseload operation). Under lower utilization factors, unit costs may significantly exceed the presented ranges due to the distribution of fixed costs. The comparison of average levelized costs of electricity (LCOE) reveals significant economic disparities among the analyzed technologies, primarily driven by emission-related charges and the specific structure of capital expenditures. In the case of renewable energy technologies (onshore wind and photovoltaics), despite exhibiting the lowest LCOE values, investment costs are largely front-loaded, with the vast majority of expenditures incurred during the construction phase. A different cost structure characterizes gas-fired power generation, which features relatively low capital expenditures (CAPEX) but a high sensitivity to variable costs, particularly fuel prices. Nuclear power and offshore wind energy, in turn, are associated with very high entry costs and substantial upfront investment requirements. For coal-fired power plants, capital expenditures for new units are currently subject to the highest financial risk, largely due to the necessity of incorporating high emission-related costs into project budgets.

Among the technical and operational criteria presented in Table 2, the comparison focuses on plant lifetime and the annual number of operating hours.

Table 2.
Selected technical and operational parameters

No.	Technology	Operational lifetime [years]	Availability Factor [h]	Relative Availability Factor [%]
1.	Coal power plants	40	7000	79,91
2.	Gas power plants	30	7000	79,91
3.	Nuclear power plants	60	8000	91,32
4.	Hydroelectric power plants	80	4000	45,66
5.	Solar power plants	25	900	10,27
6.	Onshore wind farms	25	2300	26,26
7.	Offshore wind farms	25	3100	35,39

Source: authors' own elaboration based on (Prochacka, 2025).

The Availability Factor parameter determines the technical availability of power, not the actual time of power utilization (Utilization Factor), which is significantly lower for renewable energy sources. The presented data indicate significant differentiation among technologies in terms of infrastructure lifetime and their availability within the power system. Hydropower plants (80 years) and nuclear power plants (60 years) exhibit the longest lifetimes, which, combined with the very high capacity factor of nuclear energy, defines these sources as the backbone of stable -generation. In contrast, renewable energy technologies such as photovoltaics and wind power are characterized by shorter lifecycles and substantially lower annual operating hours, resulting from their dependence on weather conditions.

From a technical perspective, a key distinction is made between weather-dependent generation sources and dispatchable (controllable) units, which include only coal-, gas-, and nuclear-fired power plants. Unlike the intermittent generation from wind farms or photovoltaic installations, these technologies offer full controllability, allowing the system operator to precisely adjust electricity production to current demand levels.

Among the environmental criteria, land-use requirements for the construction of generation facilities were selected for comparison. The results are presented in Table 3.

Table 3.
Selected environmental parameters

No.	Technology	Land use per MWh per year
1.	Coal power plants	11-23
2.	Gas power plants	0,2-1,3
3.	Nuclear power plants	0,1-0,5
4.	Hydroelectric power plants	24-40
5.	Solar power plants	1,1-35
6.	Onshore wind farms	8,4-247
7.	Offshore wind farms	N/A

Source: authors' own elaboration based on (Ritchie, 2025).

The analysis of the environmental criterion regarding land use reveals drastic differences in the energy density of individual sources. Nuclear and gas power plants exhibit the highest spatial efficiency. Within the category of conventional sources, coal power plants show a significantly higher demand for land, which is associated with extensive infrastructure for fuel storage and mining waste. Particular attention should be paid to the results for renewable technologies, which are characterized by the largest data dispersion. Solar power plants require a moderate amount of land, whereas onshore wind energy shows extremely high upper-end requirements. Such high values for wind result from the necessity of maintaining large buffer zones between turbines, although it should be noted that this land can often be co-used for agricultural purposes. Offshore wind energy does not occupy any land area, which constitutes a significant advantage in countries with limited availability of free investment sites. However, it should be remembered that occupying water areas limits their use for other purposes. In future studies, the catalog of environmental indicators should be expanded to include other parameters, such as the carbon footprint of component production and the demand for critical raw materials, which will allow for a more complete assessment of the ecological cost of the transition.

Among the security and social criteria, the dispatchability of supply – understood as the unit's ability to operate independently of external factors – was selected for comparison. The results are presented in Table 4.

Table 4.
Selected security and social parameters

No.	Technology	Dispatchability level	Reliance on external factors
1.	Coal power plants	Very high	Negligible
2.	Gas power plants	Very high	Moderate (fuel)
3.	Nuclear power plants	Very high	Negligible
4.	Hydroelectric power plants	High	Moderate (hydrological conditions)
5.	Solar power plants	Low	Total (weather-dependent)
6.	Onshore wind farms	Low	Total (weather-dependent)
7.	Offshore wind farms	Low	Total (weather-dependent)

Source: authors' own elaboration based on (Prochacka, 2025).

Table 4 highlights the particularly low dispatchability of solar power plants and wind farms compared to the reliable operation of coal and gas units. This underscores the structural necessity of maintaining dispatchable units or expanding energy storage capacity to balance the system during periods lacking weather-dependent generation.

The analysis of dispatchability must be considered alongside fuel security, which alters the strategic assessment of individual sources. Hard coal and lignite remains the only sources fully based on domestic resources, guaranteeing the highest degree of sovereignty in crisis situations. Nuclear power, despite the necessity of fuel imports, offers a high level of strategic security – the small volume of fuel rods allows for the accumulation of reserves sufficient for several years of plant operation, making the system resilient to sudden disruptions in supply chains. For simplicity, the distinction between run-of-river, reservoir, and pumped storage hydroelectric power plants has been omitted. Low dispatchability level should be understood as none, unless combined with storage.

The situation for gas power is entirely different. Due to the lack of significant domestic resources and the difficulties in storing gas quantities sufficient for long-term power generation purposes, this technology exhibits the highest sensitivity to geopolitical factors and price fluctuations on global markets. Further analysis requires consideration of additional socio-economic aspects, in particular the degree of control over technology supply chains, the potential for involvement of domestic industry (so-called local content), and the impact of investment location on the labor market and public acceptance.

3.5. Scenario analysis of the energy mix development

Based on the methodology proposed in the study (Prochacka, 2025) and the results discussed in the previous section, three scenarios for the transformation of the Polish energy sector have been proposed:

1. Continuation Scenario (Business as Usual – BAU).
2. Radical RES Scenario (Green Transition).
3. Balanced Scenario (Nuclear-RES Mix).

The Continuation Scenario assumes maintaining the dominant role of hard coal and lignite as primary sources, with a moderate increase in the share of RES. Utilizing existing domestic resources ensures high fuel sovereignty and high security; however, it generates the highest systemic costs regarding the LCOE indicator when including CO_2. High emissions and potentially low acceptance from parts of society make this variant difficult to accept from a political perspective.

The Radical RES Scenario assumes maximizing the share of photovoltaics and wind energy (onshore and offshore) with the total phase-out of coal and not building nuclear power. Its advantages include low unit costs of energy production and political acceptance. The drawbacks are the highest land-use requirements and critically low source dispatchability. This scenario would require building massive capacity in gas-fired power plants as a backup,

which in turn increases dependence on fuel imports. Alternatively, building massive energy storage capacity would be necessary, which would radically increase energy costs for the economy. Based on an analysis of the forecasts contained in (NECP, 2024), maintaining stability with such a generation profile would require, in Polish conditions, at least several GW of reserve capacity in gas sources. In addition, it would also be necessary to implement at least several GW of energy storage facilities with an operating time of at least 4-6 hours. Without such a profound, costly, and addictive infrastructure modernization, it would not be possible to ensure the security of supply, and the levels of forced curtailment of RES generation could reach from several to several dozen percent of annual production, which would drastically reduce the profitability of investments and the efficiency of RES use.

The Balanced Scenario assumes stable nuclear generation alongside the development of offshore wind and photovoltaics. Nuclear power provides stable base-load operation, replacing decommissioned coal units. At the same time, it allows for the role of gas to be limited exclusively to balancing functions, which minimizes geopolitical risks associated with raw material imports. This variant optimizes the energy trilemma: costs, security, and ecology (Prochacka, 2025). In practice, such effects result from the diversification of the national energy mix (nuclear energy, RES, regulatory gas sources or storage, and fuel-secure coal sources).

3.6. Synthesis of the obtained results

The synthesis of the collected technical-economic data and the scenario analysis allows for the formulation of the following findings:

Unit Economic Efficiency vs. Systemic Costs. The results indicate a cost dualism. Although RES technologies offer the lowest LCOE, their integration in the "Radical RES" scenario generates high indirect costs stemming from the necessity of building backup capacity in gas or capital-intensive energy storage. Significant expansion of the power grid, control systems, and ensuring cybersecurity are also required. Conversely, the "Continuation" scenario exhibits the highest direct costs due to the burden of CO_2 emission fees on coal. It should be emphasized that RES do not offer the same product as dispatchable sources, because RES offer energy only at selected times depending on weather conditions, while dispatchable sources offer energy on demand.

Spatial and Environmental Optimization. There is a strong negative correlation between the degree of dispatchability and land use. Stable technologies (nuclear, gas) require minimal area, whereas low-dispatchability technologies (wind, solar) require areas tens to hundreds of times larger. The synthesis indicates that the "Balanced Scenario" best resolves land-use conflicts by utilizing the high power density of nuclear energy.

Security and Energy Sovereignty. The analysis showed that fuel sovereignty is highest in the case of coal (domestic resources) and nuclear (the possibility of long-term fuel storage). A scenario based exclusively on RES, despite no fuel requirement, paradoxically increases geopolitical risks due to the need to balance the system with imported natural gas.

Balancing the Energy Trilemma. A comparison of the scenarios proves that only the "Balanced Scenario" (a nuclear-RES-gas/coal mix) allows for the simultaneous achievement of three strategic goals: emission reduction (a political goal referred to as ecological), maintaining security of supply through dispatchable sources and guaranteed fuel availability (the security goal), and avoiding extreme energy storage costs and risks associated with gas price volatility (the economic goal).

4. Discussion

The results of this analysis cast new light on the structural and systemic challenges facing the Polish power system amidst advancing decarbonization. Particularly significant is the distinction between the unit Levelized Cost of Electricity (LCOE) and the total cost of power system operation, which also includes the costs of balancing, power reserves, grid expansion, and maintaining security of supply. With high shares of RES in the mix, actual costs can be substantially higher than LCOE would suggest. The lack of constant RES dispatchability necessitates investment in backup sources and storage. In public debate and some policy analyses, this distinction is often overlooked, leading to oversimplified conclusions regarding the competitiveness of individual technologies.

The low dispatchability (regulatability) and high variability of RES production, particularly evident in photovoltaics, significantly limit or even eliminate their ability to contribute to ensuring the country's energy security. Weather-dependent sources are unable to serve as a stable foundation for the power system without the mass deployment of energy storage technologies or support from dispatchable sources – currently coal-fired, and in the future, gas-fired as well.

The analysis confirms the economic necessity of moving away from coal as the base of the national energy mix if CO_2 emission costs in the EU ETS system are included in the energy price. Poland, characterized by one of the highest emission intensity rates in the European Union, is also particularly vulnerable to fluctuations in emission allowance prices. Consequently, energy sovereignty understood as possessing one's own fuel resources becomes, in a sense, an economic trap, causing funds collected as CO_2 emission costs to flow from the energy sector to other sectors via the state budget (in part), in accordance with political decisions, and to the EU ETS system (in part – currently at least several billion PLN). On balance, from participation in the EU ETS system alone, Poland therefore loses significant amounts of money. This implies that the reasons for this state of affairs are purely political in origin and are unrelated to the operational efficiency of the power sector.

These conditions necessitate a redefinition of the concept of energy security: from a model based on raw material availability to a model based on access to advanced low-emission generation technologies with high power density. In this context, the discussed balanced scenario, in which nuclear energy serves as the stable pillar of the power system, takes on special significance. The analysis showed that despite high investment outlays, nuclear power plants offer exceptionally high dispatchability and very low land use. Nuclear power plants with Long-Term Operation (LTO) achieve the lowest generation costs among all low-emission technologies. These parameters are crucial not only for security of supply but also for social acceptance.

In the discussion regarding the NIMBY phenomenon, the spatial argument carries particular weight. The construction of a single centralized nuclear power plant, located in a limited area, may prove more socially acceptable than the necessity of installing thousands of wind turbines scattered across large areas of the country, or dozens of SMR plants once that technology reaches commercial maturity. This aspect is often marginalized in purely cost-based analyses, despite being a significant barrier to RES development in practice.

The radical RES scenario, which assumes a mix based almost entirely on renewable sources, also requires critical reflection. Poland's specific climatic conditions – including low solar irradiation in winter and seasonal wind variability – mean that a lack of nuclear energy would have to be compensated for by a significant increase in capacity from gas-fired power plants. Excessive reliance on a single source of uncertain raw materials is difficult to accept. Dependence on gas increases the system's vulnerability to price spikes and regulatory changes (CO_2 allowance prices). Furthermore, burning gas still generates CO_2 emissions, and its extraction process can cause methane leaks – a potent greenhouse gas. This leads to a transformation paradox: in striving for decarbonization, the system becomes increasingly dependent on natural gas imports, which increases risks to national energy security in the context of an unstable geopolitical situation. Natural gas, despite its flexibility and relatively lower emission intensity, should serve as a transition and regulatory fuel rather than a long-term foundation of the energy mix.

The considerations are supplemented by an analysis of the sensitivity of key parameters, which allows the resilience of individual scenarios to market volatility to be determined. The most critical factor for the continuation scenario remains the volatility of CO_2 emission allowance prices in the EU ETS system, which directly determines the costs of production in coal-fired units and may transform fuel sovereignty into an "economic trap." In turn, the radical RES scenario shows the highest sensitivity to fluctuations in natural gas prices on global markets and to the rate of decline in energy storage technology costs (learning curves), as the lack of a stable basis forces the use of fossil fuels as a necessary system backup. In the case of nuclear energy, which is a pillar of the sustainable scenario, the key parameters of uncertainty are the cost of capital (WACC) and the risk of exceeding the budget during the construction phase (CAPEX), but once operational, these units offer the lowest and most predictable

generation costs in long-term operation. Taking the above uncertainties into account confirms that diversifying the mix within the sustainable scenario best mitigates the risks arising from the unpredictability of commodity markets and climate policy, providing the best response to the energy trilemma. Consequently, the energy mix must be balanced. Strategic discussion should not focus on a dichotomous choice of "RES or Nuclear", but on determining the correct proportions between technologies. Synergy between low LCOE but unstable renewable sources and nuclear energy – which is costly to build but stable and spatially efficient – allows for maintaining acceptable energy prices for industry and households. This combination of technologies allows for the limitation of total system costs while ensuring continuity of supply amid variable RES shares. As a result, the energy transition appears not as a purely technological process, but as a multidimensional optimization of the energy trilemma, in which security of supply, the politicization of climate, and economic competitiveness must be treated as equals.

5. Conclusions

As part of this paper, a comprehensive comparative analysis of generation technologies in the Polish energy sector was conducted, based on a multi-criteria synthesis of economic, technical, environmental, and security indicators. Utilizing an original methodology, three transformation scenarios were evaluated: continuation, radical RES, and balanced, which allowed for the identification of a desirable energy mix capable of meeting the needs of the national economy. By integrating factual data with security analysis, directions for further transformation planning were formulated, demonstrating the synergy between nuclear energy and renewable energy sources. Thus, the analyses carried out have made it possible to identify the desired direction of transformation, although it should be noted that the ultimate effectiveness of the selected scenarios will depend, among other things, on the dynamics of CO_2 emission allowance costs and the pace of commercialization of energy storage technologies.

The scientific value of the paper and the proposed methodology lies in a holistic approach to the energy trilemma, extending beyond the standard framework of purely cost-based analysis. In relation to previous studies, which often focus in isolation on the LCOE indicator or exclusively on climate aspects, this work introduces a link between technical dispatchability, energy density, and fuel sovereignty. Such an approach allows for more precise modeling of real systemic costs, representing a significant contribution to the development of energy economics theory under the conditions of transforming mono-technological systems into diversified systems.

The utilitarian value of the paper is reflected in the possibility of its direct use by the management of energy companies, market analysts, and government administration bodies responsible for shaping the state's energy policy. The presented syntheses of technical-economic parameters can serve as a ready-made tool supporting decision-making processes regarding investment portfolio selection and risk assessment related to raw material availability. Demonstrating the high spatial efficiency of nuclear energy can be utilized in educational campaigns aimed at increasing social acceptance for large-scale energy investments.

Despite the broad scope of the analysis, there are certain limitations in the application of the presented results, primarily resulting from the high dynamics of market variables. The study did not include a detailed account of the costs of modernizing transmission and distribution networks, which, in the case of the radical RES scenario, may significantly affect the final energy price for the end consumer. Furthermore, the analysis does not account for the volatility of the weighted average cost of capital (WACC) over time, which, in the case of long-term investments such as nuclear power plants, may modify the final LCOE indicator. The analysis also does not consider potential technological breakthroughs in the field of commercial long-cycle energy storage.

Future research directions should focus on three levels. Researchers should strive to develop power system models that account for real-time system balancing costs and the impact of digitalization on mix efficiency. For economic practitioners, it will be essential to study the possibilities of sector coupling, which could utilize surpluses from RES. Politicians, on the other hand, should focus on creating stable regulatory frameworks conducive to long-cycle investments, such as nuclear power, while simultaneously developing mechanisms to support local acceptance for fully controllable, weather-independent distributed energy sources.

References

1. Aldeman, M.R., Jo, J.H., Loomis, D.G., Krull, B. (2023). Reduction of solar photovoltaic system output variability with geographical aggregation. *Renewable and Sustainable Energy Transition*, *3*. doi:10.1016/j.rset.2023.100052
2. Bani Ahmad, A., Ooi, C. A., Ali, O., Charin, C., Maharum, S.M.M., Swadi, M., Salem, M. (2025). Renewable integration and energy storage management and conversion in grid systems: A comprehensive review. *Energy Reports*, *Vol. 13,* doi: 10.1016/j.egyr.2025.02.008
3. Bogdanov, D., Farfan, J., Sadovskaia, K., Aghahosseini, A., Child, M., Gulagi, A., Oyewo, A.S., de Castro, G., Breyer, C. (2019). Radical transformation pathway towards sustainable electricity via upwards convergence. *Nature Communications, Vol. 10, Iss. 1, No. 1*, pp. 1-14, doi: 10.1038/s41467-019-08855-1

4. Brown, T., Schlachtberger, D., Kies, A., Schramm, S., Greiner, M. (2018). Synergies of sector coupling and transmission reinforcement in a cost-optimised, highly renewable European energy system. *Energy, Vol. 160*, doi: 10.1016/j.energy.2018.01.001
5. Cherp, A., Jewell, J. (2014). The concept of energy security: Beyond the four As. *Energy Policy, 75,* doi: 10.1016/j.enpol.2013.09.019
6. IEA (2023). *International Energy Agency. World Energy Outlook 2023,* https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf, 30.11.2025.
7. IEA (2024). *International Energy Agency, Energy Technology Perspectives*, https://iea.blob.core.windows.net/assets/34511d5d-8dc8-42a2-8faf-b83606cffced/EnergyTechnologyPerspectives2024.pdf, 30.11.2025.
8. IRENA (2025). Renewable Energy Statistics 2025. *International Renewable Energy Agency*, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2025/Jul/IRENA_DAT_RE_Statistics_2025.pdf, 30.11.2025.
9. Lund, H., Østergaard, P.A., Connolly, D., Mathiesen, B.V. (2017). Smart energy and smart energy systems. *Energy, Vol. 137, Iss. 1, No. 1*, pp. 556-565, doi: 10.1016/j.energy.2017.05.123
10. Markard, J., Raven, R., Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy, Vol. 41, Iss. 6, No. 1*, pp. 955-967, doi: 10.1016/j.respol.2012.02.013
11. Mrozowska, S., Wendt, J.A., Tomaszewski, K. (2021). The Challenges of Poland's Energy Transition. *Energies***,** *14(23)*, 8165. doi:10.3390/en14238165
12. Musango, J.K. (2017). Sustainability of technology-society systems: The case of electricity in South Africa. *Energy Policy, Vol. 105, Iss. 1, No. 1*, pp. 73-86, doi: 10.1016/j.enpol.2017.02.030
13. Musango, J.K. (2024). Energy technology assessment in managing sustainable energy transitions: A bibliometric analysis. *Sustainable Energy Technologies and Assessments***,** *72*. doi:10.1016/j.seta.2024.104021
14. NECP (2024). National Energy and Climate Plan for 2021–2030. *Ministry of Climate and Environment*. https://www.gov.pl/web/klimat/krajowy-plan-na-rzecz-energii-i-klimatu, 30.11.2025.
15. NREL (2024). *2024 Standard Scenarios Report: A U.S. Electricity Sector Outlook*. National Renewable Energy Laboratory. https://docs.nrel.gov/docs/fy25osti/92256.pdf, 30.11.2025.
16. Prochacka, K. (2025). *Selection of energy technologies in the context of Poland's energy security (in Polish).* Master's thesis. Warsaw: Warsaw University of Technology, Faculty of Management.
17. Ritchie, H. (2025). *How does the land use of different electricity sources compare?* OurWorldinData.org. https://archive.ourworldindata.org/20251125-173858/land-use-per-energy-source.html, 30.11.2025.

18. Saini, K., Saini, M., Kumar, A., Saini, D.K. (2025). Performance analysis and optimization in renewable energy systems: a bibliometric review. *Discover Applied Sciences*, *Vol. 7, No. 178,* doi: 10.1007/s42452-025-06585-2
19. Schmitz, R., Flachsbarth, F., Plaga, L.S., Braun, M., Härtel, P. (2025*).* Energy security and resilience: Revisiting concepts and advancing planning perspectives for transforming integrated energy systems*. Energy Policy, Vol. 207,* doi:10.1016/j.enpol.2025.114796

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STRATEGIES FOR DEVELOPING WIM CONTROL INFRASTRUCTURE FROM AN ECONOMIC PERSPECTIVE

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Purpose: The main objective of the study is to evaluate the economic effectiveness of developing a modern control infrastructure in Poland, using the example of an automated weigh-in-motion (WIM) system. Specifically, the paper aims to identify the optimal investment implementation strategy while taking into account the benefits of infrastructure and partly social.
Design/methodology/approach: Based on a review of the literature and data on the investment costs of a potential automatic weighing system for vehicles in motion, a cost-effectiveness analysis was performed using the extended NPV focusing on infrastructure and safety externalities model for various implementation strategies for WIM stations in Poland. The model covered 15 years, for which different installation strategies were examined at different time intervals and at the installation level, taking into account additional potential costs and savings from using the WIM system.
Findings: Implementing a WIM system in Poland, with 300 locations, can be feasible from both an economic and partial social perspective focused on safety and infrastructure. A key factor that influences investment is the timing of the investment. Implementation strategies that generate or distribute WIM station rates over the study period yield significantly lower NPVs than phased implementation strategies (E and F) provide the highest economic efficiency.
Research limitations/implications: The analysis considered only measurable social outcomes, such as reduced road accidents. Other outcomes, such as reduced pollution and noise, were described qualitatively. Further research should also consider these evolving parameters, as well as the legal, technological, and organisational conditions that may impact the system's long-term functioning.
Originality/value: The research shows that the development of the control infrastructure with a modern vehicle weighing system in Poland can bring potential benefits to the country's transport system both economically and socially.
Keywords: automatic vehicle weighing system, WIM, control infrastructure, efficiency of road investments.
Category of the paper: empirical surveys, scientific surveys.

1. Introduction

The development of road infrastructure in Poland, particularly in the context of growing heavy-duty vehicle traffic, requires the implementation of modern control solutions that will enable effective enforcement of regulations concerning the maximum allowed weight of vehicles. Therefore, the development of effective control infrastructure solutions for the identification of overloaded vehicles in road traffic is one of the possible ways to reduce the negative impact of heavy and overloaded vehicles on road durability and road safety (Ghosn, 2010). However, the current selective vehicle weighing control system in Poland is not sufficient to effectively identify all overloaded vehicles travelling on national roads (Ossowski, Burnos, 2015). An effective solution may be to implement the concept of automatic weighing of vehicles in motion. The Weigh-in-Motion (WIM) system responds to these needs by enabling the identification of overloaded vehicles without the need to stop them. The implementation of such a system not only increases the effectiveness of controls but also contributes to reducing road surface degradation and improving road safety (Ryś, Judycki, Jaskuła, 2014).

WIM technology enables continuous monitoring of loads generated by heavy goods vehicles and automatic recording of violations, which contributes to better maintenance of road infrastructure and increased traffic safety (Ryś, Judycki, Jaskuła, 2014). The automatic weighing system for vehicles in motion significantly improves the effectiveness of vehicle weight control by focusing exclusively on identifying suspicious cases (Sujon, Dai, 2021). At the same time, the installation of this type of system involves high investment costs, especially in the initial phase of implementation (Sochoń, Siedlanowska-Chałuda, 2014). However, neglect in this area can result in accelerated infrastructure degradation through faster wear and tear, and thus an increase in road safety risks (Sokołowicz, Przygodzki, 2016). Therefore, the aim of the study was to assess the economic efficiency of the development of modern control infrastructure in Poland using the example of an automatic weigh-in-motion (WIM) system.

2. Literature review

2.1. Impact of heavy vehicle overloads on road infrastructure

Deterioration of the road surface caused by excessive traffic of overloaded heavy-duty vehicles is one of the most serious operational problems of the transport infrastructure. The impact of heavy vehicles on the road surface is well described by the so-called fourth power law, according to which the impact of vehicle axle load on the surface increases exponentially (Cho, Lakatos, 2022). This means that even a slight exceedance of the permissible gross vehicle

weight can lead to a drastic increase in the degree of road surface degradation (Ryguła et al., 2020; Dzienis, Karkowski, 2010). An OECD report (2011) also confirms that exceeding the permissible weight of a heavy goods vehicle by 50% increases the destructive effect by 400% and exceeding it by 100% increases it by up to 16 times. These data have a direct impact on the frequency of partial and periodic repairs, as well as on the durability of road structures, which directly into increased road infrastructure maintenance costs. In regions with high heavy truck traffic, especially in locations with high average annual and daily traffic volumes, infrastructure is subject to faster wear and tear, which generates higher maintenance costs.

Overloaded vehicles affect not only the technical condition of the road surface, but also road safety elements such as energy-absorbing barriers, horizontal and vertical markings, and signaling devices (Ryś, 2012). Investments in the development of the control infrastructure, which also includes a modern vehicle weighing system, can significantly reduce the negative impact of overloaded heavy vehicles on the road surface (Ślusarczyk et al., 2025). The implementation of a weight-in-motion (WIM) system allows for the identification of overloaded trucks in real time. The implementation of this type of investment project in the development of road control infrastructure enables more efficient and effective exclusion of overloaded vehicles from traffic, thereby reducing their negative impact on road surfaces. Effective overload control has been shown to extend the life of the road surface by up to 30-40%, which translates into real savings for the road administrator (Mulyono et al., 2010; Nowak, 2015). Also "WIM enables the transfer of vehicle load data, allows data to be transferred when limits are exceeded and can send a message for more effective preventive actions" (Chłąd, 2024).

2.2. Social costs associated with heavy overloaded vehicles

In addition to its control function, the WIM system also plays an important role in reducing the social costs associated with road transport. Overloaded vehicles are statistically more likely to be involved in road accidents, which translates into a higher risk of accidents, a greater number of victims, and higher costs of treatment, rehabilitation, and material losses (Taylor, Bergan, Lindgren, 2000). The GDDKiA (2024) report clearly indicates that locations with heavy truck traffic are characterized by a higher accident rate. The available studies do not provide an exact figure for the proportion of overloaded trucks involved in road accidents, but the available data allow general conclusions to be drawn. However, it is known that combination trucks with additional trailers are involved in approximately 1.7% of fatal accidents (U.S. Department of Transportation, 2021). According to statistics, in China, 80% of accidents on mountain roads involving trucks are due to their overload (Wen et al., 2022). Furthermore, of all heavy trucks involved in accidents, only 0.08% are overloaded or improperly loaded, and 0.43% of vehicles carry oversized loads (Green et al., 2020). Overloaded trucks are estimated to account for 0.2% of all trucks involved in road accidents (US Department of Transportation, 2021). Furthermore, the social costs associated with

accidents are classified as external costs, which are not borne directly by the perpetrators, but by society as a whole (JASPERS, 2023). Taking these costs into account in the investment effectiveness analysis allows a more complete understanding of the benefits of implementing a WIM system. Reducing the number of overloaded vehicles leads to a decrease in the number of accidents, which translates into a lower burden on the health system, lower material losses, and an improvement in the quality of life of residents. The WIM system also has a preventive effect: drivers' awareness of the possibility of automatic vehicle weight control influences their behaviour, leading to greater compliance with regulations. Although difficult to measure directly, is an important factor in improving safety and reducing social costs.

2.3. Assessment of the profitability of investments in control infrastructure

The development of road infrastructure is based on numerous EU and national investment projects aimed at implementing specific measures in the country's transport network, primarily leading to financial, social, or infrastructural benefits (Domański, 2009). Infrastructure investments require not only significant capital expenditure but also appropriate organizational, technical, and legislative support. In the case of public projects such as WIM, it is also important to take into account social aspects such as the impact on road safety, the quality of life of residents, and the durability of infrastructure. These projects are long-term in nature and their effects are spread over time, which requires the use of appropriate methods of profitability assessment, taking into account the volatility of money value and the impact of external factors (Ślusarczyk, Grondys, 2025).

The evaluation of investment profitability is a key element of the decision-making process, allowing rational allocation of resources and minimisation of financial risk. Some of the most common tools are NPV (Net Present Value), IRR (Internal Rate of Return), payback period, sensitivity analysis, and scenario analysis (Zadora, 2013; Kozłowski, 2012). The NPV indicator allows the net value of an investment to be determined by discounting future cash flows to their present value. It takes into account the principle of the change in the value of money over time, which is particularly important in the case of long-term projects such as investments in road infrastructure. Furthermore, the use of the NPV method to assess the profitability of implementing a WIM system allows for the consideration of both initial costs and benefits spread over many years. This approach is also justified by the nature of the investment, in which cash flows are irregular and depend on many external factors (Uyar, 2009). In addition, the analysis of the profitability of investments using the NPV method allows for the consideration of not only financial aspects, but also social and environmental aspects that arise in the case of WIM system implementation. At the same time, due to the need to analyse other factors as well, traditional methods of profitability assessment, focusing exclusively on financial flows, that is, the NPV method, do not provide a complete picture of the effectiveness of infrastructure investments (Mielcarz, Paszczyk, 2013).

In the broader context of cost-effectiveness, extended models such as the eNPV method are increasingly being used, which allow for the inclusion of costs and benefits that cannot be directly measured in monetary terms, e.g., reduction in the number of road accidents, improvement in air quality, or noise reduction. The NPV method is an extension of the classic cost-benefit analysis model, taking into account social and environmental effects that are important in the case of public investments. In the context of the WIM system, the use of the eNPV model is particularly justified but requires quantified social and environmental data. The WIM system not only improves the effectiveness of overload control, but also reduces the social costs associated with infrastructure degradation and road accidents. Taking these effects into account in the economic analysis allows for a more complete assessment of the cost-effectiveness of the investment and a better justification for its implementation within the country's transport policy. At the same time, due to the limited possibilities of calculating environmental costs, the study mainly refers to the economic effects of the investment implementation, taking into account only selected social effects.

3. Research methodology

3.1. Research Objective and research method

This article presents an analysis of the development strategy for the WIM control infrastructure in Poland from an economic perspective. Five implementation options were evaluated, differing in terms of the pace and distribution of investments over time. The objective of the study was to assess the economic efficiency of the development of modern control infrastructure in Poland on the example of an automatic weigh-in motion (WIM) system, which will ensure an optimal return on investment while taking into account social and infrastructural benefits. The study assumes the implementation of the WIM system in Poland.

Due to the lack of market valuations of all external costs, the model takes into account quantifiable social benefits in terms of road safety (accident reduction), omitting quantitative environmental aspects (noise, emissions), which are described only qualitatively. Therefore the extended NPV (socio-economic NPV approach) focusing on infrastructure and safety externalities model for various implementation strategies for WIM stations in Poland was used to assess the project's profitability, taking into account only some social effects. The analysis took into account both the revenues generated by the system and the investment and operating costs. Revenues included income from administrative penalties, savings resulting from a reduction in the number of road accidents, and savings from deferred infrastructure repairs. The costs included investment outlays, the operating costs of the WIM stations, and the operating costs of the system headquarters. The profitability assessment also took into

account technical parameters such as the type of support structure, the length of the station, drainage requirements, and the availability of energy infrastructure, which directly affect investment costs.

The literature indicates that optimising these parameters can lead to significant savings, especially in the case of large infrastructure projects (OECD, 2011). Based on the standard results of infrastructure investments in Poland, taking into account the cost of capital, investment risk, and the share of public financing, the model assumes a discount rate of 6% over a 15-year time horizon, which corresponds to the expected life expectancy of the investment. According to the assumptions of the NPV model, the study covered specific categories of potential expenditures and revenues related to the implementation of the WIM control infrastructure (Table 1).

Table 1.
Types of potential expenditures and revenues related to the implementation of the WIM system

Investment income	Investment costs	Operating costs
Revenue from administrative penalties for exceeding the permissible gross vehicle weight	Expenditures for the construction of WIM stations	Ongoing maintenance of WIM stations (calibration, data transmission, legalization)
Savings resulting from a reduction in the number of road accidents involving overloaded vehicles.	Purchase of servers, software, and office equipment for the system headquarters	System headquarters operating costs (server room, Internet connections, IT support, management)
Savings from deferred road infrastructure repairs.	Costs of modernisation and maintenance of control infrastructure in subsequent years	

Source: own research.

3.2. Scope of input data

The input data for the model were developed on the basis of a detailed analysis of 1825 road sections in Poland, from which 300 locations with the greatest potential for economic efficiency were selected. The location of the WIM stations and the technical parameters of the infrastructure were key in evaluating the effectiveness of the system. The selection of appropriate measurement points took into account traffic intensity, the share of heavy-duty vehicles in traffic, the number of lanes, the availability of power connections, and the possibility of reorganising traffic during installation. Additionally, the number of lanes, the number of road accidents, the unit costs of repairs, and the technical parameters of the infrastructure were taken into account. Based on these data, locations were selected using the TOPSIS multi-criteria method, taking into account, among other things, SDRR (average daily annual traffic), SC (heavy goods vehicle traffic), and SCP (heavy goods vehicle traffic with trailers and semi-trailers) indicators. The developed location selection algorithm allowed for the creation of a ranking of measurement points, which formed the basis for a further detailed analysis of implementation strategies. The model assumes a decreasing share of overloaded vehicles in subsequent years of the system's operation, which affects the value of savings.

3.3. Assumptions of the implementation strategy model

The objective of this study is to maximize the economic net present value subject to a 15-year planning horizon and a 6% discount rate. The definition of possible implementation strategies for the WIM system is based on the assumption that 300 vehicle weighing stations will be installed over a 15-year period. This means that regardless of the implementation option adopted, the total number of stations installed during the analysed period remains constant, while the decision variable is its distribution over time — both in terms of the number of stations installed in individual years and the pace of investment. This approach allows for a comparative analysis of different implementation scenarios, taking into account the impact of the pace of investment on the economic value of the project. In particular, it allows for an assessment of the extent to which the intensity of investment in the first years of the system's operation affects the net present value (NPV). Each strategy has been designed to reflect realistic organisational and budgetary possibilities, while at the same time allowing for the identification of the optimal implementation option from the point of view of economic efficiency.

3.4. The investments in various implementation strategies

The calculation model was developed in the form of an active proprietary simulation model, enabling the simulation of NPV values for various implementation strategies. The model allows for the analysis of the profitability of system implementation in various time and investment variants. Six variants of the strategy were considered, differing in the number of stations implemented in individual years (Table 2).

Table 2.
Distribution of WIM station installations over time

Year of investment	Identification of implementation strategies					
	A	B	C	D	E	F
	Number of installations					
1	100	300	100	150	25	5
2	0	0	100	0	25	10
3	0	0	100	0	25	15
4	200	0	0	0	0	25
5	0	0	0	0	25	40
6	0	0	0	0	25	0
7	0	0	0	0	25	0
8	0	0	0	150	0	25
9	0	0	0	0	25	35
10	0	0	0	0	25	45
11	0	0	0	0	25	0
12	0	0	0	0	0	0
13	0	0	0	0	25	15
14	0	0	0	0	25	35
15	0	0	0	0	25	50

Source: own research.

Based on the ranking of the WIM station locations, they were then divided into four percentiles, each containing 75 stations. This division was used to develop a simulation of the NPV value in the adopted strategic variants, assuming the construction of 25 to 300 stations over 15 years. This assumption is intended to show changes in the NPV value for twelve different ranges specifying the construction of the number of WIM stations.

3.5. Economic profitability results for individual implementation strategies

The NPV was then calculated for each strategy, taking into account revenues, costs, and the discount rate. Revenues included the estimated decreasing value of administrative penalties for vehicle overloading, potential savings from the reduction of accidents involving heavily overloaded vehicles, and the amount of savings that could be generated from deferred road repairs. The costs included the costs of operating the stations, managing the system, and the capital expenditure associated with building the system. The results of the cost-effectiveness assessment of individual strategies A, B, C, D, E, and F for the 12 ranked location ranges are presented in Table 3.

Table 3.
NPV calculation results for the adopted implementation strategies [PLN]

Range	**1**	**2**	**3**	**4**	**5**	**6**
Number of stations	**25**	**50**	**75**	**100**	**125**	**150**
Strategy A	-52 105 219	-31 458 267	-24 073 032	-26 068 772	-20 083 725	-24 301 512
Strategy B	-52 105 219	-31 458 267	-24 073 032	-26 068 772	-34 566 799	-53 267 659
Strategy C	-52 105 219	-31 458 267	-24 073 032	-26 068 772	-29 455 233	-43 044 527
Strategy D	-52 105 219	-31 458 267	-24 073 032	-26 068 772	-34 566 799	-53 267 659
Strategy E	-52 105 219	-26 346 701	-9 027 668	7 751 434	22 077 090	30 019 571
Strategy F	-46 087 07	-11 866 90	13 434 821	32 508 314	54 936 978	69 882 395
Range	**7**	**8**	**9**	**10**	**11**	**12**
Number of stations	**175**	**200**	**225**	**250**	**275**	**300**
Strategy A	-3 591 524	12 765 888	15 787 791	30 178 722	65 084 996	**119 573 631**
Strategy B	-47 040 746	-45 166 406	-56 627 577	-56 719 720	-36 296 520	**3 709 041**
Strategy C	-31 706 047	-24 720 142	-26 247 515	-16 405 859	13 951 138	**63 890 498**
Strategy D	-16 793 951	15 327 181	34 112 804	64 267 456	114 937 450	**185 189 805**
Strategy E	69 892 762	108 620 438	137 038 133	183274118	266 701 467	**357 069 668**
Strategy F	112 321 234	151 048 910	192 586 276	255498283	326 284 122	**416 652 323**

Source: own research.

The determined NPV values should be interpreted in terms of the WIM system as a whole for 300 stations. The results clearly show that for each of the adopted strategies, the NPV value is greater than zero (range 12 is the summary of the extended NPV value for all 300 stations), but with a clear difference in its value. The strategy variants assume specific numbers of WIM stations to be implemented in a given year of the investment. The appearance of negative values suggests low profitability of the investment in the initial stages. Visible positive values start at 75 stations and reflect the positive end result for each strategy at different stages of system implementation, depending on the number of weighing stations in operation.

The simulation results showed significant differences in the extended NPV values between the strategies. Strategies spread over time (E and F) achieved the highest NPV values, indicating their greatest economic efficiency. The intensive strategies (B and C), despite their rapid implementation, were characterised by lower profitability due to high investment costs in a short period of time. The analysis showed that the break-even point (i.e., the point at which NPV becomes positive) varies depending on the strategy:

- Strategy A: positive NPV with the implementation of >175 stations.
- Strategy B: positive NPV only with the full implementation of 300 stations.
- Strategy C: positive NPV with 250 stations.
- Strategy D: positive NPV with 175-200 stations.
- Strategy E: positive NPV with as few as 75-100 stations.
- Strategy F: positive NPV with as few as 75 stations.

These results indicate that strategies with lower investment intensity in the initial years allow for faster achievement of a positive NPV, which is beneficial from the point of view of investment risk management.

4. Conlucions

The analysis of the economic efficiency of implementing a weigh-in-motion (WIM) system in Poland allows us to draw clear conclusions regarding the validity of the investment and the optimal strategies for its implementation. Although the model adopts a societal perspective, it is limited to costs related to the safety of infrastructure users. Environmental externalities, such as noise and emission reductions, are not quantified in the model, but only qualitatively. This means that the estimated quantitative effects of the extended NPV represent a lower bound on the system's possible societal benefits. The results obtained using the extended NPV focusing on infrastructure and safety externalities calculation model indicate that the implementation of the WIM system on a national scale, covering 300 locations, is a profitable undertaking from both an economic and social point of view.

The main factor influencing the effectiveness of the investment turned out to be the distribution of expenditure over time. Implementation strategies that assumed an even or staggered pace of WIM station installation showed significantly higher NPV values than intensive variants implemented in the short term. Strategies E and F proved particularly advantageous, as they implemented the system in stages, taking into account investment interruptions and fluctuations in the number of stations installed in individual years. These scenarios were identified as optimal according to the NPV maximization criterion, assuming 6% discount rate and the lack of full quantification of benefits (e.g., environmental). First, investment expenditures incurred in later years (strategies E and F) have a significantly

lower present value than the same expenditures incurred at the beginning (short-term strategies). On the other hand, these strategies do not take into account quantified environmental benefits. It can be assumed that once they are incorporated, the advantage of short-term strategies (faster emission reductions by eliminating overloaded vehicles) will be greater.

From a public interest point of view, the implementation of the investment is also strongly justified by the scale of potential social and environmental benefits. Reducing the number of road accidents involving overloaded vehicles will reduce the costs of treating victims, limit material losses, and improve road safety, which has a measurable impact on the quality of life of residents and the functioning of the transport system.

At the same time, the effective implementation of the WIM system in Poland should be carried out in stages, taking into account the locations with the highest efficiency and using a strategy of installing weighing stations spread out over time. This approach to investment allows for optimal economic results, minimisation of investment risk, and maximization of social benefits. The study has certain limitations that should be considered in future research. The analysis only took into account measurable social effects, such as a reduction in the number of road accidents. Other effects, such as a reduction in pollutant emissions or noise, were described only qualitatively. At the same time, further studies should take into account changing parameters, as well as legal, technological, and organisational conditions that may affect the functioning of the system in the long term.

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References

1. Chłąd, M. (2024). SWOT Analysis for investment management in the scope of implementing an automatic vehicle weighing system in motion. *Polish Journal of Management Studies*, *Vol. 30, No. 1,* 42-65, DOI: 10.17512/pjms.2024.30.1.03
2. Cho, S., Lakatos, É. (2022). Finite element and fatigue analysis of flexible pavements based on temperature profile modelling. *Roads and Bridges - Drogi i Mosty*, *21*, 103-116. https://doi.org/10.7409/rabdim.022.006
3. Dzienis, T., Karkowski, M. (2010). *Inteligentny system preselekcji wagowej pojazdów – Degradacja dróg.* Wrocław: Instytut Badawczy Dróg i Mostów.
4. GDDKiA (2024). *Ogólne informacje o sieci dróg krajowych*, https://www.gov.pl/web/gddkia/ogolne-informacje-o-sieci-drog-krajowych
5. Ghosn, M. (2010). Minimising Illegal Overweight Truck Frequencies through Strategically Planned Truck Inspection Operations Acknowledgements. *Journal of Transportation Engineering*, *142(9).*
6. Green, E., Ross, P., Blackden, Ch., Fields, M., Agent, K. (2021). *Kentucky Traffic Collision Facts 2020*. Kentucky Transportation Centre Research Report, 1732. https://uknowledge.uky.edu/ktc_researchreports/1732.
7. JASPERS (2023). *Niebieska księga, Infrastruktura drogowa.* CUPT, https://www.cupt.gov.pl/wp-content/uploads/2023/06/upload_blue-book_roads_150623-final_3610_132.pdf
8. Jastrzębowski, A. (2015). *Zakres i znaczenie współcześnie identyfikowanych funkcji rachunkowości.* Poznań: Wydawnictwo UE w Poznaniu.
9. Kozłowski, P. (2012). *Infrastruktura transportowa jako element rozwoju gospodarczego*. Warszawa: Szkoła Główna Handlowa.
10. Mielcarz, P., Paszczyk, P. (2013). *Analiza projektów inwestycyjnych w procesie tworzenia wartości przedsiębiorstwa*. Warszawa: PWN.
11. Mulyono, A.T., Parikesit, D., Antameng, M., Rahim, R. (2010). Analysis of loss cost of road pavement distress due to overloading freight transportation. *Journal of the Eastern Asia Society for Transportation Studies*, *8*, 706-721.
12. Nowak, P. (2015). Przeciwdziałanie pojazdom przeciążonym. *Drogownictwo*, *nr 9,* 306-310.
13. OECD (2011). *Moving Freight with better Trucks*.
14. Ossowski, R.L., Burnos, P. (2015). Ważenie pojazdów w ruchu. Stan obecny oraz perspektywy zastosowania systemów Weigh-In-Motion w celach administracyjnych. *Metrologia i Probiernictwo – Biuletyn Głównego Urzędu Miar*, *1-2,* 8-9.
15. Ryguła, A., Brzozowski, K., Maczyński, A. (2020). Limitations of the effectiveness of Weigh in Motion systems. *Open Eng*., *10,* 183-196.

16. Ryś, D. (2012). Pojazdy przeciążone na polskich drogach. *Drogownictwo, 12*.
17. Ryś, D., Judycki, J., Jaskuła, P. (2014). Wpływ pojazdów przeciążonych na trwałość nawierzchni asfaltowych. *Logistyka, nr 6,* 9318-9328.
18. Ślusarczyk, B., Grondys, K. (2025), Combating overloaded vehicles on the roads – potential economic benefits. *System Safety: Human -Technical Facility – Environment*, *7(1),* 29-37, DOI: 10.2478/czoto-2025-0004
19. Ślusarczyk, B., Grondys, K., Sałek, R. (2025), Assessment of the potential of automatic Weigh-In-Motion (WIM) systems from the perspective of transport enterprises. *Production Engineering Archives*, *31(2),* 173-182, DOI: 10.30657/pea.2025.31.17
20. Smeden, M., Moons, K.G., de Groot, J.A. (2019). Sample size for binary logistic prediction models: Beyond events per variable criteria. *Statistical Methods in Medical Research*, *28(8),* 2455-2474.
21. Sochoń, A., Siedlanowska-Chałuda, O. (2014). *Bezpieczny transport*. Retrieved from: www.ungc.org.pl
22. Sokołowicz, M., Przygodzki, Z. (2016). Logistyka miejska i transport zrównoważony. In: A. Nowakowska (Ed.), *EkoMiastoGospodarka. Zrównoważony, inteligentny i partycypacyjny rozwój miasta.* Łódź: Wydawnictwo Uniwersytetu Łódzkiego.
23. Sujon, M., Dai, F. (2021). Application of weigh-in-motion technologies for pavement and bridge response monitoring: State-of-the-art review. *Automation in Construction*, *130*, 103844.
24. Taylor, B., Bergan, A., Lindgren, N. (2000). The importance of commercial vehicle weight enformcement in safety and road asset management, C.B.P.D.P. *Eng, Annual Rev*., *237*, 234.
25. U.S. Department of Transportation (2021). *Large Truck and Bus Crash Facts 2019.* National Highway Traffic Safety Administration FMCSA-RRA-15-055.
26. Uyar, A. (2009). The Relationship of Cash Conversion Cycle with Firm Size and Profitability: An Empirical Investigation in Turkey. *International Research Journal of Finance and Economics*, *24*, 186-193.
27. Wen, H., Du, Y., Chen, Z., Zhao, S. (2022). Analysis of Factors Contributing to the Injury Severity of Overloaded-Truck-Related Crashes on Mountainous Highways in China. *Int. J. Environ. Res. Public Health*, *19*, 4244. https://doi.org/10.3390/ ijerph19074244
28. Zadora, E. (2013). *Inwestycje i finansowanie przedsiębiorstw.* Kraków: Wydawnictwo UE w Krakowie.

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USING LARGE LANGUAGE MODELS IN PROJECT MANAGEMENT

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Purpose: The purpose of this work is to present preliminary research results on the automatic detection of destructive emotions in project management using large-scale language models. The paper aims to present an architecture for identifying negative emotions in open-source projects.
Design/methodology/approach: This article focuses on identifying destructive emotions in text-based communication available in open-source projects through the use of Large Language Models (LLMs). Using available training data with labels describing emotions associated with text, the BERT model is instructed to identify basic emotions in text. The LLM model will be trained to identify instances where anger—an example of a destructive emotion—appears in email correspondence related to open-source projects. The trained model can then be used to identify emotions in further correspondence. This approach will be used to develop a system architecture that will enable automatic emotion identification.
Findings: The results of this study demonstrate that it is possible to configure Large Language Models (LLM) to identify emotions in project-related electronic communications. Detailed research is needed to confirm the effectiveness of this approach. However, such research requires significant computing power.
Research limitations/implications: The study concentrated on the potential of Large Language Models to automatically detect emotions in project management communication. Rather than achieving high-quality identification, the objective was to validate the concept of utilizing Large Language Models for this purpose. The sole instance of such a model utilized was BERT.
Originality/value: The novelty of this paper is the attempt to use Large Language Models to automatically detect emotions in project management. Previously, this type of analysis used dictionary-based methods for sentiment analysis. This paper continues the idea of identifying negative emotions.
Keywords: project management; emotion recognition; natural language processing, Large Language Models.
Category of the paper: Conceptual paper.

1. Introduction

Traditionally, project management focused solely on the three fundamental dimensions defined by the project management triangle: scope, time, and cost. As the perspective on project success shifted (Jugdev, Müller, 2005), with stakeholder relationships playing a significant role, the perception of emotions also changed. They ceased to be a distraction and became a crucial parameter to consider when managing projects.

In modern project management, the most important key parameter is stakeholder engagement. Engaging stakeholders, including customers, employees, investors, and regulators, is crucial for project success. Clear communication, managing expectations, and addressing stakeholder concerns are essential to maintain support and alignment throughout the project life cycle.

In contemporary projects, stakeholder relations rely on electronic communication tools. This creates ample opportunity to utilize advanced analysis based on Natural Language Processing (NLP). Many computer methods of natural language processing are currently being developed. They are methods of text and speech processing (speech recognition, word segmentation), morphological analysis (lemmatization, stemming), syntactic analysis (parsing), lexical semantics (sentiment analysis with emotion recognition, terminology extraction), and many others like automatic summarization and machine translation. Sentiment analysis seems to be a particularly useful tool for analyzing communication in a project. Another tool being developed in this area is emotion identification.

The latest tool developed in NLP, widely used in many areas of human activity, is Large Language Models (LLM). Large language models are neural networks and are classified as generative artificial intelligence. Examples of LLMs include the GPT series built by OpenAI, used in the ChatGPT, Google Gemini, Microsoft Copilot chatbots, and the Llama models built by Meta Platforms. There are also Chinese models like DeepSeek and Polish models like Bielik and PLLuM (Large language model, 2025).

Nagarajan (2024) presents possible areas of application of LLM Project Management:

- Decision Support: LLM acting as an assistant for project managers to brainstorm risks, identify potential stakeholders, or suggest mitigation strategies.
- Task Automation: LLM can help PM generate project artifacts, such as creating a project charter, creating a work breakdown structure (WBS), or writing status reports.
- Information Retrieval: Briefly summarizing and extracting key information from vast amounts of project documentation (e.g., contracts, past lessons learned, and technical specifications).
- Communication: LLM can assist in drafting clear and consistent communications for different stakeholders, including emails, presentations, and reports.

In this paper, we propose yet another application of AI in project management: analyzing emotions occurring in projects. Given its crucial importance in stakeholder management, this tool may have promising applications.

The aim of this paper is to present findings in automatic destructive emotion detection in project management with Large Language Models.

The paper is divided into the following parts. The first section presents a literature review of the topics of interest. The next section describes the data used and the research procedure employed. This section also presents the research question. The next section presents the obtained results. The next section presents a discussion of the obtained results. The whole paper ends with a summary.

2. Literature survey

2.1. Psychology in Project Management

Clarke (2010) was probably the first to notice that projects are emotional. However, despite previous work on the significance of conflict in projects (Chen, 2006) and recognizing that conflict is a source of strong emotions (Barki, Hartwick, 2004), the topic of recognizing emotions in the project has not been considered in the literature on the subject. In the mentioned paper, Clark (2010) analyzes how emotions affect project manager behaviors and decisions to better understand why projects go in very different directions from those expected within the predominant rationalist paradigm. He interviewed PMs who participated in emotional intelligence training, and they understood the importance of emotion in decision-making.

Today four key concepts emerge in the area of emotion analysis in the context of project management.

The first, pioneered by Goleman, is the analysis of emotional intelligence focused on the project manager. The research in this area applies Goleman's (1996) model of Emotional Intelligence (EQ) directly to the project manager's role. This model includes self-awareness of the PM, who recognizes his emotions and understands how they affect their team and decisions. The PM's self-regulation means the PM controls his impulses. Can the PM remain calm and professional during a crisis instead of panicking or blaming others? PM Empathy: Can he accurately read the emotional state of team members and stakeholders? PM Social Skills, if the PM can use their understanding of emotions to build rapport, influence stakeholders, communicate clearly, and resolve conflict (Rodrigues et al. 2024).

The second key concept is focused on the emotional dynamics of project teams. This body of research moves beyond just the project manager and looks at the project team as an “emotional system”. Mogård et al. (2022) discussed psychological safety. Team members

who feel psychologically safe are more likely to admit mistakes, ask questions, and propose innovative ideas, which is critical for solving complex project problems. Sigal et al. (2018) discussed emotional contagion. A single, highly negative team member can poison the group's morale, while an optimistic and resilient PM can create a positive climate. As projects are, by definition, temporary, high-pressure environments, much research is devoted to stress, burnout, and resilience (Mubarak et al., 2022).

The third key concept is devoted to emotion in project decision-making. This research applies behavioral economics to project environments (Manderscheid, Brynteson, 2015).

The fourth key concept is devoted to stakeholder emotional management. Projects fail more often due to stakeholder issues than technical ones. These papers focus on the PM's role in managing the emotions in projects. Managing Expectations, Emotional Labor, and Negotiation and Conflict are discussed in this area. Sentiment analysis is also used (Targiel, 2023) and emotion identification (Targiel, 2024).

2.2. Human emotions

Human emotions are a very complex phenomenon. For this reason, models of this phenomenon are considered in psychology. A fairly wide overview of the models can be found in (Nandwani, Verma, 2021). The most widely used are the Ekman model (Ekman, 1992) and Plutchik's Wheel of Emotions (Plutchik, 1980). The Ekman model is a categorical one, with six defined emotions: anger, disgust, fear, joy, sadness, and surprise. Plutchik considered two types of emotions. Basic ones, which include Ekman's six emotions supplemented by trust and anticipation, and mixed emotions, which are made from the combination of basic emotions. Plutchik represents his emotions on a colored wheel. The Plutchik model is also a categorical one. The opposite type of models are dimensional emotion models (Nandwani, Verma, 2021). They are based on three parameters: valence (positive, neutral, or negative), activation or arousal (excited, neutral, or calm), and dominance or power (weak, neutral, or strong).

In the context of project management, destructive emotions may be of particular importance. They can significantly impact team dynamics, decision-making, and consequently overall project success. A short catalog of such destructive emotions is presented below:

- **Anger:** Anger can arise from conflicts, unmet expectations, or stress. It can lead to hostility among team members, creating a toxic work environment and hindering collaboration. For these reasons, it is especially important to recognize these types of emotions (Hekkala, Stein, 2016; Wang et al., 2023).
- **Frustration:** Frustration often stems from obstacles or setbacks. It can result in decreased motivation and productivity, making it harder for teams to focus on goals. It is not that important, but it affects the productivity of individual team members (Hartman, Jugdev, 1998; Jugdev et al., 2000).

- **Fear:** Fear of failure, criticism, or the unknown can inhibit creativity and risk-taking. Team members might avoid voicing ideas or addressing issues, which can stifle innovation. Such emotions reduce the creativity of the design team (Hartman, Jugdev, 1998; Jugdev et al., 2000).
- **Jealousy:** Jealousy can occur when individuals feel threatened by colleagues' success. This can damage relationships and foster competition instead of collaboration (Andiappan, Dufour, 2020).
- **Anxiety:** Anxiety about deadlines, performance, or the project's future can lead to decreased focus and increased stress levels, causing team members to struggle to perform at their best (Wang et al., 2021).
- **Despair:** A sense of hopelessness about project outcomes can lead to disengagement and lack of effort from team members, jeopardizing project timelines and quality (Potosky, Azan, 2023).

Project managers can employ several strategies to mitigate the impact of these destructive emotions on project success. Some of them are fostering open communication, setting clear goals, promoting a positive culture, and encouraging reflection. In case of anger and frustration, they can provide conflict resolution resources. They can equip the team with tools and techniques to resolve conflicts constructively. However, such support is based on recognizing the emotions occurring. Hence the importance of methods for recognizing destructive emotions.

2.4. AI and Project Management

There has been a significant increase in the development of computer natural language processing methods in recent years. After the first periods of Symbolic NLP (1950s–early 1990s) and Statistical NLP (1990s–2010s), present NLP methods have gigantic potential for implementation. Dinov (2018) defines Natural Language Processing (NLP) as the automated execution of machine-driven algorithms to comprehend human language and extract information. Lexical semantics, relational semantics, syntactic analysis, morphological analysis, discourse, and text and speech processing are typical tasks for these approaches (Natural Language Processing, 2025). Natural language production, machine translation, and automatic summarization are a few of the new uses. Sentiment Analysis (SA) and Emotion Analysis (EA) are highly intriguing areas of NLP development in the context of project management, as they facilitate emotion recognition.

Müller et al. (2024) provide a comprehensive editorial that synthesizes the current state of AI in project management research. It demands more rigorous empirical research to verify the real-world effects of AI tools and establishes a research agenda for the future. The publication of Korczak et al. (2023) offers a more comprehensive examination of the application of generative AI in management. It underscores the potential of integrating LLMs with Business

Intelligence (BI) systems to enhance managerial decision-making and provide more sophisticated analytical insights for project control.

The application of Large Language Models to “knowledge work,” which is the foundation of project management, is covered in the Brachman et al. (2025) paper. It explores categories of use like creation, information retrieval, and automation, all of which are directly relevant to project management tasks.

Karnouskos's (2024) paper directly evaluates the capabilities of LLMs like ChatGPT by testing their performance on project management certification questions. The paper comes to the conclusion that LLMs and project managers should be seen as a "dynamic duo", with the LLMs adding to human skills rather than taking them away.

Chen's paper from 2024 talks about the problems developers face when they try to use LLMs to make apps, such as API errors, outputs that are hard to predict, and security issues. This challenge is directly applicable to any team that is attempting to develop custom PM tools using LLMs.

Some research investigates the use of LLM-powered agents within the Scaled Agile Framework (SAFe). It provides empirical results on how these agents can perform roles and improve project metrics in a simulated environment (Cinkusz et al., 2024).

The systematic review, which is available in (Bento et al., 2022), provides a comprehensive overview of the landscape of AI applications in project management, including decision support, risk management, and automation. It provides an excellent pre-LLM baseline for understanding the evolution of AI in the field.

3. Methods

3.1. Data on communications

Typically, communication within a project takes place through designated channels and is confidential. Fortunately, communication in open-source software projects relies on mailing lists, which are, by definition, publicly available. An example of such a project is the Apache Foundation's OpenOffice project.

The mailing list of the Apache OpenOffice project, implemented in the open-source formula, was selected in this work. Project communication is publicly available at "https://openoffice.apache.org/mailing-lists.html". The mailing list has been in operation since 2011. Several hundred messages show up on all sublists combined each month.

The eighteen channels of communication for the project are shown as mailing lists with themes. These mailing lists fall into two categories: English Language Mailing Lists and Native Language (non-English) Mailing Lists. There are German, Japanese, Italian, and French lists

among the second ones. Our attention will be on lists in English. Specifically, the mailing lists for developers and users are very active. Several hundred emails appear on these lists every year. Native language lists aren't as active, receiving only a few dozen emails per year. Against this background, the German list is particularly active, receiving up to three hundred emails per year.

3.2. Data on emotion patterns

In the 1990s, a group of psychologists all over the world collected data in the ISEAR project, directed by Klaus R. Scherer and Harald Wallbott (1994). Students were asked to describe instances in which they had felt each of the seven main emotions. In each case, the questions covered the way they had appraised the situation and how they reacted. The final data set thus contained reports on seven emotions, each by close to 3000 respondents in 37 countries on all 5 continents.

Table 1.
Structure of the ISEAR dataset

Emotion	Text
joy	"On days when I feel close to my partner and other friends. When I feel at peace with myself and also experience a close contact with people whom I regard greatly"
fear	“Every time I imagine that someone I love or I could contact a serious illness, even death"
anger	"When I had been obviously unjustly treated and had no possibility of elucidating this"

Source: own elaboration.

The ISEAR dataset is the outcome of this project, which comprises a collection of sentences that have been labeled. This is a collection of 7516 sentences labeled with 7 major emotions (joy, fear, anger, sadness, disgust, shame, and guilt). Using this set, a neural network was trained to identify the main emotions. The structure of the ISEAR dataset is shown in Table 1.

3.3. Large language models

A wide range of LLM models is currently available. Table 2 summarizes the available models. The rate of new model development is particularly interesting. In 2023, five new models were introduced and are being further developed into higher versions.

In this paper, the oldest BERT model was considered, as the best understood one. However, the existence of a wide range of other models offers the opportunity to improve the quality of the obtained identifications.

3.4. Research questions

Previous research on the analysis of sentiment in open-source projects (Targiel, 2022) and attempts to identify emotions in this communication using neural networks (Targiel, 2023) inspired the concept of utilizing Large Language Models for this purpose.

Table 2.
The most well-known models of large language

No	Name	Type	Size (No param.)	Developer	Introduced
1	BERT	transformer-based model	1.27B (BERT. xlarge)	Google	2018
2	Claude LLM	Closed-source	No official number	Anthropic	2023
3	Gemini	Closed-source	No official number	Google	2023
4	Gemma	open-source language models	27B (Gemma 3)	Google	2024
5	DeepSeek-LLM	open-source reasoning model	67B	DeepSeek	2023
6	GPT-3	Closed-source	175B (davinci)	OpenAI	2020
7	GPT-4	Closed-source	~1.8T	OpenAI	2023
8	LLaMA	transformer architecture	400B (Maverick)	Meta	2023

Source: own elaboration.

Large language models (LLM) are neural networks (NN) that are trained using self-supervised machine learning on a vast amount of text, such as Wikipedia articles and works of fiction. These networks learn the syntax, semantics, and ontologies present in human language corpora by utilizing vast amounts of data. It's possible to fine-tune LLMs to do certain jobs.

Thus, the following research question emerges:

RQ1: Using fine-tuned Large Language Models, is it possible to find negative emotions in project communication?

A positive answer to this question creates the possibility to quickly recognize negative emotions, especially destructive ones, which could help prevent potential conflicts in project teams and increase their effectiveness by reducing emotional contagion.

3.5. Research procedure

The research procedure involves analyzing available literature to then select appropriate components for the proposed system's architecture. This begins with selecting appropriate patterns for training neural networks, proceeding through selecting the neural network architecture implemented using the language model, and finally, finally, the method of utilizing the trained language model. Selecting appropriate metrics to evaluate the effectiveness of the proposed solution is also crucial.

4. Results

The main result of the research is a proposed architecture for emotion identification research in open-source projects. It is presented in Figure 1.

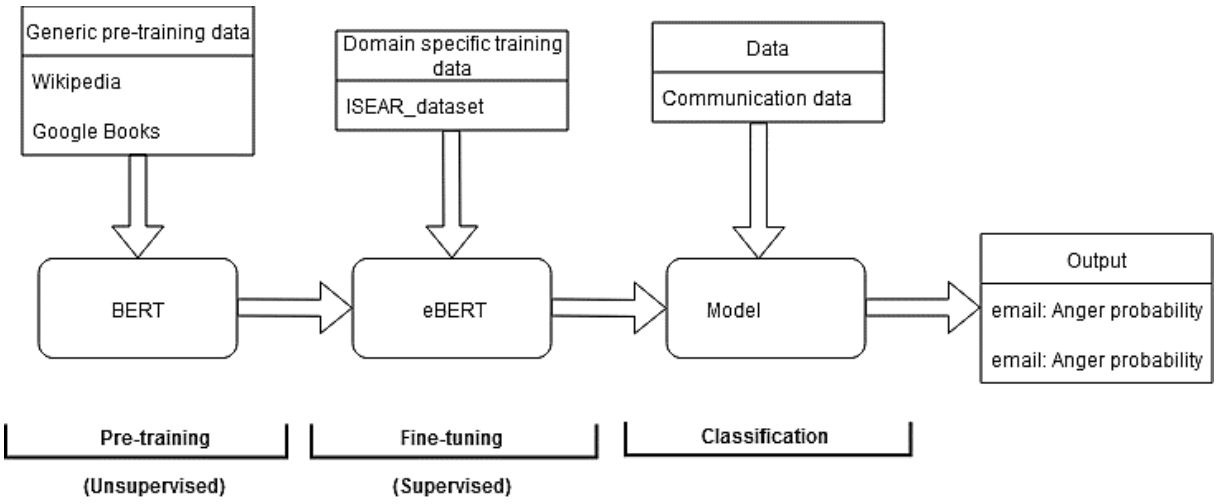


Figure 1. Architecture of the proposed system.

Source: own elaboration.

The ISEAR dataset is prepared for training by converting the emotions described in the dataset into numerical values in a manner that is appropriate. The ISEAR dataset has the structure shown in Table 2. A series of consecutive integers from 1 to 7 were used to encode the seven emotions that were present in this dataset.

Fine-tuning the BERT model entails instructing it to classify emotions that are present in the ISEAR dataset. The result is a neural network that can classify emotions based on text.

Then, the network trained in this way is used to find negative emotions (anger) in the communication set of the OpenOffice project.

The messages identified by the NN are then manually verified for the presence of negative emotions such as anger. The architecture of the proposed system can be seen in Figure 1.

The entire procedure can be written in the following steps:

1. The ISEAR dataset's preparation for training.
2. Fine-tuning the BERT model.
3. Using the trained BERT model to identify messages in the communication set.
4. Manual verification of identified messages.

The use of the above procedure will not only allow for the identification of negative emotions but also for the verification of the quality of the procedure.

5. Discussion

Our research identified the correct architecture for identifying emotions in mailing lists. This method has not been used in project management before, as far as we know. Nevertheless, many authors have demonstrated the significant importance of emotions in projects (Goleman, 1996; Sigal et al., 2018). However, they refrained from employing AI in their investigation. Our results indicate that it is feasible to implement artificial intelligence techniques for emotion identification. The effectiveness of this approach is unknown at this time.

Further research plans include implementing the proposed architecture. This will enable testing its effectiveness. However, this requires access to significant computing power. The research question can be satisfactorily addressed based on the results that have been obtained.

6. Summary

The cloud environment of Amazon Web Services was utilized to implement the system depicted in Figure 1. Adapted scripts described in (Fregly, Barth, 2021) were used. This demonstrated the ability to identify emotions in electronic communications generated in open-source projects. For this purpose, OpenOffice project data (OpenOffice, 2025) were used. Fine-tuning needed a lot of computer power. Therefore, the primary objective was to verify the hypothesis, rather than to achieve satisfactory outcomes.

The presented work is only a preliminary step in a broader effort to develop a system for automatic detection of negative emotions in IT projects. Its intended scope is limited to projects where communication is publicly available, such as open-source projects. Its new contribution is the specific architecture of the proposed solution. Positive results obtained from further research allow the proposed system to be used for more effective IT project management.

After access to high-performance computing power becomes available, future research will concentrate on obtaining precise, fine-tuned models. There is evidence that these models may have practical applications.

References

1. Andiappan, M., Dufour, L. (2020). Jealousy at work: A tripartite model. *Academy of Management Review, Vol. 45 Iss. 1*, pp. 205-229.
2. Barki, H., Hartwick, J. (2004). Conceptualising the construct of interpersonal conflict. *International Journal of Conflict Management, Vol. 15, No. 3*, pp. 216-44.
3. Bento, S., Pereira, L., Gonçalves, R., Dias, Á., da Costa, R.L. (2022). Artificial intelligence in project management: Systematic literature review. *International Journal of Technology Intelligence and Planning, Vol. 13, Iss. 2,* pp. 143-163. doi.org/10.1504/ijtip.2022.126841
4. Brachman, M., El-Ashry, A., Dugan, C., Geyer, W. (2025). Current and Future Use of Large Language Models for Knowledge Work. Proc. *ACM Hum.-Comput. Interact., Vol. 9, Iss. 7,* pp. CSCW222:1-CSCW222:24. doi.org/10.1145/3757403
5. Chen, M.-H. (2006). Understanding the benefits and detriments of conflict on team creativity process. *Creativity and Innovation, Vol. 15, No. 1,* pp. 105-16.
6. Chen, X., Gao, Ch., Chen, Ch., Zhang, G., Liu, Y. (2024). An Empirical Study on Challenges for LLM Application Developers. *arXiv preprint arXiv:2408.05002*.
7. Cinkusz, K., Chudziak, J.A., Niewiadomska-Szynkiewicz, E. (2025). Cognitive Agents Powered by Large Language Models for Agile Software Project Management. *Electronics*, *Vol. 14, Iss. 1,* p. 87. doi.org/10.3390/electronics14010087
8. Clarke, N. (2010). *Projects are emotional: How project managers' emotional awareness can influence decisions and behaviours in projects, Vol. 3, Iss. 4,* pp. 604-624, doi:10.1108/17538371011076073
9. Dinov, I.D. (2018). Natural Language Processing/Text Mining. In: I.D. Dinov (ed.), *Data Science and Predictive Analytics: Biomedical and Health Applications Using R* (pp. 659-95). Cham: Springer International Publishing.
10. Ekman, P. (1992). An argument for basic emotions. *Cognition and Emotion, Vol. 6, Iss. 3-4*, pp.169-200. doi:10.1080/02699939208411068
11. *Emotion recognition* (2025). Wikipedia. Retrieved from: https://en.wikipedia.org/w/index.php?title=Emotion_recognition&oldid=1153310432, 28.10.2025.
12. Fregly, C., Barth, A. (2021). *Data Science on AWS: Implementing End-to-End, Continuous AI and Machine Learning Pipelines*. Sebastopol: O'Reilly Media.
13. Goleman, D. (1996). *Emotional Intelligence: Why It Can Matter More Than IQ*. New York: Bantam Books.
14. Hartman, F., Jugdev, K. (1998). *Leadership undertow: Project manager fears and frustrations.* Proceedings of the 29th Annual Project Management Institute Seminars and Symposium. Long Beach, USA.
15. Hekkala, R., Stein, M.-K. (2016). Silences and Voices of Fear, Anger, and Rationality: Emotionologies in an Information Systems Project. *Emotions and Organizational*

Governance, Research on Emotion in Organizations, *Vol. 12*. Leeds: Emerald Group Publishing Limited, pp. 381-408. doi: 10.1108/S1746-979120160000012012

16. Jugdev, K., Hartman, F., Thomas, J. (2000). Leadership fears and frustrations in project management. *Projects as Business Constituents and Guiding Motives*, pp. 183-192.
17. Jugdev, K., Müller, R. (2005). A retrospective look at our evolving understanding of project success. *Project Management Journal, Vol. 36, Iss. 4*, pp. 19-31.
18. Karnouskos, S. (2024). The Relevance of Large Language Models for Project Management. *IEEE Open Journal of the Industrial Electronics Society, Vol. 5*, pp. 758-768. doi.org/10.1109/OJIES.2024.3412222
19. Korczak, J., Pawełoszek, I., Pondel, M. (2023). Generatywne modele sztucznej inteligencji w zarządzaniu. *Przegląd Organizacji, Vol. 3, Iss. 998,* pp. 255-263. doi.org/10.33141/po.2023.03.27
20. *Large language model* (2025). Wikipedia. Retrieved from: https://en.wikipedia.org/w/index.php?title=Large_language_model&oldid=1319023820, 28.10.2025.
21. Manderscheid, S., Brynteson, R. (2015). *Behavioral economics and decision making: 51 reproducible exercises.* Belchertown: HRD Press.
22. Mogård, E.V., Rørstad, O.B., Bang, H. (2022). The Relationship between Psychological Safety and Management Team Effectiveness: The Mediating Role of Behavioral Integration. *International Journal of Environmental Research and Public Health, Vol. 20, Iss. 1,* p. 406, doi.org/10.3390/ijerph20010406
23. Mubarak, N., Khan, J., Khan, A.K. (2022). Psychological distress and project success: The moderating role of employees' resilience and mindfulness. *International Journal of Project Management, Vol. 40, Iss. 5*, pp. 566-576, doi.org/10.1016/j.ijproman.2022.05.004
24. Müller, R., Locatelli, G., Holzmann, V., Nilsson, M., Sagay, T. (2024). Artificial Intelligence and Project Management: Empirical Overview, State of the Art, and Guidelines for Future Research. *Project Management Journal, Vol. 55, Iss. 1*, pp. 9-15. doi.org/10.1177/87569728231225198
25. Nagarajan, P. (2024). *How Large Language Models Enhance Project Management Efficiency.* Retrieved from: https://https://integranxt.com/blog/large-language-models-project-management/, 18.10.2025.
26. Nandwani, P., Verma, R. (2021). A review on sentiment analysis and emotion detection from text. *Social Network Analysis and Mining, Vol. 11, Iss. 1,* p. 81. doi:10.1007/s13278-021-00776-6
27. *Natural language processing* (2025). Available online: https://en.wikipedia.org/wiki/Natural_language_processing, 29.10.2025.
28. *OpenOffice.org*. Retrieved from: https://en.wikipedia.org/wiki/OpenOffice.org, 29.10.2025.

29. Potosky, D., Azan, W. (2023). Leadership behaviors and human agency in the valley of despair: A meta-framework for organizational change implementation. *Human Resource Management Review, Vol. 33, Iss. 1*, p. 100927.
30. Plutchik, R. (1980). General Psychoevolutionary Theory of Emotion. In: R. Plutchik, H. Kellerman (Eds.), *Theories of Emotion* (pp. 3-33). Academic Press. doi:10.1016/B978-0-12-558701-3.50007-7
31. R Development Core Team (2024). *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing, http://www.R-project.org/.
32. Rodrigues, N.J.P., Matos, C.I.V. (2024). The Relationship Between Managers' Emotional Intelligence and Project Management Decisions. *Administrative Sciences, Vol. 14, Iss. 12*, p. 318. doi.org/10.3390/admsci14120318
33. Sigal, G. Barsade, Constantinos, G.V. Coutifaris, J.P. (2018). Emotional contagion in organizational life. *Research in Organizational Behavior, 38*, 137-151. https://doi.org/10.1016/j.riob.2018.11.005
34. Scherer, K.R., Wallbott, H.G. (1994). Evidence for universality and cultural variation of differential emotion response patterning: Correction. *Journal of Personality and Social Psychology, Vol. 67, Iss. 1,* p. 55. doi.org/10.1037/0022-3514.67.1.55
35. Targiel, K.S. (2022). The Impact of the Covid-19 Pandemic on the Level of Sentiment in IT Projects Implemented in the Open Source Formula. *Scientific Papers of Silesian University of Technology – Organization and Management Series, Vol. 163,* pp. 597-608. dx.doi.org/10.29119/1641-3466.2022.163.37
36. Targiel, K.S. (2023). Analysis of Emotions in IT Projects Implemented in the Open Source Formula using Machine Learning Methods. *Scientific Papers of Silesian University of Technology. Organization and Management Series, Vol. 177*, p. 645-654. doi.org/10.29119/1641-3466.2023.177.37
37. Tourani, P., Yiang, Y., Adams B. (2014). Monitoring sentiment in open source mailing lists: exploratory study on the apache ecosystem. *Proceedings of 24th Annual International Conference on Computer Science and Software Engineering, CASCON'14*, pp. 34-44.
38. Wang, L., Lin, H., Jiang, W. (2021). Effects of project leader workplace anxiety on project team member organizational citizenship behavior: A moderated mediation model. *Project Management Journal, Vol. 52, Iss. 4*, pp. 340-353.
39. Wang, W., Chen, X., Ning, G., Wang, Y., Song S. (2023). The relationship between anger and learning from failure: The moderating effect of resilience and project commitment. *Current Psychology, Vol. 42*, pp. 22726-22737. doi:10.1007/s12144-022-03330-5

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IMMERSIVE AR INSTRUCTION FOR PREPARING A MILLING MACHINE IN LABORATORY

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Purpose: This study aims to develop and evaluate an immersive augmented reality (AR) instruction to support the preparation of a CNC milling machine in a laboratory, addressing the lack of standardized instructions and limited student autonomy.
Design/methodology/approach: The research followed a prototype-based, implementation-experimental approach within a CNC laboratory case study. Key stages of machine preparation were identified, optimal forms of visualization and interaction in AR were defined, and the impact of the AR instruction on student autonomy was evaluated through iterative testing with students of different experience levels.
Findings: The AR instruction increased student autonomy by 150% (from 4/10 to 10/10 engagement), reduced preparation time by 42%, and decreased problem incidents by 90%. Iterative user feedback refined the prototype, improving usability and learning effectiveness.
Research limitations/implications: The study involved a single lab and limited participants (n = 11), affecting generalizability. Future research should explore different machines, larger cohorts, and long-term learning outcomes.
Practical implications: Augmented reality technology support can increase lab efficiency, reduce instructor workload by 80%, and support student self-directed learning. It has applications in technical education and industrial training.
Originality/value: The paper presents a novel AR instruction for CNC machine preparation, incorporating iterative user feedback, and offering practical design guidance for immersive learning in technical education.
Keywords: augmented reality, CNC machine, immersive learning, student autonomy, technical education.
Category of the paper: research paper, case study.

1. Introduction

The dynamic development of production systems and the further increase in their automation and autonomy. While this brings benefits such as cost reduction, increased production capabilities, and product quality, pose a number of challenges for society. More complex devices, employees are required to have a broader range of skills concerning their operation. This also applies to individuals entering the labor market, who should acquire practical skills needed in their profession during their education. Consequently, this necessitates adapting teaching methods and systems to current needs in replicating real-world conditions while maintaining cost efficiency and safety standards. Schools and universities, on one hand, must allow students to interact with various devices, but on the other hand purchasing physical tools such as lathes, machine tools, or transport vehicles involves huge expenses and poses potential threats. Due to this fact, operating such equipment requires constant supervision by the instructor, which means only one person can learn at a time.

Mixed reality technologies can be an important aid in educational processes by enabling the creation of immersive simulations with a high degree of interactivity. Implementing them into the educational process allows for conducting previously unavailable training and provides the opportunity to acquire skills that were previously difficult to obtain in educational institutions.

The following article describes the introduction of the above technology into the teaching process at Białystok University of Technology. It covers activities from the preparation of physical and virtual materials, through conducting classes and comparing their results with the standard use of a physical device, to the evaluation of outcomes. The research problems include the lack of standardized paper instructions in CNC laboratories, the need for continuous instructor assistance during exercises using the device, the varied level of students' competencies in operating CNC machines, and the need to increase students' autonomy in the learning process. The main goal of the research is to develop a methodology for creating an immersive AR instruction for learning how to prepare a CNC milling machine for operation. The specific objectives include the identification of key stages in machine preparation, determining optimal visualization forms in an AR environment, investigating the impact of AR instructions on students' learning autonomy, and developing guidelines for creating virtual instructions in a technical environment.

The study concerns a process that has been practically unexplored in the Polish academic environment: the creation of a comprehensive AR instruction project for a specific CNC machine, focusing on the process of preparing it for operation rather than on machining design. A comparative study was also conducted on the effectiveness of learning with and without experience with the machine, and an iterative methodology for improving augmented reality instructions based on feedback from study participants was applied.

2. Literature review

2.1. Types and definitions of XR technologies

The concepts of virtual (VR), augmented (AR), and mixed reality (MR) are currently considered one of the important technological issues that may affect a range of matters related to the functioning of society, including entertainment, access to culture, private and business communication (Hartmann, Fox, 2021), or industry, for which they are supposed to constitute one of the elements of the so-called Fourth Industrial Revolution (Roberto et al., 2024). All of the mentioned technologies, also collectively referred to as XR, fundamentally concern the use of cybernetics solutions to enhance user capabilities through the constant and immersive creation of digital objects, usually with the use of head-mounted devices (often referred to as goggles), yet they demonstrate significant differences in their scope and purpose of function.

Virtual reality (VR) is based on creating a fully virtual environment, which is displayed directly in front of the eyes of a person wearing goggles that prevent viewing the real surroundings. This makes it possible to fully replicate inaccessible conditions, but functioning with physical objects is practically impossible. Another issue is the manner of movement and interaction, which often requires additional equipment. (Zhao, Ren, Cheah, 2023) Some studies present no fewer than 109 solutions designed to enable users to simulate movement (Lang, 2021). This solution is particularly advantageous when replicating conditions that are difficult to achieve in the location where VR goggles are used (for example, an airplane cockpit, a museum, or a burning warehouse). The first use of this technology dates back to the 1960s (Hartmann, Fox, 2021).

Augmented reality (AR), on the other hand, means overlaying digital elements onto the physical reality surrounding the user. This requires the use of transparent goggles or another medium on which the desired images are displayed. These can include both additional information and various objects. (Zhao, Ren, Cheah, 2023) It can be considered that some of the first examples of applying certain AR solutions were the transparent displays used in combat aviation (so-called HUD, Head-Up Display) (BEASystems), which nowadays are sometimes integrated with goggles, even though it is prototype technology (Pečečnik, Tomažič, Sodnik, 2023). A user utilizing ARs moves in a natural way, while the proper functioning in terms of motion is usually managed by a system in the headset that analyzes the surroundings and the user's behavior.

Mixed reality (MR) represents a direct combination of the virtual and real worlds. In this case, an important aspect is the natural interaction of objects from both categories with each other, which is particularly beneficial when using them for designing new solutions or operating devices. (Wang, Southwick, Robinson, Nitsche, Esch, Mazalek, Welsh, 2024). Occasionally, the term „hybrid reality" is also used to emphasize the connection between virtual and physical objects (Ke, Xiang Zhang, Zuo, 2019). To operate virtual objects, specific gestures are usually

applied, most often mirroring those used with physical devices (for example, „pressing" icons in a virtual interface). Therefore, in some situations, when analyzing theoretical materials, it was necessary to consider the possibility of mixing concepts and to rely on the description of a specific technology or the context of its use.

While the concept of virtual reality is simple and intuitive, the distinction between augmented reality and mixed reality can sometimes be a matter of debate or present challenges. This is visible, among other things, in product descriptions concerning devices, particularly headsets, which can be classified by different distributors as either AR or MR kits. Similarly, some scientific papers do not make a distinction, using the term „AR" to describe solutions that would essentially qualify as MR. At the same time, some theorists consider AR to be a type of MR, placing a greater emphasis on the real world in which digital objects appear (Chang et al., 2022). This arises from a number of similarities between the described technologies, both in terms of visually similar devices (head-mounted displays) and the use of digital elements such as real-time simulation, 3D graphics, human-machine integration technologies. At the same time, the main differences should be taken into account, including those related to hardware requirements, level of immersion, and the interaction itself (Ke, Xiang Zhang, Zuo, 2019).

Thus, the collective term "XR" (extended reality) is often used, which is intended to encompass the aforementioned technologies. (Crogman, Cano, Pacheco, Sonawane, Boroon, 2025) However, it is mainly used in the scientific sphere rather than in the media or commercial sectors. In the further part of the article, the terms VR, AR, MR, and XR and their equivalents will be used in accordance with the definitions described above.

2.2. Platforms for creating industrial AR instructions

In addition to hardware devices, proper functioning of the goggles requires the use of appropriate software and programs with the desired functionalities. These are the ones responsible for the direct user experience. They also allow for the actual use of the equipment, including for educational purposes and for creating instructions. A few examples are presented below.

A product in this category from PTC is the Vuforia program, specifically designed for creating virtual instructions for service and manufacturing companies. The environment also supports mobile devices, including telecommunication devices, as well as augmented reality headsets such as Magic Leap, Microsoft HoloLens 2, and RealWear. The Vuforia Studio component allows for the development of models directly imported from CAD environments. Furthermore, using the program does not require specialized programming knowledge (no-code/low-code). An important element is also the tool for remote support or collaboration using AR technology called Vuforia Chalk. It is intended to make it easier to solve complex problems without the need for the physical presence of consulting or technical teams (PTC).

Another example is the Dynamics 365 Guides application offered by Microsoft, which is more broadly connected, among others, with Microsoft Dynamics 365 Field Service, and is intended to enable the seamless transfer of information and instructions to 'field' employees. The application itself allows for the intuitive preparation of instructions, without requiring the use of specialized notations, for tasks such as the operation and maintenance of a given device. Some actions are performed using goggles, which allows for controlling how the content is presented to the end user. The process itself is divided into steps and allows for the addition of text and multimedia files, as well as built-in shapes (Microsoft).

LightGuide from the company of the same name is another example of an environment for creating instructions in the form of augmented reality, intended for various applications, including production, training, and warehouse management. The main benefit highlighted here is the reduction of reliance on the operator's memory, thereby increasing so-called 'cognitive ergonomics.' The created instructions can be integrated with various types of equipment and mobile devices. According to the manufacturer, the use of this solution reduces training time by 75% (LightGuide).

Another application is Manifest by Taqtile, Inc. In this case, in addition to the functions of creating and generating instructions intended for use in augmented reality, the tool is supported by components utilizing artificial intelligence, thereby replacing some actions with task description inputs (so-called Prompts). In addition, this technology is also characterized by a no-code approach and is intended to be user-friendly and easy to use (Taqtile).

Easemble, in turn, is intended largely for use on traditional mobile devices. It allows for creating simple instructions and generating virtual models of real components in their actual environment. Unlike the previously mentioned tools, here the user is primarily the end customer, often without production qualifications (Easemble).

2.3. Applications in industry and education

Theoretically, the use of AR- and MR-based systems is supposed to offer a number of benefits, including reducing the cost of training a new employee (by up to 50%) and increasing their productivity (by up to 40%) (PTC). The introduction of Vuzix AR Smart Glasses with special software by Airbus within a month led to a sixfold acceleration in the assembly of cabin seats, while Lockheed Martin, in collaboration with Ngrain, increased the production rate of F-35 aircraft by 30% and minimized number of errors (Airforce Technology). Other examples of companies using AR include STERIC (reducing errors and improving the efficiency of industrial dishwashers), Howder (development of instructions for users repairing equipment based on three-dimensional CAD models), Vectrona (accelerating training and enabling remote participation), Peterbilt (increasing service efficiency and accuracy), and Volvo (improving the „quick response" system for failures) (PTC). At the same time, various types of limitations and barriers hinder the widespread adoption of augmented and mixed reality technologies in this industry. These include both internal factors within

companies, such as a lack of understanding of the significance and benefits of implementing headsets, insufficient funding, and the time resources required for implementation, as well as external factors related to the relatively low software quality in terms of lacking proper functions, difficulties in use, or failure to meet industrial requirements (Roberto et al., 2024).

Examples of industrial use of augmented and mixed reality technologies indicate their important role in employee training. This is connected with one of the proposed areas of its implementation, namely education. The main advantages in this regard include the possibility of using immersive simulations that realistically replicate various objects or environments while ensuring user safety, reducing costs due to the lack of need for physical objects, and a wide range of situations that can be presented. They also enhance the possibilities for remote or hybrid learning and increase the attractiveness of training sessions (Al-Ansi, Jaboob, Garad, Al-Ansi, 2023).

An important aspect thus becomes identifying the possibilities of implementing XR solutions in the context of education at various stages, including during technical studies. This primarily concerns so-called experiential or experimental learning, in which the trainee has the opportunity to directly encounter or observe a given phenomenon in natural conditions. Classic examples of tools used in this teaching method include conducting experiments, study visits, workshops, trips, and, more recently, the introduction of XR technology (Crogman, Cano, Pacheco, Sonawane, Boroon, 2025). The first attempts to use it date back to the decade 1989-1999, when its potential in the fields of physical sciences and medicine was being tested. In subsequent years, along with the development of technology, including both the VR headset kits themselves as well as broader computer science and cybernetics, the possibilities for implementation increased (Sala, 2021). The basic advantages include the ability to enhance immersion, present 3D models in a realistic way, increase engagement, solve more realistic problems, and offer extensive visualization possibilities for certain concepts that are not accessible under normal conditions (Chang et al., 2022; Abdullah et al., 2022). Essentially, the number of studies conducted in this area is increasing, which is reflected in a similar trend in publications on the subject (Koumpouros, 2024). To date, research has relatively rarely focused on the use of XR technology among students of technical fields, although it has been widely applied in the sciences (Abdullah et al., 2022), primarily for visualizing various issues. Most studies have focused on comparing the effects of standard instructions with AR-based instructions (Chang et al., 2022). Due to the potential of using AR and MR glasses in production and the importance of a properly trained employee, it is considered appropriate to conduct further research in this area.

3. Research methodology

The conducted study was qualitative with quantitative elements and was based on an iterative approach. It was carried out in the form of a case study of the CNC laboratory at the Faculty of Management Engineering at Bialystok University of Technology. This methodological approach is widely used in research on educational technologies, where iterative improvement of the prototype based on continuous feedback from end users is crucial. The research process involved the systematic enhancement of the immersive AR instruction prototype based on observations, interviews, and tests with the participation of the instructor and students with varying levels of experience.

The study utilized Microsoft HoloLens 2 goggles, which are mixed reality devices combining features of augmented reality with the ability to interact with virtual objects in a physical environment. The choice was based on the device's advanced technical capabilities and the availability of a dedicated platform for creating industrial and educational instructions in an AR environment. The goggles allow for gesture control without the need for physical manipulators, provide stable head mounting, and offer a battery life of 2-3 hours.

A total of eleven people participated in the study, divided into three categories differing in skill level. The first category consisted of an expert a research staff member who conducts classes in the CNC laboratory and has many years of experience. His role was to verify the instructional content for accuracy and identify key moments where students most commonly make mistakes. The second group consisted of four students from technical fields with previous experience operating CNC milling machines. The third and largest group comprised six students with no prior experience operating CNC milling machines, who represented the target audience of the instructions.

Demographic characteristics such as age and gender were not collected or analyzed, as the focus of the study was on the relationship between prior technical experience and the effectiveness of AR instructions. All participants were enrolled in the same engineering program and shared similar educational backgrounds in technical subjects, which provided a relatively homogeneous sample in terms of relevant technical knowledge and spatial reasoning abilities. The decision not to analyze demographic variables was justified by the study's specific focus on experiential learning and skill acquisition, where prior hands-on experience with CNC machines was identified as the primary variable of interest.

In the research process, methodological triangulation was applied. The primary method was participant observation, conducted both during the prototype development stage and during its practical use. Observations were systematically documented in the form of meeting notes. Complementing the observations were semi-structured interviews conducted with participants immediately after the completion of each testing session. Additionally, participants completed satisfaction questionnaires. All qualitative data were supplemented with quantitative

measurements, including the time taken to complete individual steps of the instructions, the number of errors made, and the frequency of the facilitator's interventions. The total time required for each participant to complete the entire machine preparation process was recorded using a digital stopwatch. Timing began when the participant put on the HoloLens 2 headset and ended when they successfully completed the final step of the preparation sequence. An independent observer (a research assistant trained in the measurement protocol) was responsible for all time measurements to ensure consistency and objectivity across all testing sessions. The observer remained at a fixed position in the laboratory with a clear view of the participant and the milling machine but did not interact with participants during the task execution unless a critical safety issue arose. Throughout each testing session, the observer maintained field notes documenting participants' behaviors, verbal expressions, and non-verbal cues indicating understanding, confusion, confidence, or frustration. These observations were particularly valuable for identifying interface ergonomics issues and usability problems that quantitative metrics alone might not capture. After each stage of testing, feedback from participants was systematically analyzed to identify recurring themes and specific areas requiring improvement. This feedback directly informed the modifications made in subsequent prototype iterations, following an agile development approach that prioritized user-centered design.

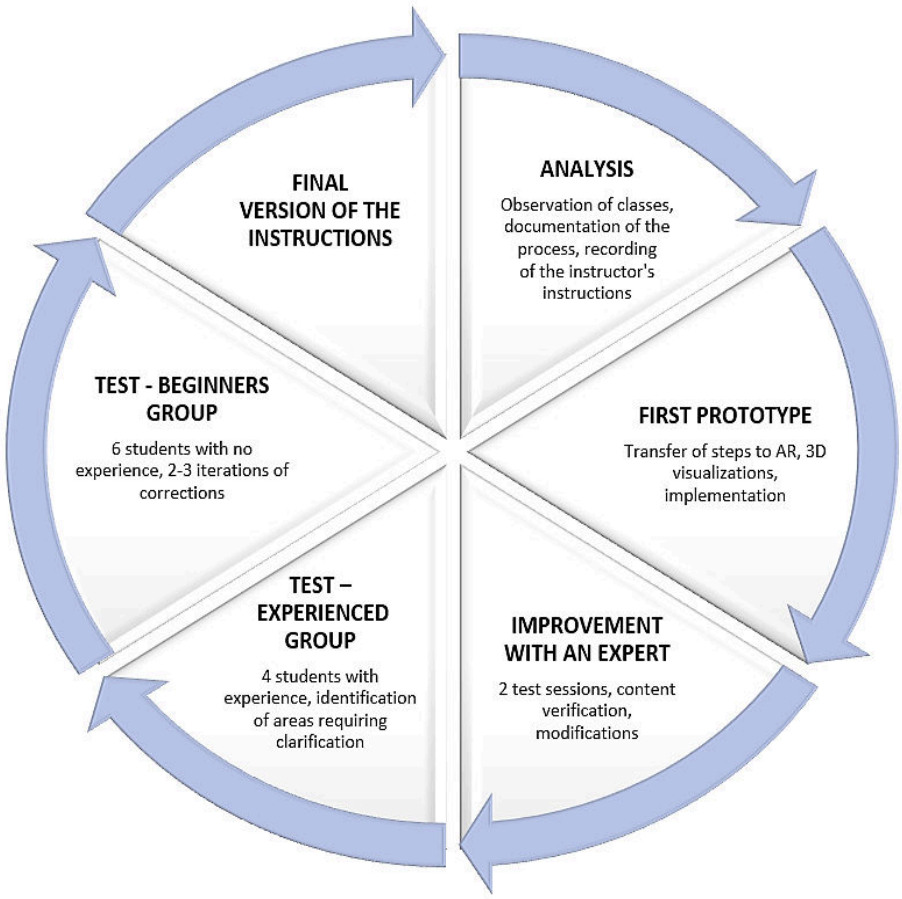


Figure 1. Research study design.

Source: own study.

The study was divided into five main stages (Figure 1). Stage 1 (needs analysis) was exploratory in nature – laboratory classes were observed, and the most common problems encountered by students were identified. Stage 2 involved developing the first prototype of AR instructions with three-dimensional visualizations of key elements of the milling machine. Stage 3 constituted an iterative refinement phase in collaboration with an expert (2-3 test sessions). Stage 4 included testing with a group of four experienced students, which allowed for the identification of information redundancies and interface ergonomics issues. Stage 5 involved testing with a group of six novices – this phase was validation-oriented and enabled the implementation of the final iterations of prototype improvements.

4. Research results

The iterative process of refining AR instructions yielded a number of significant observations regarding the design of immersive interfaces in the context of technical education. Each stage of testing revealed new aspects of user interaction with the augmented reality environment, which required modifications both in terms of the content and the way information was presented.

4.1. From visual chaos to clarity - the evolution of the first iteration

The preliminary version of the AR instructions, although substantively correct and complete, proved insufficient for students without prior experience to independently carry out the full process of preparing the milling machine. During initial tests with an expert and a group of experienced students, fundamental problems related to the organization of visual information and the structure of the message emerged. The study leader noted that some activities, which in the traditional teaching process were conveyed orally with the possibility of immediate demonstration, required a much more precise contextual description in the instructions, as well as support in the form of video materials. Particularly problematic were the procedures related to setting the tool at the zero points for individual axes, which required not only understanding the theoretical concept but also precise execution of the sequence of movements. During the interview, it was noted that „The instruction is logical, but a student without experience will not know how to set the tool at the zero points. It would be good to show this in a video – then everyone would understand what it is about".

An equally significant problem turned out to be the excess of visual elements in individual steps of the instructions, which led to confusion. Students from the experienced group reported that too many arrows, labels, and photos displayed simultaneously caused difficulties in identifying the most important information. One participant expressed it as follows: "There were so many arrows on one screen that I didn't know where to look first". Additionally,

some of the video materials duplicated content already present in the static images, leading to informational redundancy. Another student noted, „The video and photos showed the same thing – I wasted time trying to figure out what was more important".

In response to the identified issues, a series of modifications were introduced to simplify the interface and improve the readability of the instructions. The number of visual elements displayed simultaneously was reduced. Individual photos were replaced with collages illustrating sequences of actions in a single view (example in Figure 2 and Figure 3).

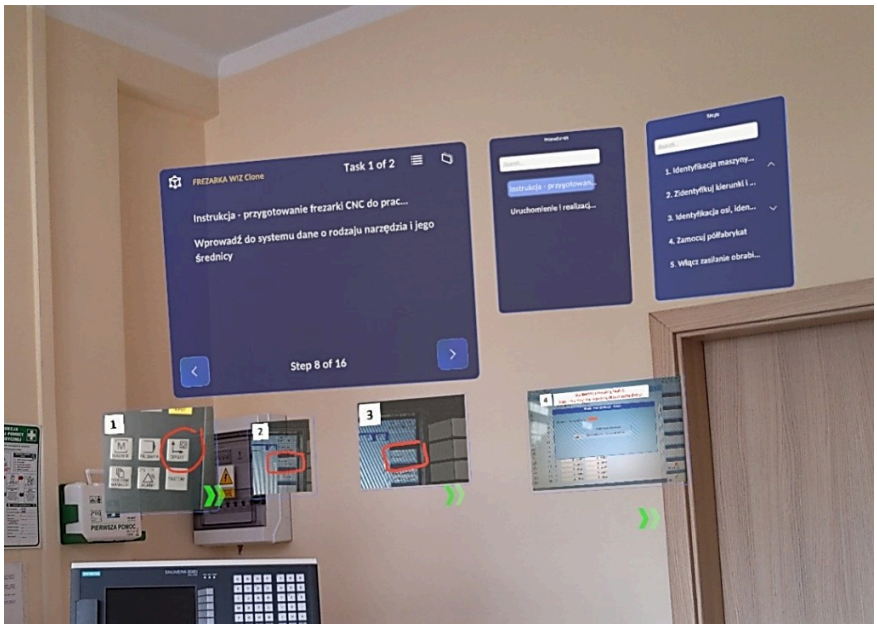


Figure 2. Example of action sequence before modifications.

Source: own study.

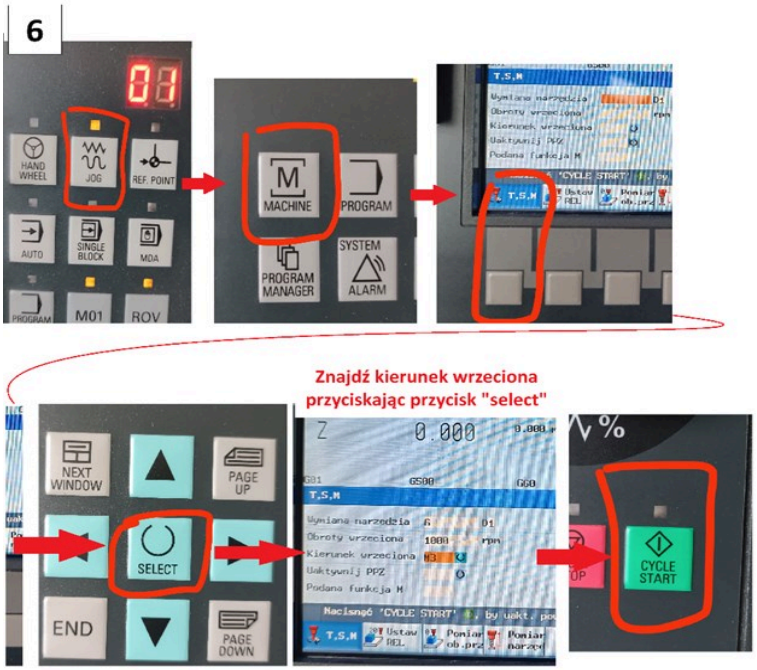


Figure 3. Example of action sequence after modifications.

Source: own study.

Additional textual descriptions explaining key technical concepts have also been introduced. Special attention was paid to standardizing the color scheme: red arrows for warnings, green for subsequent steps, blue for contextual information.

4.2. Interface ergonomics as the key to user autonomy

Despite significant improvements introduced after the first iteration, subsequent tests revealed issues related to the ergonomics of the AR interface and users' visual perception. Some students reported difficulties reading small graphical elements, despite the automatic calibration of the HoloLens 2 goggles. The problem was particularly pronounced in situations where participants slightly shifted the goggles during use. One student described it as follows: „When my glasses were slightly shifted, I couldn't see the texts clearly. After enlarging the images and moving them above the cockpit, it became much easier".

Another significant problem turned out to be the spatial arrangement of the interface elements in relation to the work area. In the second version of the instructions, the AR interface was placed at some distance from the milling machine, which required users to frequently shift their gaze between the machine and the virtual instructions. Additionally, there was a lack of precise markings on the buttons and control elements on the milling machine's cockpit, which forced students to identify the correct controllers themselves based on textual descriptions.

In the third iteration of the prototype, comprehensive changes were introduced aimed at optimizing interface ergonomics. Most graphics were significantly enlarged. The AR interface was positioned directly above the milling machine cockpit, so that it is within the user's natural field of view during operation. A system of clear markings in the form of red frames was implemented, applied directly to the buttons and control elements in the actual cockpit. For the most complex procedures, dedicated demonstration videos were added, showing precise hand movements and the desired end result.

The effects of the implemented changes exceeded expectations. In the final version of the instructions, all participants in the novice group were able to independently prepare the machine for operation using only the AR instructions, without any intervention from the instructor. The average machine preparation time was reduced by 42% compared to the first iteration, and the number of errors committed dropped to almost zero. As one participant stated: „When the buttons were marked in the pictures, everything became clear". Another added: „I no longer had to ask the instructor; I would just go back to the previous step if I missed something". Particularly interesting was the comment from a student: „Now it's more like a game—you just go step by step and everything works".

4.3. Quantitative analysis of iteration effects

The machine preparation process was decomposed into 15 distinct steps (S1-S15), each representing a critical action required to safely and correctly prepare the CNC milling machine for operation. These steps were defined based on the standard operating procedures used in the laboratory and validated by the expert instructor. Systematic measurement of the execution time of individual instruction steps, as well as the recording of all problem incidents, allowed for an objective assessment of progress in successive prototype iterations. Problem incidents were operationally defined as any occurrence requiring external intervention or correction, including: (1) explicit instructor intervention when a student performed an incorrect action or was unable to proceed, (2) student errors requiring correction (e.g., selecting wrong machine components, incorrect sequence of operations), (3) prolonged hesitation exceeding 30 seconds at a single step, and (4) safety-related stops initiated by the instructor or student (see Table 1).

Table 1.
Number of problem incidents in key steps of the instructions

Step	Stage 1	Stage 2	Stage 3
S1	1	0	0
S2	1	0	0
S3	3	0	0
S4	3	1	0
S5	2	0	0
S6	2	1	0
S7	4	0	0
S8	6	0	0
S9	9	0	1
S10	7	1	0
S11	3	1	0
S12	3	0	0
S13	1	1	0
S14	3	0	0
S15	1	0	0
Total	49	5	1
Reduction compared to stage I	-	90%	98%

Source: own study.

Each step builds upon the previous ones, creating a logical sequence that students must complete in order to successfully prepare the machine for actual machining operations.

In the first stage of testing, a total of 49 problem incidents were recorded. The most problematic steps turned out to be those related to setting zero points and operating the cockpit (S7-S10), where a total of 26 incidents were recorded (53% of all problems). This distribution indicated that the main difficulties arose when transitioning from simple mechanical tasks to more complex procedures requiring an understanding of technical concepts and precise execution of movement sequences.

In the second stage, the number of incidents dropped drastically to just 5, representing a 90% reduction. The incidents in this stage were of a different nature – they did not result from misunderstanding the instructions, but rather from participants being overly cautious and asking for confirmation that they had performed a step correctly, even though they had actually completed it properly.

In the third iteration, nearly complete elimination of problems was achieved, with only one incident recorded at step 9, related to a temporary technical issue with the calibration of the goggles for one of the participants. The remaining participants completed all steps without any intervention from the facilitator.

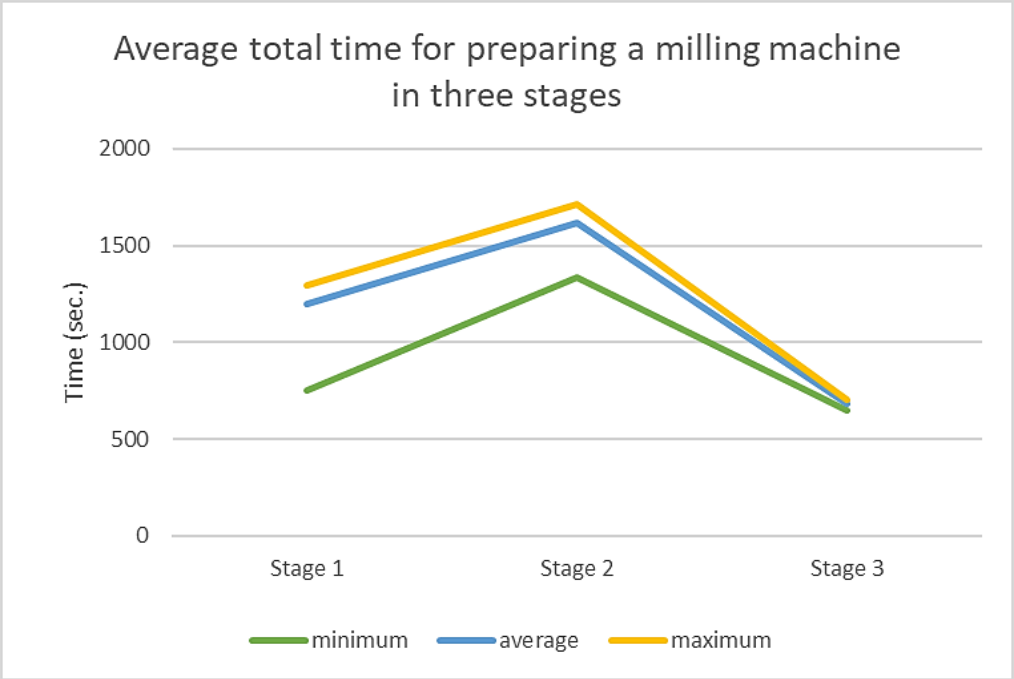


Figure 4. Average total preparation time of the CNC milling machine at different stages of the study. Source: own study.

The graph of average total time (Figure 4) clearly shows the paradox of the second stage, where the time increased by 14% compared to the first stage, followed by a drastic decrease in the third stage, achieving a 42% reduction relative to the starting point. This apparent paradox, which is longer completion time despite improved instructional materials, reflects a shift from superficial task execution to deeper conceptual engagement.

Behavioral observations from Stage 2 revealed that participants spent more time watching demonstration videos, often replaying them multiple times, and carefully studying the newly added contextual text explanations. Verbal think-aloud data further showed that participants were actively reasoning about why specific procedures were required rather than simply following visual cues. For example, one participant noted: "Oh, so the reference point establishes where the machine thinks it is". Such engagement contrasts sharply with Stage 1 behavior, where participants relied on prior experience, frequently making errors that required correction. The additional time in Stage 2 thus represented productive cognitive effort rather

than inefficiency, ultimately leading to the substantial performance improvement observed in Stage 3.

Although advanced cognitive load measures (e.g., eye-tracking) were not employed, convergent evidence from observer notes, participant comments, and performance data strongly supports this interpretation. Future research incorporating these methods could further clarify how instructional design fosters optimal balances between immediate task completion and long-term understanding.

5. Discussion

5.1. Transformation of the teaching model - from dependence to autonomy

One of the most significant effects of introducing AR instructions was a fundamental change in the teaching model from the traditional one, based on continuous guidance from the instructor, to an autonomous model in which the student independently controls the pace and manner of completing the task.

Table 2.
The evolution of the teaching model in successive stages

Stage	Commitment	Level of autonomy
Stage I	4/10	Continuous assistance from the instructor, pointing to buttons
Stage II	7/10	Periodic questions to the instructor, independent completion of most tasks
Stage III	10/10	Complete independence, instructor acting as an observer

Source: own study.

In the first stage, students performed tasks only after receiving explicit instructions from the instructor, often waiting for a physical indication of the correct machine component. The instructor was forced to continuously monitor each participant, which practically made it impossible to work with a larger number of students simultaneously. In the third stage, all participants were able to prepare the milling machine for work independently. The instructor acted as an observer and was present only for safety reasons. This transformation leads to increased laboratory throughput and a reduction of the instructor's workload by approximately 80%.

5.2. The advantage of AR instructions over traditional methods

Table 3.
Comparison of the traditional method with the AR instruction

Teaching aspect	Traditional method	AR instruction	Effects of change
Work autonomy	Small, constant supervision required	Big, the student can work independently	The ability for many students to work simultaneously
Learning pace	Low, the need to wait for the instructor's availability	Adapted to the student, work at a pace depending on the student's abilities	Better alignment with the student
Standardization	Small, dependent instructions of the instructor	High, standardized instructions for each participant	Standardization of the educational process
The number of students performing actions simultaneously	Limited by the number of machines and instructors (usually 1)	Limited by the number of AR devices	A larger number of students performing tasks simultaneously (provided there are more goggles)
Ability to return to instructions	Based on inquiry - the necessity of asking the instructor a question, the repeated instruction will usually differ from the original	Flexible – the student can go back to previous steps at any time	Increase in the student's ability to self-improve and correct mistakes
Instructor's workload	High, requiring constant supervision and providing additional instructions	Low, supervision over the group and possibly explaining problems	The ability to provide more answers in ambiguous situations
Student comfort and engagement	Low, fear of being judged by the group when asking questions, waiting time for the opportunity to start working encourages distraction	High, individual work and comfortable learning from mistakes, little or no waiting time for the opportunity to act	Greater comfort and student engagement positively affect their learning.

Source: own study.

The comparison reveals fundamental differences that impact the effectiveness of the teaching process. In the traditional method, the complete lack of standardization meant that each student received a slightly different version of instructions, depending on the current knowledge of the instructor, their fatigue, or time pressure. The student had no opportunity to return to earlier stages of the process without seeking help again, which often caused feelings of awkwardness and fear of being judged as less capable.

In contrast, the AR instruction in its final version provides full standardization of the process for all students, eliminating the human factor as a source of variability in teaching quality. The ability to freely go back and repeat steps is a fundamental advantage – a student can return to a previous stage, review the instructions again, and correct their actions without any social pressure. Simultaneous support for multiple stations means that theoretically an unlimited number of students can use the AR instruction at the same time, which radically increases the laboratory's throughput.

5.3. Key success factors in AR instruction design

The analysis of the iterative process identified five key factors that determine the effectiveness of AR instructions in technical education. These include multimodal support, which involves skillfully combining different forms of communication tailored to the specifics of individual tasks. Text descriptions are essential for explaining theoretical concepts, static images are effective for presenting target positions, collages are useful for illustrating step sequences, and video materials provide the most comprehensive form of communication for complex procedures requiring the simultaneous execution of several coordinated movements; **contextual placement** of content, that is, the positioning of AR interface elements in physical space, which minimizes the user's cognitive load. Placing key instructional elements directly above the milling machine cockpit radically shortened task completion time. Overlaying labels directly onto the physical machine components eliminates the need for mentally mapping information from the instructions to the real objects; **visual consistency**, in the form of appropriate use of graphic elements, color schemes, and information hierarchy. Users quickly learn the meaning of individual visual elements if they are applied consistently. A color-coding system (red - warnings, green - next steps, blue - contextual information) allows for intuitive navigation through the instructions; **progressive simplification**, that is, the systematic elimination of unnecessary visual and informational elements. An excess of visual elements leads to perceptual chaos and increases the time needed to process information. The principle of „less is more" has proven fundamental for designing effective AR interfaces, where visual space is limited, and the user must simultaneously process information from both the physical and virtual reality; **feedback loops**, that is, mechanisms for confirming the completion of steps as well as the possibility of self-monitoring and self-correction. Adding photos showing the final effect of each step allowed users to independently verify the correctness of the actions performed. The ability to freely go back to previous steps supports the learning process through trial and error, which is natural for humans.

Research on the application of augmented reality technology in training and education is not a domain of recent years. The issues of implementing AR in higher education and employee training have been considered for a relatively long time; however, they often remained theoretical or developmental proposals due to costs and imperfections of the devices themselves (Lee, 2012). Technological development in many respects has solved this problem, making more accurate, as well as accessible and convenient, tools available. A key issue is to compare and assess to what extent the use of augmented reality technology enhances (or does not enhance) the knowledge acquisition process. Between 2014 and 2023, there was a dynamic increase (except for the year 2016) regarding the number of publications on empirical studies concerning higher education classes using virtual instructions, reaching over 30 in the record year of 2020. Furthermore, the vast majority of analyses were empirical in nature (Li, Luo, Chen, Wang, Yin, Zhang, 2025). Research may focus on experiences related to the use of

goggles (Saez-Lopes, Cozar-Gutierrez, Gonzalez-Calero, Corrasco, 2020); however, introducing a comparative analysis between traditional methods and those utilizing augmented reality technology represents a very important direction of research that makes results more objective. An example of this is the comparison of test results of student groups preparing either without or with AR technology, where in the latter case, there was a significant improvement not only in performance but also in student engagement (Tian, Ironsi, 2025). Another example was the implementation of augmented reality techniques for learning 3D object design in a virtual environment, where an improvement in pass rates of over 20 percentage points was also observed (Rizov, Rizova, 2015).

The originality of this study is evident in several aspects. First, the detailed documentation of the design process itself and the iterative refinement of the AR instructions provides valuable guidance for future designers. Second, it is one of the few studies conducted in the Polish academic environment. Third, the focus on the process of preparing the machine for work, rather than on programming or the machining process itself, fills a gap in the literature. Fourth, the use of a mixed-methods approach, combining qualitative and quantitative methods, allowed for obtaining both deep descriptions of user experiences and objective measures of effectiveness.

5.4. Study limitations and directions for future research

This study has a number of limitations that should be considered when interpreting the results. The first limitation is the relatively small sample size (n = 11), which does not allow for advanced statistical analyses or generalization of the findings to larger populations. Some students participated in subsequent stages of the study, introducing a potential learning effect independent of the AR instruction itself. The second limitation is the focus on a single specific machine in one laboratory, meaning that directly transferring the solution to a different type of machine would require significant adaptations. The third limitation is the lack of long-term measurement of knowledge retention – the study did not assess how long students retain the ability to independently set up the machine after a week, a month, or a semester following the training. Additional limitations are hardware issues related to the HoloLens goggles (overheating, limited battery life, weight), controlled laboratory conditions that differ from real industrial conditions, and the lack of a control group learning using traditional methods during the same period.

The identified limitations indicate directions for future research:

- Study on a larger sample with a control group and participant randomization.
- Long-term analysis of knowledge retention (tests after a week, a month, a semester).
- Analysis of skill transfer to other types of CNC machines.
- Expansion of instructional content to include machining programming elements.
- Testing in real industrial conditions with typical stressors.

- Application of advanced methods for cognitive load analysis.
- International comparative studies in different cultural contexts.

6. Summary

The conducted study provides compelling evidence that immersive augmented reality instructions can effectively support the learning process for operating complex technical devices in an academic environment. The application of an iterative approach involving end-users allowed for a 42% reduction in machine setup time, a 90% decrease in the number of problematic incidents, and an increase in student autonomy from 4/10 to 10/10 engagement points.

The most important conclusion is the observation that iterative design involving end users is necessary to create an effective AR instruction. None of the prototype versions reached a satisfactory level of functionality without multiple tests and modifications based on observations of real-world usage. This conclusion has significant practical implications for institutions and companies planning to implement AR technology – they must account for the time and resources required for the testing and refinement phase in their budgets and schedules.

The second key conclusion is a radical change in the teaching model resulting from the use of AR instructions – a shift from students being fully dependent on the continuous assistance of the instructor to complete autonomy in performing the task. The instructor ceases to be the source of procedural knowledge and becomes a designer of educational experiences and a mentor. This change in role aligns with the principles of contemporary pedagogy, yet the implementation of these principles in technical education has so far been limited due to the need for direct demonstration of manual activities.

The third significant conclusion is the fundamental importance of video materials for the effectiveness of AR instructions in the case of complex tasks requiring spatial precision and sequential movements. Static images proved insufficient for illustrating dynamic procedures. At the same time, overusing video materials can lead to longer task completion times, so designers must make a conscious choice of the form of communication.

The fourth conclusion is the particular importance of AR interface ergonomics – seemingly minor design decisions regarding the size of graphical elements, their placement relative to the workspace, or device calibration have a direct and significant impact on the usability of the entire solution. Even an instruction that is factually correct can be nonfunctional if the user has difficulty visually perceiving the interface elements.

The fifth conclusion is the phenomenon of spontaneous gamification of the learning process, where students begin to perceive working with an AR instruction as a form of interactive game. In the case of the study, gamification was not intentionally designed but arose

naturally from the characteristics of the AR interface, which structures the task into clearly defined steps, provides immediate visual feedback, and allows progress tracking.

The final conclusion is the importance of the 'less is more' principle in AR interface design. An effective instruction does not consist of maximizing the amount of presented information, but of consciously selecting the appropriate form of communication and eliminating all unnecessary or redundant elements. In the context of AR, this principle becomes particularly significant due to the limited visual space and the need to simultaneously process information from both the physical and virtual reality.

In summary, the study confirms the significant potential of AR technology in higher education, while also revealing that designing effective instructions requires an iterative approach, special attention to interface ergonomics, and a conscious selection of delivery methods. AR technology is not a universal solution and comes with technological limitations and implementation costs; however, in appropriate contexts and with proper design, it can be a valuable complement to traditional teaching methods, opening up new possibilities for personalizing the educational process and supporting learners' autonomy.

Acknowledgements

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References

1. Abdullah, N., Baskaran, V., Mustafa, Z., Ali, S., Zaini, S. (2022). Augmented Reality: The Effect in Students' Achievement, Satisfaction and Interest in Science Education. *International Journal of Learning Teaching and Educational Research. Vol. 21, Iss. 5*, pp. 326-350, doi: 10.26803/ijlter.21.5.17
2. Al-Ansi, A., Jaboob, M., Garad, A., Al-Ansi A. (2023). Analyzing augmented reality (AR) and virtual reality (VR) recent development in education. *Social Sciences & Humanities Open, Vol. 8, Iss. 1*, pp. 100532-100542, doi: https://doi.org/10.1016/j.ssaho.2023.100532
3. *AR and VR's role in aviation*. Retrieved from: https://www.airforce-technology.com/analyst-comment/ar-vr-role-aviation/?cf-view, 19.09.2025.

4. Chang, H.-Y., Binali, T., Liang, J.-C., Chiou, G.-L., Cheng, K.-H., Lee, S., Tsai, C.-C. (2022). Ten years of augmented reality in education: A meta-analysis of (quasi-) experimental studies to investigate the impact. *Computers & Education, Vol. 191*, pp. 104641-104665, doi: https://doi.org/10.1016/j.compedu.2022.104641
5. Crogman, H., Cano, V., Pacheco, E., Sonawane, R., Boroon, R. (2025). Virtual Reality, Augmented Reality, and Mixed Reality in Experiential Learning: Transforming Educational Paradigms. *Educ. Sci., Vol. 15(3),* 303, doi: https://doi.org/10.3390/educsci15030303
6. Easemble. *Step into the Future with Augmented Reality (AR) Feature.* Retrieved from: https://www.easemble.com/features/augmented-reality, 20.09.2025.
7. Hartmann, T., Fox, J. (2021). Entertainment in Virtual Reality and Beyond: The Influence of Embodiment, Co-Location, and Cognitive Distancing on Users' Entertainment Experience. In: P. Vorderer, C. Klimmt (Eds.), *The Oxford Handbook of Entertainment Theory* (pp. 717-732). Oxford: Oxford University Press.
8. *Industrial Augmented Reality.* Retrieved from: https://www.ptc.com/en/technologies/augmented-reality, 19.09.2025.
9. Ke, S., Xiang, F., Zhang, Z., Zuo, Y. (2019). A enhanced interaction framework based on VR, AR and MR in digital twin. *Procedia CIRP, Vol. 128*. pp. 753-758, doi: https://doi.org/10.1016/j.procir.2019.04.103
10. Koumporos, Y. (2024). Revealing the true potential and prospects of augmented reality in education. *Smart Learning Environments, Vol. 11*, pp. 1-62, doi: https://doi.org/10.1186/s40561-023-00288-0
11. Lang, B. (2021). *Locomotion Vault Catalogs & Compares 100+ VR Movement Techniques*. Retrieved from: https://www.roadtovr.com/locomotion-vault-vr-movement-techniques-catalog-database/#google_vignette, 18.09.2025.
12. Lee, K. (2012). Augmented Reality in Education and Training. *TechTrends, Vol. 56,* pp. 13-21, doi: 10.1007/s11528-012-0559-3
13. Li, G., Luo, H., Chen, D., Wang, P., Yin, X., Zhang, J. (2025). Augmented Reality in Higher Education: A Systematic Review and Meta-Analysis of the Literature from 2000 to 2023. *Educ. Sci., Vol. 15, Iss. 6*, doi: https://doi.org/10.3390/educsci15060678
14. LightGuide. *How AR-Powered Digital Work Instructions Drive Operational Excellence in Manufacturing*. Retrieved from: https://www.lightguidesys.com/resource-center/blog/digital-work-instructions-explained-the-ultimate-guide/, 20.09.2025.
15. Microsoft. *Usługa Dynamics 365 pomaga pracownikom współpracować i uczyć się.* Retrieved from: https://www.microsoft.com/pl-pl/dynamics-365/topics/augmented-reality/what-is-augmented-reality, 20.09.2025.
16. Pečečnik, K., Tomažič, S., Sodnik, J. (2023). Design of head-up display interfaces for automated vehicles. *International Journal of Human-Computer Studies, Vol. 177,* pp. 103060-103077, doi: https://doi.org/10.1016/j.ijhcs.2023.103060

17. PTC. *Vuforia: Market-Leading Enterprise AR.* Retrieved from: https://www.ptc.com/en/products/vuforia, 20.09.2025.
18. Rizov, T., Rizova, E. (2015). Augmented reality as a teaching tool in higher education. *International Journal of Cognitive Research in Science, Engineering and Education, Vol. 3*, pp. 7-15.
19. Robert, R., Breyer, F., Betts, J., Newnes, L., Shokrani, A. (2024). A Study of Commercial Augmented Reality Applications in Manufacturing: A Subject Matter Expert Analysis. *Procedia CIRP, Vol. 128,* pp. 186-191, doi: 10.1016/j.procir.2024.04.003
20. Sala, N. (2021). Virtual Reality, Augmented Reality, and Mixed Reality in Education: A Brief Overview. In: D. Choi, A. Dailey-Hebert, J.S. Estes (Eds.), *Current and Prospective Applications of Virtual Reality in Higher Education.* New York: IGI Global.
21. Sáez-López, J.M., Cózar-Gutiérrez, R., González-Calero, J., Carrasco, C. (2020). Augmented Reality in Higher Education: An Evaluation Program in Initial Teacher Training. *Educ. Sci., Vol. 10, Iss. 2,* doi: https://doi.org/10.3390/educsci10020026
22. Taqtile. *The AI-powered, everyday digital work assistant platform.* Retrieved from: https://taqtile.com/manifest/, 20.09.2025.
23. Tian, X., Ironsi, C. (2025). Examining the impact of augmented reality on students' learning outcomes. *Scientific Reports, Vol. 15*, doi: https://doi.org/10.1038/s41598-025-20833-w
24. Wang, X.M., Sothwick, D., Robinson, I., Nitsche, M., Resch, G., Mazalek, A., Welsh, T. (2024). Prolonged exposure to mixed reality alters task performance in the unmediated environment. *Scientific Reports, Vol. 14*, doi: https://doi.org/10.1038/s41598-024-69116-w
25. *What is a Head-up Display?* Retrieved from: https://www.baesystems.com/en-us/definition/what-is-a-head-up-display, 18.09.2025.
26. Zhao, X., Ren, Y., Cheah, K. (2023). Leading Virtual Reality (VR) and Augmented Reality (AR) in Education: Bibliometric and Content Analysis From the Web of Science (2018-2022). *SAGE Open, Vol. 13, Iss. 3*, doi: https://doi.org/10.1177/21582440231190821

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THEMATIC MAPPING AND EVOLUTION OF RESEARCH ON GENERATIONS IN ORGANIZATIONS USING VOSVIEWER: A BIBLIOMETRIC APPROACH

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Purpose: The aim of the study is to map and analyze the scientific literature on intergenerational differences, generational identity, and marginalization in organizational and social contexts from 1993 to 2026. The research identifies the main research streams, thematic evolution, and gaps, particularly regarding younger generations (Y, Z, Alpha) and intergenerational diversity in the workplace.
Design/methodology/approach: The study is based on a bibliometric and thematic analysis of 41 publications from the Scopus database (BUSI, SOCI). VOSviewer was used to visualize keyword co-occurrences, map thematic evolution, and identify research clusters.
Findings: Research has evolved from demographic and cohort-based approaches to analyses of identity, values, and intergenerational interactions. Dominant topics include generational differences, generational identity, and intergenerational diversity. There is growing interest in younger generations, particularly Generation Z.
Research limitations/implications: The analysis is limited to 41 publications and the Scopus database, which may not cover the entire global body of research. Future studies should expand the sample, consider various cultural and institutional contexts, and examine the impact of generational diversity on organizational outcomes.
Social implications: The study raises awareness of the risk of marginalizing employees due to generational stereotypes, supports inclusion, and promotes a responsible approach to workplace diversity.
Originality/value: The study combines bibliometric and thematic approaches in analyzing generational differences and marginalization, revealing the evolution of research and identifying gaps relevant to scholars in management, sociology, and work psychology.
Keywords: generational differences; generational identity; marginalization; intergenerational relations; multigenerational workplace.
Category of the paper: research paper; bibliometric analysis**.**

1. Introduction

Intergenerational differences, generational identity, and phenomena of marginalization in organizational and social contexts currently constitute a significant area of interdisciplinary research. In the scientific literature, this topic is gaining importance not only in management studies but also in sociology, psychology, and human capital research (Costanza et al., 2023; Fuchs et al., 2023; Seifert et al., 2023). Generations are not merely a simple demographic classification but complex socio-cultural constructs encompassing shared historical experiences, values, narratives, and identity (Mannheim, 1952; Ortega y Gasset, 1992; McCrindle, 2014). Understanding these phenomena is crucial in the context of managing age diversity in organizations, designing HR policies, and analyzing intergenerational relations in society.

The aim of this study is to systematically map and analyze the scientific literature on intergenerational differences, generational identity, and marginalization in organizational and social contexts from 1993 to 2026. The study primarily seeks to identify the main research streams, including dominant topics, theories, and concepts used in the literature, as well as to examine the thematic and temporal evolution of research on generations in management and sociology. An important element is also to determine the structures of connections between key concepts in the literature, such as generational differences, generational identity, and marginalization, which allows for understanding how theoretical and empirical research complement each other. Another objective is to identify research gaps and potential directions for future studies, particularly concerning younger generations (Y, Z, Alpha) and issues related to intergenerational diversity in the workplace, thereby outlining areas requiring deeper investigation in future research.

Based on the research objectives, research questions were formulated from a bibliometric and thematic perspective. Primarily, the study aims to determine which main thematic streams dominate the scientific literature on generational differences in organizations and social contexts during the analyzed period. It is also important to understand how research on generations has evolved over time and what thematic shifts can be observed. Further questions concern identifying which concepts and constructs play a central role in studies on generational differences and generational identity, as well as the relationships between theoretical and empirical research. The study also aims to identify research gaps and underexplored areas in the context of intergenerational diversity and marginalization in organizations, and to determine how geographic and institutional contexts shape the directions of research on generational differences.

2. Literature review - generational identity as a socio-cultural construct

An individual's development depends on the environment in which they grow up – from family relationships, through school experiences, to interactions during adolescence and career path choices. Each person participates in a diverse socio-cultural development over which they had no control, which significantly shapes the characteristic traits of particular generations. As Mark McCrindle (2014) emphasizes, generations differ not only in their birth dates but also in the context of the world in which they grew up (Folta, 2020, p. 23). José Ortega y Gasset defines a generation as a historical unit, encompassing shared sensibilities, worldviews, and behavioral patterns of individuals shaped by the same era (Ortega y Gasset, 1992). Mannheim, on the other hand, points out that generations are not merely age groups but groups of people who share a common position within a socio-historical context and a sense of collective experience (Mannheim, 1952). From a research perspective, these theories help to understand how shared historical experiences shape generational identity, as well as the risk of identity reduction and the marginalization of individuals who do not fit into stereotypical generational frameworks (Aguilar, 2015).

Generational cycle theories constitute an important area of research on generational identity and intergenerational relations, although the topic is complex, heterogeneous, and controversial, which may explain its continued presence in the scientific literature. Karl Mannheim (1952) emphasized that generations are not merely age groups but communities of people embedded in a specific socio-historical context (*location*) and possessing a conscious or unconscious sense of shared experience (*generational consciousness*). In his framework, key processes include the entry of new cultural participants, the departure of older members (*disappearance*), the transmission of cultural heritage, and the maintenance of continuity across generational transitions. From a research perspective, Mannheim's theory provides useful frameworks for analyzing how shared historical experiences shape generational identity (Pilcher, 1993). This approach also allows for the examination of risks such as reducing an individual's identity to a mere generational label or their marginalization when they do not fit stereotypical generational norms. At the same time, the theory faces limitations, primarily concerning the difficulty of operationalizing the concept of generation and accounting for significant intra-generational diversity, arising, for example, from social class or region of residence (Aguilar, 2015).

In contrast, the generational cycle theory proposed by William Strauss and Neil Howe (1991) presents human life from a cyclical perspective, where individual experiences are connected both to historical events and personal milestones. According to the authors, human life can be divided into four phases, growth, awakening, unraveling, and crisis, spanning an average of 80-100 years. The growth phase is characterized by community, tradition, and family stability; the awakening phase by individualism and rejection of established norms;

the unraveling phase by egocentrism, chaos, and fragmentation of relationships; and the crisis phase by renewed social unity, idealism, and personal sacrifice for the common good. This theory enables the analysis of employees' values, attitudes, and expectations in relation to their generational phase, which can be useful in intergenerational management and HR policy, though it carries the risk of simplifications and stereotyping. Critics point to weak empirical support, excessive determinism, and insufficient consideration of class, racial, and contextual differences (Strauss, Howe, 1991).

Despite differences in approach and scope, both theories help to understand how historical and social experiences shape generational identity and highlight challenges related to reducing individuals to generational labels or generalizations. The topic remains active and controversial in the scientific literature, as reflected in numerous theoretical discussions and empirical studies on the role of generations in social, cultural, and organizational contexts.

Generational diversity in the workplace can lead to differing interpretations of the same messages and varied expectations toward the organization. Older generations, such as Baby Boomers and Generation X, tend to place greater emphasis on loyalty to the employer, job stability, and organizational predictability. In contrast, Generations Y and Z focus on personal development, work flexibility, and opportunities for remote work. The youngest Generation Alpha, currently entering the labor market, is characterized by technological fluency, and collaboration with artificial intelligence is expected to become the norm for them (Westover, 2024).

Literature analyses indicate that generational differences can manifest in work-related values: systematic studies reveal that Generations X, Y, and Z differ in their expectations regarding the work environment, work-life balance, autonomy, and career paths (Fuchs et al., 2023). Stiglbauer et al. (2022) discuss the risk of organizational conflicts arising from differing value orientations across generations.

At the same time, the category of *generation* is increasingly seen not merely as a demographic division (year of birth) but as a complex socio-cultural construct, encompassing identity mechanisms, symbolic "us vs. them" frameworks, and generational narratives. Research shows that people may identify with generational labels, such as *Millennials* or *Generation Z*, which form part of their self-concept. However, the scope and significance of this identification vary—individuals may simultaneously hold both age-based and generational identities, with the latter differing widely in importance (Costanza et al., 2023; Rudolph et al., 2021).

Systematic literature reviews indicate that, although many studies reference generational categories, their conclusions are often ambiguous due to methodological differences and contextual factors (Fuchs et al., 2023). A critical warning is that treating generations as rigid categories can promote identity reduction and marginalization of individuals who do not fit dominant generational narratives. Seifert, Van Ness, Eddy, Buff, and D'Abate (2023)

demonstrate that work-related ethical traits differ significantly between generations, which can lead to erroneous assumptions if generations are treated as homogeneous groups.

Therefore, adopting generation as an analytical category requires a critical approach. Generational membership should be recognized as one of many dimensions of differentiation, alongside age, class, gender, or culture, rather than as a primary variable determining behavior. Only then can research on multigenerational teams and diversity management practices reduce the risk of oversimplification, individual identity reduction, and marginalization of employees who do not fit stereotypical generational frameworks. The construct of "generation" should thus be used cautiously, taking into account its complex socio-cultural character and intra-generational diversity.

Despite a growing body of research on generations, generational identity, and phenomena of marginalization in organizational and social contexts, the literature remains fragmented and inconsistent. In particular, there is a lack of systematic analyses that connect theoretical concepts of generations (Mannheim, Ortega y Gasset, Strauss & Howe) with practical implications for organizational functioning and intergenerational relationships.

The majority of studies focus on simple demographic or cohort-based classifications, treating generations as relatively homogeneous groups, which oversimplifies complex identity processes and increases the risk of stereotyping. Intra-generational diversity—arising from social class, place of residence, professional experience, or cultural background—is also largely overlooked.

Another limitation is the insufficient attention paid to younger generations (Y, Z, Alpha) and the consequences of intergenerational diversity in the workplace, including mechanisms of marginalization and exclusion of those who do not fit dominant generational narratives. Few studies examine how generational identification influences behaviors, values, and relationships within organizations, or how geographic, institutional, and sectoral contexts shape these dynamics.

Consequently, there is a need for a critical and systematic approach to literature analysis that enables researchers to:

- identify the main theoretical and empirical research streams,
- capture the evolution of studies on generations,
- pinpoint underexplored areas, particularly regarding younger generations, intergenerational diversity, and marginalization,
- and link theoretical discourse with practical implications for diversity management and HR policies.

3. Research methodology

The study was conducted based on a systematic bibliometric and thematic analysis of the scientific literature on intergenerational differences, generational identity, and marginalization in organizational and social contexts. The analysis aimed to map the evolution of the topic, identify the main research streams, and determine the relationships between key concepts in the scientific literature.

The data source was the Scopus database, selected for its interdisciplinary coverage and extensive inclusion of publications in management studies (BUSI) and sociology (SOCI). The search was limited to publications containing in the title, abstract, or keywords combinations of terms related to generations and generational differences: *(generation OR generational AND differences) AND (identity OR marginalization) AND (multigenerational OR intergenerational).*

Additionally, filtering was applied based on keywords such as *generational differences*, *generation X/Y/Z, age, cohort analysis* and *intergenerational relations*, and the search was limited to articles in the fields of management studies and sociology. The final sample comprised 41 publications from 1993 to 2026. The selection of this number of articles was driven by the need to ensure a representative sample while allowing for in-depth analysis. This approach enabled a detailed tracking of thematic evolution, identification of main research streams, and mapping of relationships between key concepts, while maintaining the quality of the analysis. Including a larger number of publications could have led to dispersion of focus and made it difficult to capture subtle connections and research gaps, whereas a smaller number of articles might not have been representative or captured the complexity of the field. Therefore, the choice of 41 publications represents a compromise between depth of analysis and breadth of coverage, allowing for a systematic and rigorous mapping of the literature and identification of research gaps, particularly concerning younger generations (Y, Z, Alpha), intergenerational diversity, and the influence of geographic and institutional contexts on research directions.

The study employed bibliometric analysis using VOSviewer, which enables the visualization and exploration of citation, co-citation, co-authorship, and term co-occurrence networks in the scientific literature. This allows the identification of structural relationships and dominant topics within a given research area (van Eck, Waltman, 2010; Waltman et al., 2010). Using VOSviewer, it is possible to examine how specific concepts (such as *generation, age diversity, generational identity*) are interconnected in the literature, which publications form the core of the discourse, and which research gaps, such as those between classical theory and contemporary approaches, remain underexplored. VOSviewer also supports text mining for analyzing the co-occurrence of keywords and terms in abstracts and titles, enhancing the interpretation of thematic trends (van Eck, Waltman, 2010; Waltman et al., 2010; Li, Hassan, 2023).

The analysis was conducted in the following steps: first, keyword identification was performed, determining the 35 most frequently occurring terms in the publication set. Next, a network of relationships was created, identifying 166 links between terms with a total strength of 595, which enabled the extraction of seven thematic clusters. The next step involved mapping thematic evolution, identifying changes over time in dominant concepts and research streams; node colors reflected the average publication year of each term, allowing visualization of temporal trends. Finally, a density analysis was carried out, which identified central research nodes and assessed the intensity of term co-occurrence within the studied area.

Publications were further classified across several dimensions. First, the document type was considered, distinguishing between research articles, book chapters, conference papers, reviews, and notes. Next, publications were classified by year, enabling observation of the research field's dynamics from 1993 to 2026. Another criterion was the thematic area, including, among others, social sciences, psychology, and medicine. Additionally, the authors' country affiliations were recorded, allowing for assessment of the geographical concentration of research, and institutional affiliations were noted, enabling the identification of leading research centers in the field.

4. Results of the bibliometric analysis of publications

4.1. Bibliometric analysis of publications – analysis of data from the Scopus database

The analysis of the structure of document types forming the basis for the keyword co-occurrence analysis in the Scopus database reveals a strong dominance of research articles, which account for as much as 80.5% of the 41 publications examined. This prevalence indicates that conclusions regarding the multidimensionality of research on generations, identity, and marginalization in the contexts of management studies (BUSI) and sociology (SOCI) are largely shaped by current content published in peer-reviewed journals. The remaining documents are marginal, with equal but significantly lower shares of book chapters (7.3%) and conference papers (7.3%), suggesting some inclusion of knowledge synthesis (books) and the latest findings (conferences), while notes (2.4%) and reviews (2.4%) represent the least numerous categories, emphasizing the focus of the analysis on publications presenting primary research. Detailed data are presented in Figure 1.

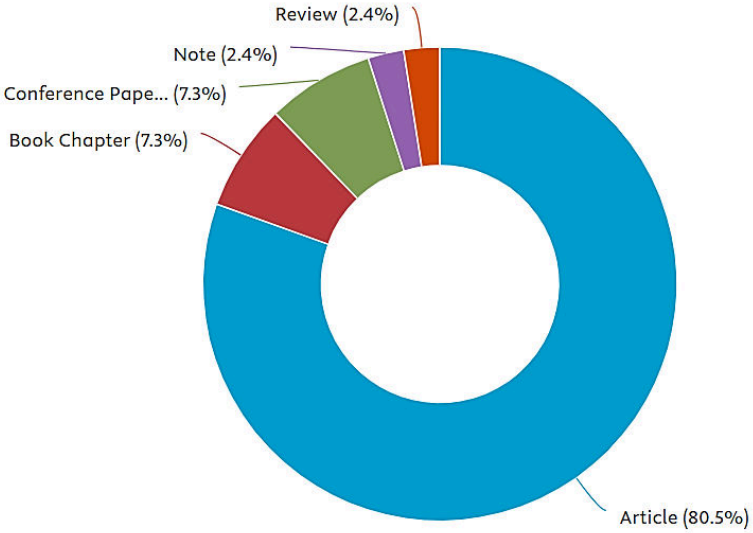


Figure 1. Document type.

Source: Scopus.

Based on the *Documents by year* chart, which shows the publication dynamics in the analyzed set of 41 documents, it is evident that the research field on intergenerational differences in management studies and sociology is characterized by considerable irregularity, with growing interest in recent years. From 1993 onwards, the number of publications remained low (0-1 per year) with numerous gaps; however, periodic peaks of activity are visible, particularly in 2006 (3 documents) and 2013 and 2015 (4 documents each). After a relative stabilization at 1-2 documents per year between 2018 and 2023, the chart shows a marked resurgence in 2024, reaching the highest activity with 4 publications. This suggests that the studied topics—identity, marginalization, and intergenerational relations—are gaining relevance and significance in the current research period. Detailed data are presented in Figure 2.

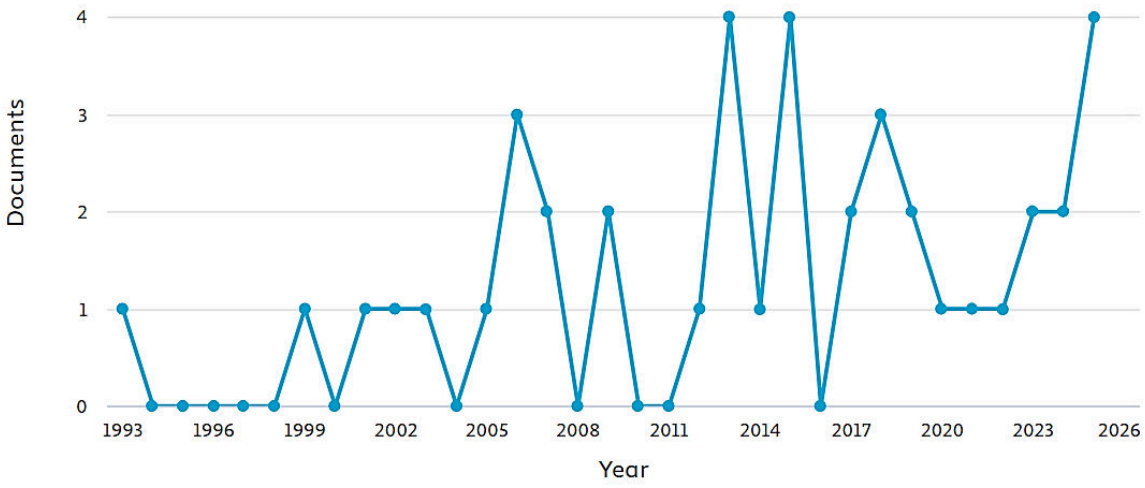


Figure 2. Documents by year.

Source: Scopus.

The interdisciplinary set of 41 publications forming the basis for the keyword co-occurrence analysis shows a strong grounding in Social Sciences (52.0%), with significant contributions from Psychology (13.3%) and Medicine (12.0%). This suggests that the main research focus is on the social and psychophysiological consequences of intergenerational relations, with managerial or economic aspects receiving less attention. Nevertheless, the majority of the information comes from research articles (80.5%), indicating that conclusions are based on current primary studies. Temporal analysis reveals that the research field is unstable, with noticeable publication peaks in 2013 and 2015, and a particularly marked increase in interest in 2024 (4 publications), highlighting the growing relevance and importance of generational differences in current scientific literature. Detailed data are presented in Figure 3.

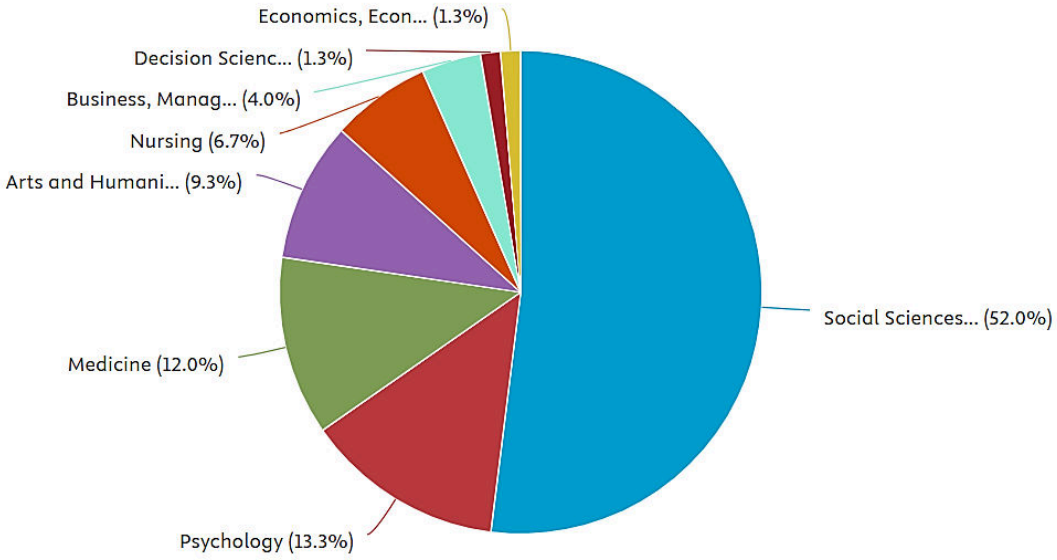


Figure 3. Document by subject area.

Source: Scopus.

The analysis of the *Documents by country or territory* chart reveals a significant concentration of research on intergenerational issues in social sciences and management within English-speaking and Western European countries. The United States clearly dominates, accounting for 12 of the 41 publications, almost one-third of the total, highlighting its central role in shaping this research field. Next in line are Australia (4) and the United Kingdom (4), which together with the USA account for 20 publications (nearly half of the dataset) from the Anglo-Saxon cultural sphere, indicating an international but strongly localized nature of the research. Additionally, there is a notable contribution from Western European countries: Canada (3), Switzerland (3), and Belgium (2). The presence of Asian countries, such as India (2), Japan (2), and China (1), as well as a Central European country, the Czech Republic (1), although limited, suggests gradual globalization and growing interest in the topic beyond European and American contexts. Detailed data are presented in Figure 4.

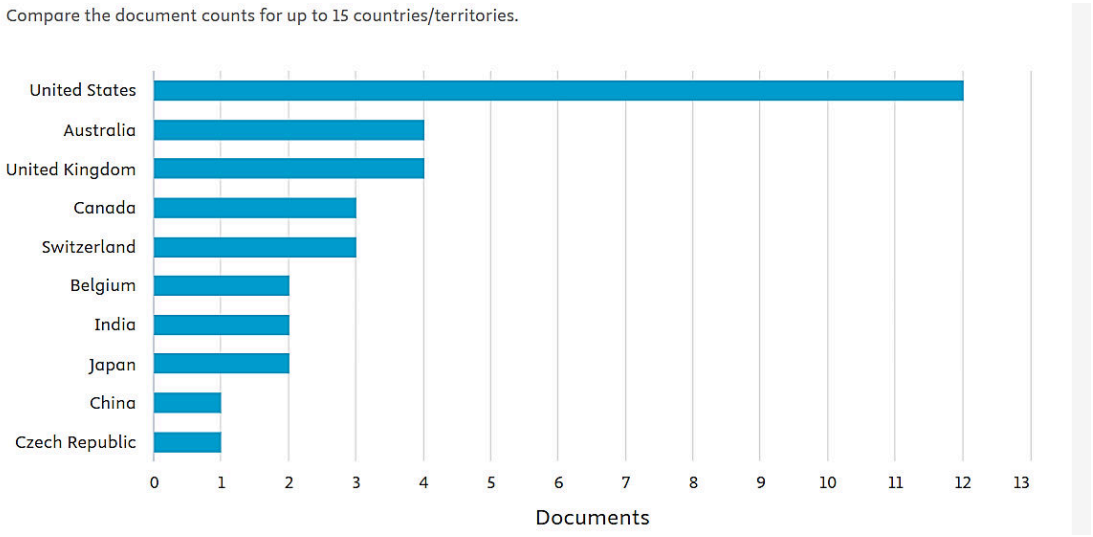


Figure 4. Documents by country.

Source: Scopus.

The analysis of the *Documents by affiliation* chart, which presents institutional contributions to the examined set of 41 publications, shows that the field is characterized by considerable dispersion of authors, with the exception of one clearly leading institution. The University of Antwerp (Universiteit Antwerpen) is the only institution with two publications, making it the most productive center in this sample, although its advantage is minimal. The remaining nine top affiliations, including research centers such as Alter und Generationen INAG and the Swiss Centre of Expertise in Life Course Research, as well as universities like Université de Lausanne (UNIL), University of Glasgow, and The University of Texas at San Antonio, each contributed one publication. This structure demonstrates that research on intergenerational differences, identity, and marginalization is conducted by a diverse and broad network of institutions, with no single center, apart from the slight lead of the University of Antwerp, serving as a dominant research hub. Detailed data are presented in Figure 5.

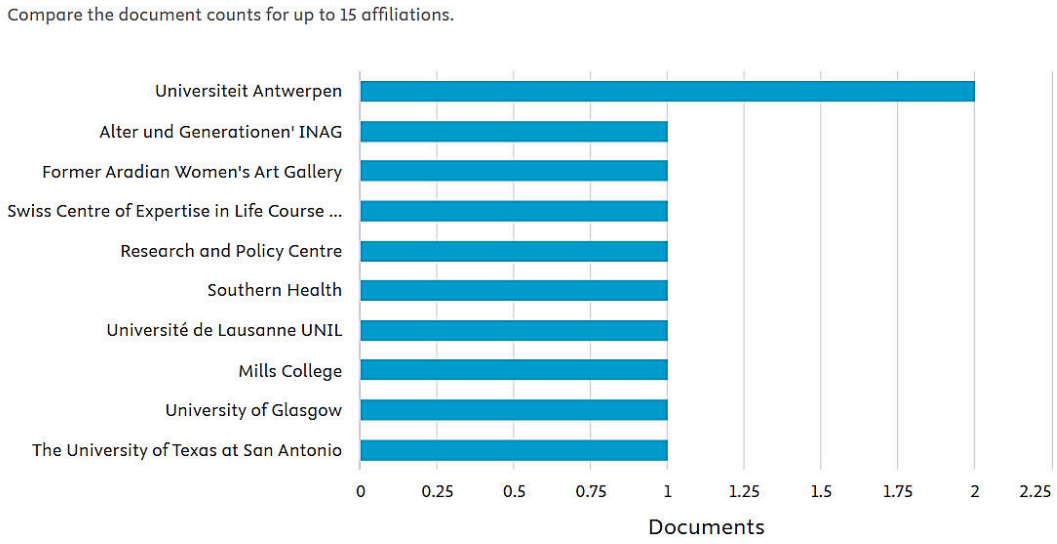


Figure 5. Documents by affiliation.

Source: Scopus.

In summary, the bibliometric analysis of publications from the Scopus database indicates a growing, though irregular, interest in intergenerational differences, strongly rooted in the social sciences, dominated by research articles, and geographically concentrated in Anglo-Saxon countries and Western Europe, which provides a starting point for further keyword co-occurrence network analysis using the VOSviewer tool.

4.2. Bibliometric analysis of publications using VOSviewer

The first map visualizing the results of the keyword co-occurrence analysis in the Scopus database, prepared using VOSviewer, includes 41 publications in which 35 terms forming 7 clusters, 166 links, and a total link strength of 595 were identified. The data were limited to articles in the fields of management studies (BUSI) and sociology (SOCI) related to intergenerational differences, identity, marginalization, and inter- and multigenerational relations. The network structure reflects the multidimensionality of research on generations, with dominant demographic, psychological, and organizational themes. Central concepts, such as *generational differences*, *generation*, *generations*, *age*, and *generational cohorts*, serve as nodes connecting the individual thematic groups, highlighting their key role in research on intergenerational differences. Detailed data are presented in Figure 6.

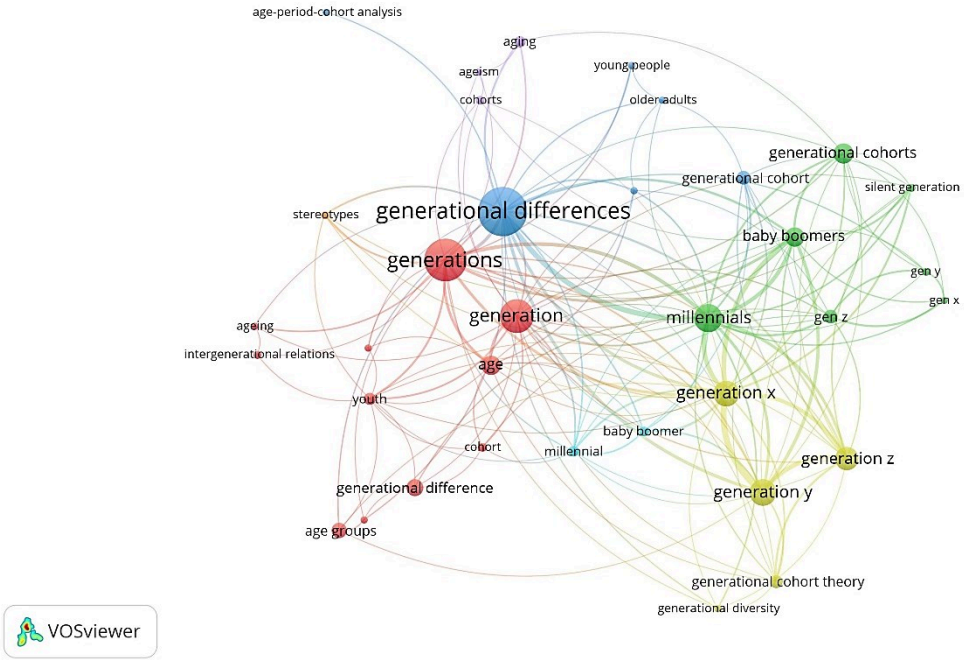


Figure 6. Keyword Co-Occurrence Map on Intergenerational Differences in Scopus Publications (n = 41, 1993-2026).

Source: VOSviewer.

The network analysis reveals seven thematic clusters. The first cluster (red) centers on the terms *generation, age, age groups, cohort, intergenerational relations, stereotypes, and ageing*, focusing on intergenerational relationships and phenomena related to aging, age stereotypes, and ageism. The second cluster (blue) includes nodes such as *generational differences,*

generations, age-period-cohort analysis, and *cohorts,* reflecting theoretical and methodological studies that emphasize cohort analyses and the conceptualization of generational differences. This cluster serves as the intellectual core of the network, integrating the other research areas. The third cluster (green) pertains to classical studies of *generational cohorts, encompassing terms like generational cohorts, baby boomers, generation X, generation Y, generation Z, silent generation, Gen Y,* and *Gen Z.* These studies are primarily empirical and comparative, analyzing differences in attitudes, values, and behaviors across generations, especially in work and organizational contexts. The fourth cluster (yellow) focuses on younger generations and their diversity, including terms *generation Y, generation Z, generational cohort theory,* and *generational diversity.* These studies address changes in values, communication, and expectations of generations Y and Z regarding the workplace, serving as a key reference point in research on demographic diversity management. The fifth cluster (purple) relates to aging and ageism, containing terms such as *aging, ageism, older adults,* and *young people*, with a socio-psychological focus on attitudes toward age, inclusion, and generational marginalization. The sixth cluster (orange) revolves around *identity, intergenerational transfer, psychological aspect,* and *attitudes,* addressing generational identity, knowledge and value transfer between generations, and attitudes toward other age groups. It is interdisciplinary, combining sociological, psychological, and organizational perspectives. The seventh cluster (brown) includes less central terms such as *generational status* and *generational difference*, representing less-cited, often context-specific studies or case studies on particular generational groups.

The analysis of connections shows moderate network cohesion, reflecting thematic diversity while maintaining shared theoretical frameworks. The strongest links are observed between *generational differences, generations, generation, age, generational cohorts, millennials, generation X, generation Y,* and *generation Z*, indicating that research on generational differences focuses on the relationships between age, cohort membership, and attitudes and behaviors, particularly in work and organizational contexts.

The findings indicate that research on generational differences has evolved from demographic and cohort approaches toward studies on identity, values, and intergenerational interactions. Increasing attention is given to younger generations, especially Generation Z, and to intergenerational diversity in the workplace. The network reveals a gradual shift from structural analyses to research on attitudes, identity, and relational dynamics between age groups. Simultaneously, there is growing integration of perspectives, from demographic analyses to psychological and organizational approaches, confirming that the study of generational differences is complex and interdisciplinary.

A second map, also developed in VOSviewer, illustrates the thematic evolution of research on intergenerational differences over time. Node colors correspond to the average publication year of each keyword—from purple (older publications, around 2016) to yellow (recent publications, around 2022). Detailed data are shown in Figure 7.

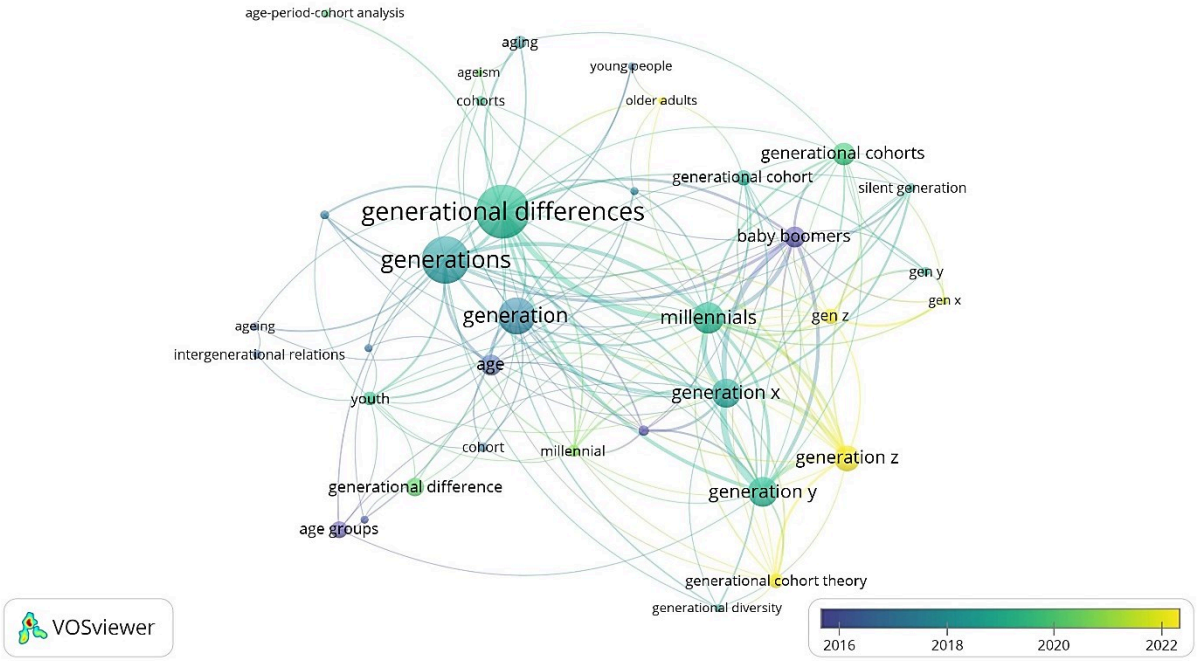


Figure 7. Temporal map of keyword co-occurrence related to intergenerational differences in publications from the Scopus database (n = 41, 1993-2026).

Source: VOSviewer.

In the central part of the map, the terms generational differences, generations, and generation dominate, indicating that they have long served as the main axes of research in this area. These terms are marked with intermediate colors (green-blue), suggesting their continuous presence in the literature over the past decade and their role as integrating concepts. Surrounding them are terms related to age and cohorts, such as *age, age groups, cohort,* and *intergenerational relations*, which belong to an earlier research period (purple-blue shades), showing that initial studies focused on demographic aspects and intergenerational relationships.

More recent publications (marked in green-yellow and yellow) shift the focus toward studies on specific generations, such as *generation Y, generation Z, millennials, Gen Y,* and *Gen Z*. This reflects the clear development of empirical research on younger generational cohorts, their values, attitudes, work styles, and relationships with other age groups. In this context, terms like *generational diversity* and *generational cohort theory* appear increasingly, reflecting growing interest in intergenerational diversity in organizations and theoretical approaches to these phenomena.

In contrast, terms such as *ageing, ageism,* and *older adults* are located in the upper, purple-blue area of the map, indicating that research on societal aging, age discrimination, and intergenerational social relations represented an earlier stage of scientific exploration. These topics were more often addressed from sociological and psychological perspectives before researchers' focus shifted to organizational and managerial contexts.

Overall, the map shows the evolution of research topics from demographic and cohort analyses (earlier period, dominant in literature until 2018) to studies on younger generations and intergenerational diversity (post-2019). Recent studies focus on Generation Z and its specifics in the workplace, aligning with global trends in human resource management literature.

The analysis indicates that research on intergenerational differences has undergone a significant transformation, from descriptive and comparative age analyses to applied research on managing diversity, values, and attitudes of employees across generations. Increasing emphasis is placed on organizational context, cross-generational collaboration, and the impact of generational diversity on organizational outcomes and climate. The map thus confirms that in recent years, the topic of generational differences has gained new significance, not only as a demographic issue but also as a key element of human capital management and organizational development strategies.

The third keyword co-occurrence map, developed using VOSviewer, illustrates the thematic structure of research on intergenerational differences in the analyzed publications. The color and intensity of the fields reflect the frequency of co-occurrence of specific terms—the brighter the color (yellow), the more frequent and stronger the connections between the keywords. Detailed information is presented in Figure 8.

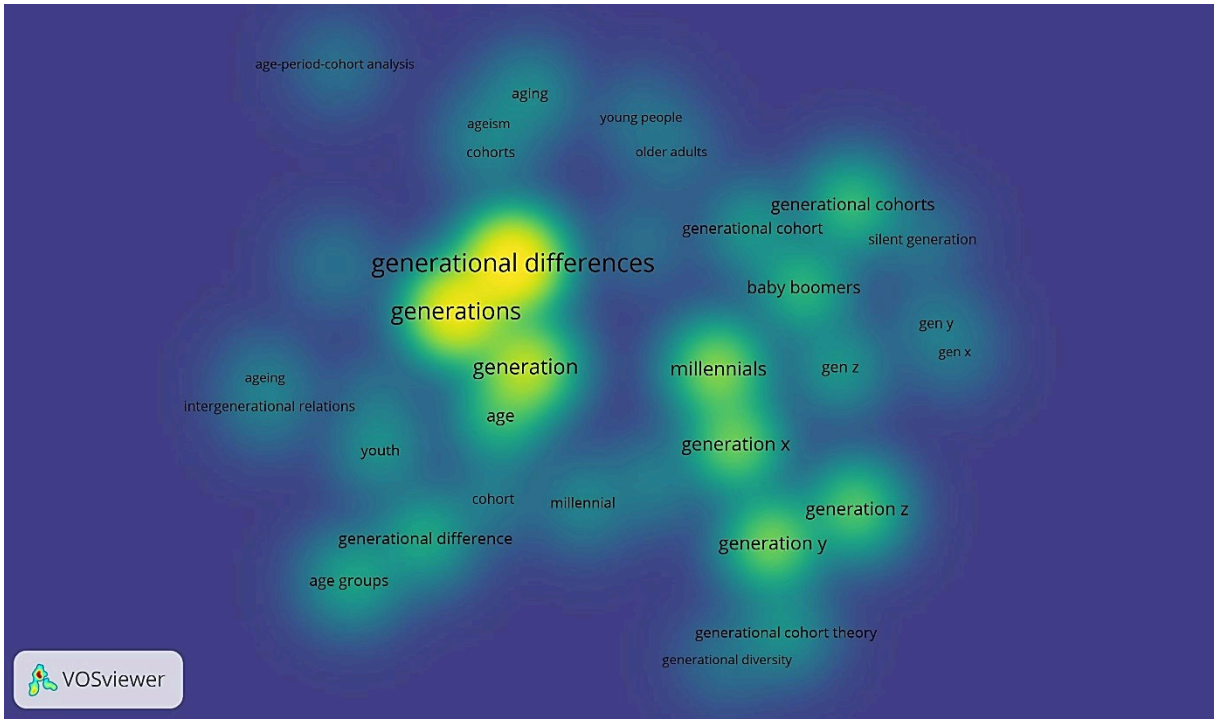


Figure 8. Keyword co-occurrence map of intergenerational differences in Scopus publications (n = 41, 1993-2026).

Source: VOSviewer.

At the center of the map are three key concepts: *generational differences, generations* and *generation*, which form the core of research in this area. Their central position and highest intensity indicate that these terms serve as integrative nodes, connecting various research threads related to generations and their differences. Around these concepts, clusters of related terms emerge, which can be interpreted as distinct thematic subareas.

The first cluster includes terms related to age analysis and intergenerational relations, such as *age, ageing, age groups, intergenerational relations, ageism,* and *cohorts*. This area represents an earlier, more demographic and sociological approach to generational research, focusing on aging processes, age structure, and the dynamics of relationships between age groups.

The second prominent thematic cluster comprises terms referring to specific generations – *generation X, generation Y, generation Z, millennials, baby boomers, silent generation, gen X, gen Y,* and *gen Z.* This group reflects the development of research focused on differences in values, attitudes, and behaviors among generational cohorts, especially in the context of work and organizational settings.

The third thematic area centers on theoretical and conceptual terms, such as *generational cohort theory, generational diversity* and *generational cohorts*. It points to efforts to theoretically structure generational research and the increasing recognition of generational diversity as a critical dimension of diversity management in organizations.

Overall, the map allows the identification of three main research streams in the literature on intergenerational differences: (1) the demographic and relational stream, (2) the cohort-based stream, focusing on specific generations, and (3) the theoretical stream, developing concepts and models to explain generational diversity. The concentration of key terms around *generation* and *generational differences* indicates that, despite the wide scope of research, this topic remains a coherent, interdisciplinary field, integrating sociological, psychological, and managerial perspectives.

5. Discussion

The analysis of 41 selected articles enabled a systematic mapping and examination of the literature on intergenerational differences, generational identity, and marginalization in organizational and social contexts from 1993 to 2026. The study revealed that three main thematic streams dominate the literature: research on generational differences in the workplace, issues of generational identity, and the problem of marginalization in social and organizational contexts. Thematic and temporal evolution indicates that earlier studies primarily focused on identifying characteristic traits of specific generations, whereas recent years have seen increased interest in intergenerational collaboration, knowledge transfer, and inclusion and

diversity in the workplace. Analysis of the conceptual links in the literature shows that key roles are played by the concepts of generational differences, generational identity, and mechanisms of marginalization, with theoretical and empirical studies often complementing each other to create a coherent understanding of the relationships between age, experience, and organizational position. Identified research gaps concern primarily younger generations (Y, Z, Alpha), intergenerational diversity, and the influence of geographic and institutional contexts on research directions, highlighting the need for in-depth studies in real organizational and social settings. The findings from the literature analysis allow for the identification of potential directions for further research, including studies on inclusive generational management practices, intergenerational interactions, and the impact of institutional and cultural factors on collaboration dynamics within organizations.

The results of the literature analysis largely align with established theoretical perspectives on generations. The findings confirm that an individual's development is shaped by the socio-cultural and historical context in which they grow up, as emphasized by Mannheim (1952) and Ortega y Gasset (1992), who highlight that generations are not merely age cohorts but communities embedded in shared historical experiences that influence worldviews and behaviors. Similarly, the cyclical generational theory of Strauss and Howe (1991) provides insight into how generational phases shape values, attitudes, and expectations, particularly in organizational contexts. Empirical evidence from the analyzed studies supports these theoretical propositions, showing that generational differences manifest in workplace values and preferences, with older generations prioritizing loyalty and stability, and younger generations emphasizing flexibility, personal development, and technological fluency (Fuchs et al., 2023; Stiglbauer et al., 2022; Westover, 2024). At the same time, the analysis highlights the risks of reducing individual identities to generational labels, as this may lead to stereotyping and marginalization of those who do not conform to dominant generational narratives (Aguilar, 2015; Costanza et al., 2023; Rudolph et al., 2021; Seifert et al., 2023).

The temporal evolution of the literature further supports theoretical expectations: earlier studies focused primarily on identifying characteristic traits of specific generations, while more recent research emphasizes intergenerational collaboration, knowledge transfer, and inclusive practices in the workplace. These findings underscore the practical relevance of generational theories for human resource management and diversity policies, particularly when addressing intergenerational interactions and the challenges of integrating multiple generations in organizational settings. At the same time, the analysis identifies persistent gaps in the literature, such as the limited attention to younger generations (Y, Z, Alpha), intra-generational diversity, and the influence of geographic and institutional contexts on generational dynamics. These gaps align with theoretical limitations noted by Mannheim and Strauss and Howe, who caution against simplistic or deterministic applications of generational constructs and stress the importance of considering contextual and individual differences.

Overall, the analysis demonstrates that theoretical frameworks on generations provide a valuable lens for understanding the formation of generational identity, the emergence of differences in values and behaviors, and the risks of marginalization. However, the literature remains fragmented, often treating generations as homogeneous demographic groups rather than complex socio-cultural constructs. The integration of theoretical insights with empirical findings highlights the need for a critical and nuanced approach to generational research, particularly in organizational settings, where understanding the interplay between historical context, individual experience, and institutional factors is essential for promoting effective intergenerational collaboration and inclusive practices.

6. Conclusions

Several theoretical implications emerge from the analysis. First, there is a clear need for further integration of multiple research perspectives, sociological, psychological, and organizational, to provide a comprehensive explanation of generational differences. Second, the increasing use of the term "generational cohort theory" indicates the development of conceptual models that help explain the behaviors, attitudes, and values characteristic of specific generations, particularly in professional contexts. Third, the observed growing interest in generational diversity in the workplace demonstrates that research on generations is increasingly aligned with broader diversity management theories. The results also confirm the evolution of the research field from descriptive approaches, focused on demographic differences, toward applied perspectives analyzing the impact of generational diversity on organizational functioning, leadership, communication, and knowledge transfer.

However, this analysis has several limitations. First, its scope was limited to publications indexed in the Scopus database, meaning that sources outside this database, such as national publications, industry reports, or non-English works, were not included. Second, the results depend on how authors select and assign keywords, which may lead to terminological inconsistencies (e.g., the interchangeable use of *millennials* and *Generation Y*). Third, bibliometric analysis identifies term co-occurrences but does not provide insight into the content or theoretical depth of studies. Fourth, the dynamic nature of the research field means that identified trends may change rapidly with the emergence of new social phenomena, such as Generation Alpha entering the labor market or the influence of artificial intelligence on generational attitudes.

Several directions for future research can be suggested. First, in-depth studies on new cohorts, especially Generation Alpha, which is beginning to enter the professional socialization phase, are necessary. Second, research should further explore mechanisms of intergenerational collaboration and knowledge transfer within organizations, with particular attention to their

impact on team innovation and efficiency. Third, it is essential to consider cultural and institutional contexts in comparative analyses to avoid excessive generalizations when defining generational traits. Fourth, the impact of technological changes, digitalization, and remote work on the behaviors and expectations of different generations should be examined. Finally, future studies should aim to integrate analyses at the individual, organizational, and societal levels to better understand how generational diversity shapes contemporary work environments and, more broadly, socio-economic dynamics.

References

1. Aguilar, M.I. (2015). The Constitution of Somaliland: The problem of constitutional generations and clan dissolution. *Sociology Mind, 5(4),* 245-254. https://doi.org/10.4236/sm.2015.54022
2. Costanza, D.P., Rudolph, C.W., Zacher, H. (2023). Are generations a useful concept? *Acta Psychologica, 241*, 104059. https://doi.org/10.1016/j.actpsy.2023.104059
3. Folta, M. (2020). X, Y, i Z. Teoria cyklów pokoleniowych Straussa-Howe'aw świetle wcześniejszych teorii. *Konteksty Społeczne, 8(2(16)),* 23-37.
4. Fuchs, O., Lorenz, E., Fuchs, L. (2024). Generational differences in attitudes towards work and career: A systematic literature review on the preferences of generations X, Y, and Z. *International Journal of Innovative Research and Advanced Studies, 11(7),* 54-71.
5. Li, P., Hassan, S.H. (2023). Mapping the literature on Generation Z purchasing behavior: A bibliometric analysis using VOSviewer. *Innovative Marketing, 19(3),* 62-73. https://doi.org/10.21511/im.19(3).2023.06
6. Mannheim, K. (1952). The problem of generations. In: P. Kecskeméti (Ed.), *Essays on the sociology of knowledge* (pp. 276-322). London: Routledge & Kegan Paul.
7. McCrindle, M. (2014). *The ABC of XYZ: Understanding the global generations*. Australia: A McCrindle Publication.
8. Ortega y Gasset, J. (1992). *Man and crisis*. New York, NY: Norton.
9. Pilcher, J. (1993). Mannheim's sociology of generations: An undervalued legacy. *The European Educational Researcher, 6(3),* 331-350.
10. Rudolph, C.W., Rauvola, R.S., Costanza, D.P., Zacher, H. (2021). Generations and generational differences: Debunking myths in organizational science and practice and paving new paths forward. *Journal of Business and Psychology, 36(6),* 945-967.
11. Seifert, C.F., Van Ness, R.K., Eddy, E.R., Buff, C., D'Abate, C.P. (2023). Generational work ethic differences: From Baby Boomers to Gen Z. *Journal of Managerial Issues, 35(4),* 401-422.

12. Stiglbauer, B., Penz, M., Batinic, B. (2022). Work values across generations: Development of the New Work Values Scale (NWVS) and examination of generational differences. *Frontiers in Psychology, 13,* 1028072.
13. Strauss, W., Howe, N. (1991). *Generations: The history of America's future, 1584 to 2069*. William Morrow & Co.
14. van Eck, N.J., Waltman, L. (2010). A comparison of two techniques for bibliometric mapping: Multidimensional scaling and VOS. *Journal of Informetrics*. https://arxiv.org/abs/1003.2551
15. Waltman, L., van Eck, N.J., Noyons, E.C.M. (2010). A unified approach to mapping and clustering of bibliometric networks. *Journal of Informetrics, 4(4),* 629-635. https://doi.org/10.1016/j.joi.2010.07.002
16. Westover, J.H. (2024). Understanding Gen Alpha: Leadership insights for the future of work. *Human Capital Leadership Review, 12(3).*

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THE IMPORTANCE OF SITUATIONAL FACTORS IN CONSUMER BEHAVIOR AND THE FUNCTIONING OF SMALL HORECA ENTERPRISES

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Purpose: The paper aims to examine the significance of situational factors in shaping consumer behavior and the operational functioning of small enterprises in the HoReCa sector, with particular emphasis on the wine industry. The study seeks to identify which situational factors most strongly influence purchase decisions and overall customer experience.
Design/methodology/approach: The research employs a qualitative case study approach, using an in-depth individual interview (IDI) with the manager of a small HoReCa enterprise. The study applies Russell Belk's (1975) taxonomy of situational factors—physical environment, social environment, temporal perspective, task definition, and antecedent states—to analyze the impact of these factors on customer behavior and operational decisions.
Findings: The study demonstrates that physical environment, social environment, and task definition play a key role in shaping consumer experience, perceived value, and purchase readiness. Physical elements such as location, store layout, and sensory cues, as well as social interactions and the purpose of purchase, significantly influence consumer engagement. The research highlights that in the wine sector, purchases are largely experiential and culturally mediated rather than purely transactional.
Research limitations/implications: The study is based on a single case, which limits the generalizability of findings across the HoReCa sector. Future research could expand to multiple enterprises or regions to validate the impact of situational factors across different contexts. Longitudinal studies could also explore temporal changes in situational influences.
Practical implications: The results suggest that small HoReCa enterprises can enhance customer experience and sales by consciously managing situational factors. Strategic attention to store atmosphere, employee competence, social engagement, and temporal dynamics of visits can increase perceived value and customer loyalty. The findings provide actionable insights for operational and marketing strategies in niche, culturally oriented markets such as wine retail.
Social implications: By promoting well-designed consumer experiences that integrate social and cultural dimensions, HoReCa enterprises can contribute to community building and enhance customer well-being. Encouraging responsible consumption and social interaction in controlled settings may positively influence public attitudes toward social and cultural engagement.
Originality/value: The paper offers new insights into the practical significance of situational factors in the HoReCa sector, particularly in the context of small enterprises and wine retail. It combines theoretical frameworks with operational practice, providing value to managers,

marketers, and researchers interested in consumer behavior, experiential marketing, and niche hospitality management.
Category of the paper: Research paper, case study.
Keywords: Situational factors, consumer behavior, wine retail, IDI.

1. Introduction

The wine industry should be regarded as a market of considerable historical and economic significance (Unwin, 1996). In the United States, for example, in 2013 wine sales reached their highest volume on record, generating a retail value of USD 37.6 billion (Taylor et al., 2018). Wine is a complex product from the consumer's perspective (Charters, Pettigrew, 2008). The analysis of consumption motives is often based on a tripartite paradigm, which encompasses utilitarian (physical), symbolic, and hedonic needs (Holbrook, Hirschman, 1982; Levy, 1986; Thompson, Vourvachis, 1995). It is suggested that wine consumption is primarily focused on experiential and symbolic categories, and only to a limited extent on utilitarian purposes (Groves et al., 2000). Key motivational factors influencing wine consumption include (Charters, Pettigrew, 2008): Enjoyment, Personal historical context, Lifestyle-related issues, and Situational factors. In the literature, enjoyment is a collective concept. Research shows that under this term one may define such motivational factors as taste, the effect of alcohol, or the intellectual challenges arising from the discovery of new wines, which for those highly involved in consumption may become almost obsessive. Such a challenge involves thinking about wine, learning about it, and developing the ability to identify its characteristics (Charters, 2008). The personal historical context refers to symbolic motivations and derives directly from the consumer's life history — the motivation to consume wine may stem from an important life event or even one's origin. Lifestyle includes factors related to symbolic motivations as well, referring to the way the consumer perceives themselves and their role in society. Wine consumption may serve to support one's self-image or to enhance the way others perceive the individual. Wine thus becomes an aesthetic commodity that defines not only relationships with others but also one's self-perception (Demossier, 2004). In studies on wine consumption, a holistic approach is essential — one that considers the interplay between internal (intrinsic, push – personal traits) and external (extrinsic, pull – situational or product-related features) motivators (Taylor et al., 2018). These motivators interactively influence personal involvement with wine, which subsequently predetermines actual consumption (Taylor et al., 2018). Understanding motivation is crucial, as motives vary depending on the specific situation (Brunner, Siegrist, 2011).

2. Situational Factors

A situation consists of situational factors — it is defined in the literature as all factors characteristic of a particular time and place of observation that do not result from either the intra-individual characteristics of the buyer or the attributes of choice alternatives, yet demonstrably influence the buyer at the moment of purchase. To systematize this concept and facilitate its operationalization, Belk (1975) distinguished five groups of so-called situational factors: physical surroundings, social surroundings, temporal perspective, task definition, and antecedent states. The physical surroundings include elements of the shopping environment such as product layout, colors, or cleanliness (Chen, 2023), as well as the distance to the store (Kvalsvik, 2022) or atmospheric conditions (Yao, 2023). Research conducted over the years shows that atmospheric factors strongly affect retail sales (Badorf, 2020; Yoo, 2024). The social surroundings refer to interpersonal interactions during the purchase, the presence of other people, and the role of staff, which may increase the likelihood of purchase (Atulkar, Kesari, 2018; Chocarro, 2013). Motivations related to wine purchase, such as the presence of family and friends, also fall into this category. The temporal perspective concerns factors related to time: the calendar period (e.g., weekend effect), the duration of the transaction, or the waiting time for it (Chen et al., 2018; Olsson et al., 2022). Studies confirm that the weekend effect influences both prices (Scholten, 2009) and the perception of stimuli at points of sale (Ahlbom, 2023). Task definition includes the intention or requirement of purchase — that is, the context in which the purchase is made. The literature distinguishes such task definitions as planned or impulsive purchases, or purchases for personal consumption versus as gifts for others. Different task definitions are associated with store choice (Kenhove et al., 1999). Antecedent states refer to temporary moods (e.g., uncertainty, pleasure, hostility) or conditions (fatigue, illness, pain), distinguishing them from enduring individual traits (Belk, 1975). They can determine consumption choices, and studies show that a positive mood reduces the tendency toward analytical evaluation of advertising content (Batra, 1990). Belk's (1975) classification remains the fundamental framework for the analysis of situational factors, widely used in research on retailing, product choice, and shopping patterns (Chocarro et al., 2013; Hand et al., 2009).

Situational factors are also of great importance in the HoReCa sector, as they determine when and why wine is chosen (Charters, Pettigrew, 2008). Sociability is identified as one of the most important factors motivating wine drinking (Charters, Pettigrew, 2008; Heath, 2000). Wine plays a role in strengthening social bonds and facilitating socialization (Douglas, 1987). It fosters socialization both through physiological and psychological effects (alcohol relaxes and breaks down barriers) and by serving as a catalyst for interaction (discussions about taste, structure, or origin) (Charters, Pettigrew, 2008). For example, for Generation Y consumers, born between 1977 and 1999, sociability is a significant element predefining consumption, as wine is perceived as a social beverage (Olsen et al., 2007). Wine consumption among friends

is strongly motivated by this factor for both men and women in this age group (Dlačić & Kadić-Maglajlić, 2013). It should also be noted that, within Belk's (1975) classification of situational factors, sociability itself is not an element of the situation, as it is an enduring characteristic of the consumer. Nevertheless, sociability translates into increased sensitivity to situational factors within the social surroundings group, such as the presence of friends, family, and acquaintances.

Food enhancement is the second most significant motivator of wine consumption, alongside taste (Thomas, Pickering, 2003). Wine complements meals in terms of flavor, providing pleasure (Charters, Pettigrew, 2008). The presence of food dominates as a motivator in situations where wine is consumed with a partner or family. Studies have shown that this factor is relevant to consumers regardless of age, as appropriately paired wine universally enhances the taste of dishes (Dlačić, Kadić-Maglajlić, 2013). This underscores the importance of the situational factor from the social surroundings group — namely, the presence of family or friends not only at the moment of purchase but also during subsequent consumption. It is worth emphasizing that another situational factor from the task definition group also plays an important role: a consumer purchasing wine for immediate consumption is differently influenced by the presence of family and friends than one buying for future consumption. Generation Y and younger consumers tend to drink alcoholic beverages, including wine, mainly in pubs, bars, and restaurants, as opposed to older generations, who more often consume at home (Teagle et al., 2010). During special occasions such as parties or business meetings, women from Generation Y are primarily motivated by sociability, whereas for men, the food factor has a greater influence (Dlačić, Kadić-Maglajlić, 2013). Wine consumption is also an important means of relaxation (Charters, Pettigrew, 2008). It may also function as a temporal marker — a point in time symbolizing the transition from work to home leisure, serving a ritualistic function (Gusfield, 1987).

In the context of HoReCa research, it is also worth mentioning the factors often discussed in the literature that negatively affect wine consumption. The COVID-19 pandemic introduced new negative and positive situational factors that strongly influenced consumer intentions regarding, among other things, wine tourism (Gastaldello et al., 2022). A higher aversion to risk reduces travel intentions (Luo, Lam, 2020). Despite physical restrictions, the lockdown period may have provided consumers with more free time to engage in other forms of leisure (Gammon, Ramshaw, 2020). In the context of wine, the acquired interest in wine (AQWINT), a form of situational involvement (SI), strengthened future wine tourism intentions (Gastaldello et al., 2022) and, consequently, future wine consumption. This factor has a strong positive impact, acting as a mediator between personal involvement (PI) in wine consumption and travel intentions (Gastaldello et al., 2022). This means that marketing activities in this area should be intensified during the consumer's planning and "dreaming" phases (Gastaldello et al., 2022). Research conducted on the wine industry focuses on the mechanisms by which various factors influence the customer; however, there are not many studies indicating clear implications derived from this research for organizations operating within the industry.

Research in the wine sector primarily focuses on the wine–consumer relationship and the mechanisms through which consumer motivations exert influence. At the same time, there is still a lack of studies systematically analyzing the significance of situational factors in the HoReCa industry and their practical implications for business operations. As noted by Jaeger et al. (2010), most consumers report that the importance of wine selection criteria would change depending on the consumption context (e.g., a dinner with friends vs. retail shopping). Therefore, in-depth research on the role of situational factors in the HoReCa sector could provide companies with concrete marketing and operational insights, enabling more effective alignment of offerings with the variable needs and motivations of consumers.

3. Research Methodology

The studied entity is a commercial and service enterprise located in the Silesian Voivodeship. The company operates a sales point situated within the Upper Silesian-Zagłębie Metropolis. This point serves both as a retail space, where sales transactions are conducted, and as a service area, where customers can consume wine and other Italian-style products. The respondent in the conducted study was the manager of the enterprise, a professional with several years of experience in the HoReCa industry. The respondent holds higher education in a non-economic field.

The study was conducted using a qualitative research method — the individual in-depth interview (IDI). This was the primary tool for obtaining empirical data within the developed case study. The application of this method made it possible to gain insight into the subjective perspective of the studied entity, allowing for the capture of meanings assigned to specific phenomena and decisions by the participant, without imposing predetermined analytical categories or structuring responses according to pre-established criteria (cf. Nikodemska-Wołowik, 1999). The respondent was the owner of the enterprise in question, directly responsible, among other things, for the planning and implementation of operational activities at the local level. The choice of respondent was determined by his access to both strategic and operational knowledge, which made it possible to obtain rich material of a cognitive and diagnostic nature.

The collected empirical data were organized and then subjected to interpretative analysis consistent with the assumptions of qualitative research methodology. The aim of the study was to identify and preliminarily assess the impact of selected situational factors (classified according to Belk's taxonomy, 1975) occurring in the environment and operational activities of the enterprise, on its functioning and managerial decision-making. Particular attention was paid to the changes observed in these factors and their potential influence on the company's current activities and adaptive mechanisms.

4. Research Results

In the context of situational factors, the physical surroundings play a significant role in the HoReCa industry, encompassing—according to Belk's (1975) classification—material and sensory elements related to the place of consumption, such as spatial layout, lighting, music, scent, or weather conditions. In the analyzed case, it was indicated that the key element influencing the operation of the establishment is its location and spatial accessibility. As the respondent emphasizes, the choice of sales location is crucial for the level of customer traffic and the perception of the offer; however, in smaller towns, unlike in large urban centers, standard location analyses do not yield the expected results. Location is therefore a situational factor of great importance, although its impact may be limited by the specificity of the local market.

"[...] in large cities [...] market research is conducted within a radius of 50-100 meters [...]. Here [...] the town is too small to carry out such studies [...]"

Another element of the physical surroundings is weather conditions, which in the analyzed case exhibit a complex, non-linear influence on buyer behavior. The respondent indicates that both unfavorable weather and exceptionally good weather conducive to outdoor activities can lead to a decrease in the number of customers visiting the establishment.

"[...] when the weather is bad, it seems like no one wants to leave the house, but on the other hand, exceptionally beautiful weather is also a factor that [...] does not encourage people to stay in the store"

As the respondent notes, the weather can even constitute a form of competition for stationary business activity, since during the summer season customers satisfy their consumption needs in other contexts—e.g., while traveling or attending outdoor events. Consequently, the vacation period, commonly regarded as a time of increased sales in gastronomy, may in the case of specialty stores result in a decline in turnover.

In the area of spatial design and sensory experience, the respondent highlights the importance of atmosphere and comfort within the establishment. She points out that a pleasant environment, appropriate lighting, and music consistent with the visual communication build positive emotions, which encourage longer visits and increase the likelihood of purchase.

"[...] it is more pleasant to spend time in a pleasant place [...]. If the customer feels good here, they are more likely to walk around the store and browse the products"

Particular attention should be paid to the specificity of the assortment, which in the analyzed case represents an important element of the consumption situation. Offering niche products, often unfamiliar to consumers, may lead to confusion and withdrawal among customers who, as the respondent observes, enter the store with a sense of competence but encounter a reality different from their expectations. This type of cognitive dissonance becomes a factor limiting purchase readiness and requires active support from the salesperson.

"[…] the customer walks confidently into the store […] only to find that there is not a single product they actually recognize […]. When the customer encounters such an unfamiliar reality—they withdraw from the purchase […]"

The analyzed case indicates that in the HoReCa industry, the physical surroundings fulfill both a communicative and emotional function, serving as an important background for customer–brand interaction. A well-designed space can minimize cognitive and emotional barriers, encourage customer returns, and strengthen their attachment to the place. At the same time, external factors such as weather or location require flexible managerial approaches and the adjustment of promotional activities to changing environmental conditions.

Another group of situational factors in Russell Belk's (1975) framework is the social surroundings, encompassing the presence and behavior of other people in the consumption setting, interactions among customers, and relationships with staff. In the HoReCa sector, this factor gains particular importance, as the customer experience is largely co-created through interpersonal contact and the social atmosphere within the establishment.

The analyzed case demonstrates that, despite attempts to build around the establishment a micro-community centered on shared interests, this process requires time and consistency. The respondent emphasizes that "the community is not yet closely connected", even though the company regularly organizes tastings and themed meetings that attract considerable interest. According to the respondent, the goal of these activities is to create a space that serves not only as a sales venue but also as a social hub- *a micro-community that, after several such meetings, will begin to function together as a group with shared interests.* Thus, the respondent perceives the development of social bonds as a potential factor that can strengthen both customer loyalty and sales performance.

The social surroundings also manifest in the relationships between customers and staff. The respondent notes that the style of service plays a crucial role in shaping the shopping experience—not so much through sales effectiveness as through the degree to which it meets customer expectations. As she explains*, proactive service undoubtedly increases the likelihood of purchase,* yet some customers were *not always satisfied* with an overly sales-oriented approach. In this context, the owner points to the need for a balance between professionalism and authenticity—customers *expect service that demonstrates expert knowledge,* rather than aggressive selling techniques.

From a managerial perspective, the analyzed business identifies situational factors as an important element requiring advance planning and staff preparation. This particularly concerns employee training: in the context of specialized sales, staff members must possess in-depth product knowledge to effectively reduce customers' cognitive and emotional barriers. The long-term process of staff preparation is viewed as an investment in building the quality of the consumer experience and in creating an environment conducive to purchase decisions.

"[…] training personnel capable of providing expert service is a much more time-consuming process […]. It requires much greater engagement from both sides […]"

In light of these observations, the social surroundings in the analyzed establishment function as a moderating factor in the purchasing experience—affecting perceptions of service quality, comfort of stay, and willingness to repurchase. This is an example where the social aspect goes beyond the mere number of people present in the space, constituting instead an element of the identity and operational character of the place.

In Russell Belk's (1975) framework, the temporal perspective refers both to the moment in time when a purchasing decision is made and to the subjective availability of time that a consumer possesses during the purchasing process. In the HoReCa industry, this factor influences not only purchase decisions but also the nature of interactions with staff and the manner in which customers engage with the establishment's offerings.

In the studied enterprise, the temporal aspect is closely linked to the atmosphere of the place and to customers' expectations regarding the shopping experience itself. As the respondent emphasizes, *customers don't come here just to enter and leave – most of them want to experience the atmosphere of this place.* This means that time availability becomes a condition for full participation in the offered experience. Customers who are not under time pressure are more likely to make purchasing decisions, and the process itself takes on a recreational and symbolic rather than merely transactional character. The respondent confirms this relationship, noting that *a high availability of time increases the likelihood of purchase.*

The second dimension of the temporal perspective concerns the point in time, that is, the specific moment of purchase. In the analyzed establishment, this dependence is particularly evident for products such as wine. As the respondent observes, *it is definitely an afternoon topic – in the morning, purchases are made rather because one must, needs it for the afternoon.* Thus, the temporal factor differentiates not only the volume of sales throughout the day but also the motivations of customers – in the morning, purchases are predominantly goal-oriented and functional, whereas in the afternoon, they acquire a more emotional and experiential character.

It is also worth noting that in this case, the respondent deliberately refrains from seasonal and short-term marketing activities, stating that she does not apply *any price marketing* and does not change prices *at any time during the year.* Despite being aware that such practices could boost sales at specific moments, the entrepreneur argues that her customers are driven by values other than temporary economic benefit. As he notes, *customers don't want discounts because they are also aware of how difficult running such a local business is.* This attitude indicates a strong anchoring of the shopping experience in social and ethical dimensions, which in turn diminishes the significance of time in the market sense while reinforcing its symbolic function.

In conclusion, in the analyzed case, the temporal perspective is not merely an operational parameter but a factor that shapes the rhythm and character of consumption. Time—understood both as an available resource and as the moment of decision—constitutes an integral element of the customer experience and co-creates the unique image of a place where shopping acquires a cultural and emotional dimension.

In Russell Belk's (1975) framework, the definition of the task refers to the goal that guides an individual during the act of consumption—it defines the context in which the purchase occurs and the expectations the consumer associates with a given experience. In the HoReCa industry, this factor plays a crucial role, as customers' purchasing motivations often go beyond purely functional needs, encompassing symbolic, cultural, and emotional aspects.

In the studied establishment, planned purchases predominate, stemming from a clearly defined consumption intention. As the respondent emphasizes, *these are planned purchases in most cases. It's not often that they are impulsive purchases, perhaps due to the nature of the store.* Customers therefore come with a specific purpose in mind, often linked to a particular event *(for Friday, they plan to serve pasta, so they know they need a certain wine),* which reflects a high level of goal awareness and a limited influence of incidental situational stimuli.

At the same time, the owner recognizes the potential for shaping a more dynamic purchase structure, noting that *it is possible to work on suggestion, to change this proportion towards more impulsive purchases,* for instance through the recommendation of complementary products to those already being purchased. Nevertheless, she admits that the nature of the store and the profile of its customers make such actions difficult. This results from the cultural and symbolic status of the offered products—they are perceived not as everyday necessities but as elements of lifestyle and expressions of taste.

Importantly, based on the respondent's statements, several distinct customer segments can be identified, differentiated by the purpose and context of the purchase. A significant group consists of customers making purchases for gift-giving purposes. The respondent notes that "people often come to such a store to buy gifts—this is, in fact, a very large area to be developed". In this case, the situational factor takes on a social and emotional dimension, as the purchase is not intended to satisfy the buyer's own needs but rather has an intentional and relational character, linked to the act of giving.

A separate segment is formed by customers driven by cultural and culinary interests, referred to by the respondent as *Italophiles*, who purchase products "for themselves, for current consumption", thereby attributing to the purchase the character of an authentic cultural experience.

In the context of the organization under study, the presence of situational factors related to task definition thus reveals a dual—and at the same time segmentally differentiated—nature of purchasing motivations: on the one hand, they are rational and planned; on the other, they are symbolically and socially charged. In both of the aforementioned customer groups, consumer behavior reflects a high level of cognitive and emotional involvement, indicating the significant role of situational factors in shaping consumption experiences within a niche, culturally oriented HoReCa sector.

The final group of situational factors analyzed comprises antecedent states, which—according to Russell Belk's (1975) framework—refer to temporary physiological and emotional conditions of the individual immediately preceding the act of consumption. These include

variables such as fatigue, hunger, emotional tension, or pain, which may substantially modify both the perception of the purchasing situation and the readiness to make a consumer decision.

The analysis of the respondent's statements confirms the importance of this category of factors in the operational context of the analyzed establishment. As she notes, "women who come in after treatments are exhausted; they often travel from a distance and arrive tired and hungry. This is something that actually drives such purchases". According to the respondent, situations of this kind occur on a regular basis, particularly on days with a high volume of visits to nearby cosmetology and aesthetic medicine clinics. This allows these purchasing situations to be treated not as incidental but as, to some extent, recurrent consumption episodes. In such cases, the purchase assumes a compensatory character: a reduced level of physical and emotional comfort encourages customers to seek small pleasures and mood-enhancing experiences.

The respondent emphasizes that in these circumstances, products with hedonic connotations are more readily purchased, serving a gratificatory function and acting as symbolic means of restoring emotional balance. These are most often items intended for immediate consumption, such as sweet baked goods, desserts, high-quality coffee, or small portions of products perceived as premium, which do not require lengthy preparation or consumption processes. In some cases, this process also takes on a social dimension—female customers accompanied by their partners after cosmetic treatments receive small gifts from them, which further reinforces the emotional aspect of consumption.

The observations cited align with a broader stream of research on the affective dimension of consumer behavior, according to which emotions and transient states may function as significant determinants of purchasing decisions, particularly in categories of luxury goods and pleasure-oriented products (Cohen, Areni, 1991). In the case of the analyzed venue, these factors assume an occasional yet cyclically recurring and meaningful form: they activate consumption during moments of heightened emotional tension, thereby complementing the rational and planned purchasing decisions discussed in previous sections.

In light of Belk's conceptual framework, it can therefore be concluded that antecedent states—although transient in nature and difficult to measure directly—exert a tangible influence on purchasing decisions in the examined case, especially with regard to products perceived as symbolically rewarding. Their managerial relevance lies in the possibility of anticipating periods of increased susceptibility to compensatory purchases and adjusting the product offering to customers' short-term, affective needs. The importance of these situational elements is particularly evident in the HoReCa sector, where consumption is frequently intertwined with the emotional and social dimensions of experience, and purchasing acts as a form of expression or compensation for affective states.

5. Summary and Managerial Implications

The conducted study confirms the significance of situational factors in shaping consumer behavior within the HoReCa industry, with particular emphasis on the wine sector. At the same time, these findings should be interpreted in light of the applied research design, which was based on a single, in-depth case study. The analysis demonstrated that three situational domains are of key importance: the physical environment, the social environment, and task definition. Each of these directly influences the shopping experience, the perceived value of the offering, and the customer's readiness to make a purchase.

The results confirm that in the context of products characterized by a high degree of symbolic meaning and consumer involvement—such as wine—the purchasing process is not purely transactional but experiential and cultural in nature. Emotions, time, and the surrounding environment jointly co-create the value perceived by the customer. At the same time, these observations are exploratory and descriptive in character, aiming to identify potential mechanisms through which situational factors operate rather than to provide empirical generalization.

From a managerial perspective, the findings point to the need for a holistic approach to consumer experience management, in which every situational element—from service quality to the atmosphere of the venue—constitutes an integral part of experience formation and should be incorporated into the marketing strategy, particularly in small enterprises operating within the HoReCa sector. It is important to emphasize, however, that the implications formulated here should be understood as interpretative guidelines derived from observations of a single organization, rather than as universal strategic recommendations applicable across the entire industry or sector.

In the context of management in small HoReCa enterprises, the conscious shaping of the customer experience through the strategic use of situational factors becomes crucial. The physical environment of the venue functions as a communication and emotion-building tool: appropriate lighting, music, scent, and spatial layout enhance customer comfort, encourage longer stays, and increase the likelihood of purchase. At the same time, staff play a critical role, as their competencies and product knowledge have strategic importance in reducing customers' cognitive uncertainty. This finding is consistent with the research of Sassenberg (2021), which identified music and social interactions—such as opportunities for shared consumption among friends—as among the most important elements of a winery's atmosphere. These elements, however, should not be interpreted as direct mechanisms of loyalty formation but rather as potential components of the consumption experience whose significance requires further verification.

Similarly, the development of social forms of consumption—such as tastings or themed events—may strengthen the social dimension of the experience; however, within the scope of the present study, it is not possible to draw definitive conclusions regarding their long-term impact on customer relationships. Incorporating the temporal dynamics of purchasing and situational segmentation allows for a more nuanced description of the diversity of decision-making contexts, without prejudging their managerial effectiveness in other locations or business formats. Moreover, in line with earlier research by Bruwer (2016), there is potential to stimulate demand through the offering of niche-based brands targeted at specific segments, such as young women.

Effective management in the wine sector requires the recognition and active shaping of situational factors as a source of competitive advantage. Wine, as a product with a high symbolic and cultural load, demands particular sensitivity to the context in which it is selected and consumed. The conclusions presented here should therefore be treated as a point of departure for further research, especially studies based on data triangulation, which would enable a more comprehensive assessment of the relationships between situational factors and managerial strategies.

References

1. Ahlbom, C.-P., Roggeveen, A.L., Grewal, D., Nordfält, J. (2023). Understanding how music influences shopping on weekdays and weekends. *Journal of Marketing Research, 60*(5), 987-1000.
2. Atulkar, S., Kesari, B. (2018). Role of consumer traits and situational factors on impulse buying: Does gender matter? *International Journal of Retail & Distribution Management, 46*(4), 386-405.
3. Badorf, F., Hoberg, K. (2020). The impact of daily weather on retail sales: An empirical study in brick-and-mortar stores. *Journal of Retailing and Consumer Services, 52*, 101921.
4. Batra, R., Stayman, D. (1990). The role of mood in advertising effectiveness. *Journal of Consumer Research, 17*(2), 203-214.
5. Belk, R.W. (1974). An exploratory assessment of situational effect in buyers' behavior. *Journal of Marketing Research, 11*(2), 155-163.
6. Belk, R.W. (1975). Situational variables and consumer behavior. *Journal of Consumer Research, 2*(3), 157-164.
7. Bruwer, J., McCutheon, E. (2016). Consumption dynamics and socio-demographics in the wine product category: Baseline behaviorism metrics for marketing strategies. *Asia Pacific Journal of Marketing and Logistics*, *29*(3), 519-536.

8. Bruwer, J., Saliba, A., Miller, B. (2011). Consumer behaviour and sensory preference differences: Implications for wine product marketing. *Journal of Consumer Marketing, 28*(1), 5-18.
9. Charters, S., Pettigrew, S. (2008). Why do people drink wine? A consumer-focused exploration. *Journal of Food Products Marketing, 14*(3), 13-32.
10. Chen, J., Chang, Y.-W. (2023). How smart technology empowers consumers in smart retail stores? The perspective of technology readiness and situational factors. *Electronic Markets, 33*(1).
11. Chocarro, R., Cortiñas, M., Villanueva, M.-L. (2013). Situational variables in online versus offline channel choice. *Electronic Commerce Research and Applications, 12*(5), 347-361.
12. Cohen, J.B., Areni, C.S. (1991). Affect and consumer behavior. In: T.S. Robertson, H.H. Kassarjian (Eds.), *Handbook of consumer behavior* (pp. 188-240). Prentice Hall.
13. Dlačić, J., Kadić-Maglajlić, S. (2013). The role of gender and situational factors in wine consumption of Generation Y. *South East European Journal of Economics and Business, 8*(1), 53-61.
14. Douglas, M. (Ed.) (1987). *Constructive drinking: Perspectives on drink from anthropology.* New York: Cambridge University Press.
15. Dubow, J.S. (1992). Occasion-based vs. user-based benefit segmentation. *Journal of Advertising Research, 32*(March/April), 11-18.
16. Gammon, S., Ramshaw, G. (2020). Distancing from the present: Nostalgia and leisure in lockdown. *Leisure Sciences, 4*(1/2), 131-137.
17. Gastaldello, G., Streletskaya, N., Rossetto, L. (2023). Glass half-full? A comprehensive PLS-SEM approach to explore the pandemic's effect on wine tourism intentions. *International Journal of Wine Business Research, 35*(2), 322-345.
18. Groves, R., Charters, S., Reynolds, C. (2000). Imbibing, inscribing, integrating and imparting: A typology of wine consumption practices. *Journal of Wine Research, 11*(3), 209-223.
19. Gusfield, J. (1987). Passage to play: Rituals of drinking time in American society. In: M. Douglas (Ed.), *Constructive drinking: Perspectives on drink from anthropology* (pp. 73-90). New York: Cambridge University Press.
20. Heath, D.B. (2000). *Drinking occasions: Comparative perspectives on alcohol and culture.* Ann Arbor: Taylor and Francis.
21. Holbrook, M.B. (1995). *Consumer research: Introspective essays on the study of consumption.* Thousand Oaks: Sage.
22. Jaeger, S., Danaher, P., Brodie, R. (2010). *Consumption decisions made in restaurants: The case of wine selection. Food Quality and Preference, 21*(4), 439-442
23. Kenhove, P.V., De Wulf, K., Van Waterschoot, W. (1999). The impact of task definition on store-attribute saliences and store choice. *Journal of Retailing, 75*(1), 125-137.
24. Kvalsvik, F. (2022). Understanding the role of situational factors on online grocery shopping among older adults. *Journal of Retailing and Consumer Services, 68*, 103009.

25. Laaksonen, M. (1993). Retail patronage dynamics: Learning about daily shopping behavior in contexts of changing retail structures. *Journal of Business Research, 28*(1-2), 3-174.
26. Levy, S.J. (1986). Meanings in advertising stimuli. In: J. Olson, K. Sentis (Eds.), *Advertising and consumer psychology, Vol. 3,* (pp. 214-226). New York: Praeger.
27. Luo, J.M., Lam, C.F. (2020). Travel anxiety, risk attitude and travel intentions towards 'travel bubble' destinations in Hong Kong: Effect of the fear of COVID-19. *International Journal of Environmental Research and Public Health, 17*(21), 1-11.
28. Nikodemska-Wołowik, A.M. (1999). *Jakościowe badania marketingowe.* PWE.
29. Olsen, J.E., Thach, L., Nowak, L. (2007). Wine for my generation: Exploring how US wine consumers are socialized to wine. *Journal of Wine Research, 18*(1), 1-18.
30. Olsson, J., Osman, M.C., Hellström, D., Vakulenko, Y. (2022). Customer expectations of unattended grocery delivery services: Mapping forms and determinants. *International Journal of Retail & Distribution Management, 50*(13), 1-16.
31. Sassenberg, A.-M., Sassenberg, C., Sassenberg, C., Heneghan, M. (2022). Effects of atmosphere on emotions and consumer behaviour at wineries. *International Journal of Wine Business Research, 34*(4), 523-541.
32. Scholten, P.A., Livingston, J.A., Chen, J. (2009). Do countercyclical-weekend effects persist in online retail markets? *Electronic Commerce Research and Applications, 8*(2), 174-181.
33. Taylor, J.J., Bing, M., Reynolds, D., Davison, K., Ruetzler, T. (2018). Motivation and personal involvement leading to wine consumption. *International Journal of Contemporary Hospitality Management, 30*(2), 702-719.
34. Taylor, L. (2016). Motivation and personal involvement leading to wine consumption. *International Journal of Contemporary Hospitality Management, 30*(2), 702-719.
35. Teagle, J., Mueller, S., Lockshin, L. (2010). *How do Millennials' wine attitudes and behaviour differ from other generations?* Proceedings 5th International Academy of Wine Business Research Conference, 8-10 February 2010, Auckland, NZ. Academy of Wine Business Research.
36. Thomas, A., Pickering, G. (2003). The importance of wine label information. *International Journal of Wine Marketing, 15*(2), 58-74.
37. Unwin, T. (1996). *Wine and the vine: An historical geography of viticulture and the wine trade.* London: Routledge.
38. Yao, W., Zhao, H., Liu, L. (2023). Weather and time factors impact on online food delivery sales: A comparative analysis of three Chinese cities. *Theoretical and Applied Climatology, 153*(3-4), 1425-1438.
39. Yoo, J., Eom, J., Zhou, Y. (2024). Thermal comfort and retail sales: A big data analysis of extreme temperature's impact on brick-and-mortar stores. *Journal of Retailing and Consumer Services, 77*, 103699.

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CREATING CAREER PATHS FOR PARTICIPANTS IN THE NATIONAL OLYMPICS OF KNOWLEDGE AND SKILLS IN THE FIELD OF ADVERTISING „CREATIVE IN ADVERTISING”

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Purpose: The article presents the results of a pilot study on the National Advertising Knowledge and Skills Competition "Creative in Advertising". The primary aim was to examine whether participation in this newly established competition influences the career path choices of young people.
Design/methodology/approach: The study employed a diagnostic survey method using questionnaires. Data were collected from finalists (third-stage participants) and their accompanying teachers during the 2024 and 2025 editions. The research logic was structured around two hypotheses: (H1) that career plans and vocational exam exemptions are primary motivators for participation, and (H2) that perceived professional benefits drive long-term teacher engagement.
Findings: The analysis revealed that approximately 70% of finalists plan a career in the advertising industry. Key motivators include both pragmatic factors (exam exemptions) and developmental ones (prestige, skill verification). Teacher surveys, analyzed through functional categorization, showed that networking and access to industry-standard certifications (e.g., DIMAQ) are the most valued benefits.
Research limitations/implications: As a pilot study, the findings are limited to a highly motivated subgroup of finalists and should not be generalized to the entire vocational student population. Selection bias is an inherent limitation of this stage of research.
Practical implications: The study highlights the Olympiad as a crucial bridge between vocational education and the dynamic requirements of "Economy 4.0", suggesting a need for updating national curricula to better align with industry expectations.
Originality/value: This is the first empirical study of the only national advertising-themed Olympiad in Poland, addressing a significant gap in the domestic vocational education research landscape.
Keywords: staff, advertising, advertising market, career path, Olympics.
Category of the paper: case study.

Introduction

Contemporary macroeconomic conditions, characterised by rapid change, advancing globalisation and pressure to innovate, are forcing a fundamental redefinition of how businesses operate. These processes directly determine new paradigms in the area of career management. Key manifestations of organisational transformation include the de-hierarchisation of structures (flattening), the evolution of professional profiles – including the disappearance of traditional specialisations in favour of new competences – and the spread of non-standard forms of employment. The consequence of these phenomena for human capital is the loss of professional stability. This requires employees to be highly adaptable, mobile and willing to pursue lifelong learning in conditions of job insecurity. The reduction in traditional jobs and the emergence of new specialisations pose significant challenges for both employment and education. Employees are faced with growing pressure to be flexible and multitask, which, in conditions of short-term employment, creates a sense of existential uncertainty. This requires them to constantly update their qualifications in order to maintain their marketability (so-called employability). In turn, the population of pupils and students faces the problem of the inadequacy of traditional educational models to the realities of Economy 4.0. The younger generation must reckon with the need to change their professional profile multiple times throughout their lives. As a result, the education process is no longer a closed stage, but a continuous process that accompanies the individual in parallel with their professional work. In the current economic reality, the future of young people, secondary school graduates, studying, among other things, advertising technology, can be very promising, but also requires flexibility and continuous development. The advertising market is characterised by dynamic changes and, as observations show, increasingly requires flexibility and interdisciplinarity from its employees. Modern technologies, digitalisation and the increasingly widespread use of artificial intelligence necessitate the development of new skills, experience and practical knowledge by young people. The aim of the article was to present the results of a study on the organisation of the National Advertising Knowledge and Skills Competition entitled Creative in Advertising and to check whether participation in a thematic competition in the field of advertising determines the choice of career path of young people, the participants of the competition, in the advertising industry. The study assumed that the factors determining students' participation in the Advertising Knowledge and Skills Competition are their planned career path in this field and the possibility of exemption from the vocational examination.

A Literature Review

Contemporary academic discourse on career planning is very diverse. Many authors analyse factors influencing motivation, creation and development of career paths. They point to the role of career offices, employment offices, employment and career counselling agencies, training companies and, finally, HR departments. However, there is a lack of publications devoted exclusively to the issue of career path creation through participation in competitions or contests at secondary school level. Career path creation issues are discussed in detail in publications on career counselling, gifted education and educational psychology. „Terms such as career, professional career and professional development are usually used interchangeably. Due to its historical connotations, the term career is used very reluctantly; in the recent past, the word 'careerist' was used in a derogatory tone to describe a person who achieved professional success for money. In general, these terms refer to a person's development in terms of values, attitudes, talents, interests, personality and knowledge in relation to work. Specifically, these terms reflect the development of an individual's needs and life goals throughout their life and in relation to the career decisions that satisfy them" (Bańka, 2016, p. 21). As A. Smolbik-Jęczmień mentions, "making the right choice of career path is usually a very important matter for every young person, and the decision on the further direction of education is most often made by a 19-year-old student, whose maturity in choosing a university is sometimes not yet fully developed. Often, the decisions made by teenagers can take the form of so-called "youthful indiscretions" with irreversible consequences. However, with wise guidance, they can also be the beginning of an attractive and satisfying professional and personal career" (Smolbik-Jęczmień, 2017, p. 177). It is also worth mentioning the changes taking place in the education system. "The basic structure of the education system consists of formal education institutions: primary schools, vocational schools (first-level vocational schools, second-level vocational schools, technical colleges, post-secondary schools) and higher education institutions. Formal education institutions primarily shape general and general vocational competences, cognitive and IT skills, and create a base of knowledge and skills that graduates will be able to expand and develop with further skills required on the labour market. Formal education is the foundation of knowledge and skills on which the effectiveness of non-formal and informal education depends. It is the basis for a smooth transition from the competences needed here and now to the as yet undefined competences of the future" (Jeruszka, 2023, p. 66). Participation in the Olympiad, willingness to learn, develop interests and prepare beyond the core curriculum can be a factor in developing new skills and helping students find the direction for their future career path. As Stefan M. Kwiatkowski mentions, "the skills of the future can only be effectively shaped and developed in an open and flexible education system focused on lifelong learning. At the heart of this system is a person who understands the need for continuous training and acquisition of new skills, enabling them to adapt to constantly changing living and working

conditions, and above all, is able to do so" (Kwiatkowski, 2018, p. 27). The Olympiads, on the other hand, were and still are a kind of 'filter' for talent. As F.W. Wawro points out, "olympiads are intended to support and improve the activation of students' talents and interests, they should initiate creative thinking, teach the application of theoretical knowledge in practice, prepare students for their future professions, and, in the case of particularly talented students, prepare them for specialised studies" (Wawro, 1999, p. 23). The most important qualities useful in career planning include: the ability to know oneself, confidence in one's abilities and effectiveness, resilience, vitality, the ability to develop oneself, self-education, self-organisation, planning ability, flexibility, intuition, orientation in an uncertain environment, the ability to reconcile contradictions, openness to new experiences and creativity, trust, tolerance without excessive emotional involvement (Santorski, Turniak, 2011, p. 27). Participation in the Olympics is undoubtedly an important factor influencing the development of the above characteristics.

National Advertising Knowledge and Skills Competition entitled Creative in Advertising – topics, objectives and organisation

In February 2022, on the initiative of the then authorities of the Faculty of Management at the Częstochowa University of Technology, an Organising Committee was established for the National Olympiad of Knowledge and Skills in Advertising, entitled Creative in Advertising. From the very beginning, the Olympiad has been organised in cooperation with the W.S. Reymont School Complex of Fashion and Advertising in Częstochowa and is aimed at secondary school students studying to become advertising technicians. The most important objectives of the competition are:

1. To develop young people's interest in advertising and its creation.
2. To encourage secondary school students studying advertising to broaden their knowledge and acquire new skills.
3. Promoting economic knowledge among young people, with particular emphasis on marketing, promotion and advertising.
4. Raising the level of vocational education.
5. Supporting students in preparing for further education, for example at university, in fields related to the creation of advertising materials, promotion, image building and marketing.
6. Encouraging young people to compete and building an atmosphere of healthy rivalry.
7. Establishing cooperation between teachers, schools and educational centres.
8. Developing young people's skills in using the latest techniques for creating advertising materials and applying them in social media.

9. Adapting the profile of future graduates and employees in the advertising technician profession to the expectations of employers and the requirements of the labour market (www1).

The schedule for the competition is developed each year and adapted to the needs of schools and the duration of the school year. School registrations are open from the beginning of September until 11 October. On 24 October, the first stage of the competition (the so-called school competition) takes place in schools. The schools then send in the results of the school competitions and a list of those who have qualified for the second stage competitions is drawn up. The second stage competitions are organised using the e-learning platform of the Częstochowa University of Technology in the first days of January of the given school year. After the second stage of the competition, the Second Stage Competition Committee sends the Main Committee a report with attached lists containing the results and archived forms of the competition sheets of all participants, as well as relevant documentation. The second stage competition consists of a single-choice and multiple-choice test comprising 50 closed questions. These questions are designed to test basic knowledge and skills in the profession (from the core curriculum and teaching programme). The third stage of the competition and the final take place on-site at the Faculty of Management of the Częstochowa University of Technology in April of the given school year. The third stage of the competition consists of a written part (all participants in the third stage) and an oral part (the five finalists with the highest scores in the written part). The selected finalists take part in the oral part, in which they compete for places one to five. This part consists of randomly selected sets of 3 problem-based questions, which the finalists answer before the Third Level Competition Committee. The winner of a given edition of the Olympiad is the competitor who has obtained the highest number of points in the written and oral parts. (..) In accordance with the Competition Rules, the following terms are used: a Competition finalist is a participant in the third stage of the competition who has obtained at least 60% of the possible points in the written part; a Competition winner is any of the five students among the finalists with the highest scores in the oral and written parts of the third stage of the competition (www1).

In the first edition of the Olympiad in the 2023/2024 school year, students from 52 schools took part in the school competitions, and 727 participants qualified for the second stage. A total of 644 students took part in the second stage of the competition, which was conducted using the e-learning platform of the Częstochowa University of Technology. Seventy-eight people participated in the third stage of the competition, and 14 reached the final. In the first edition of the Olympiad, six people were awarded the status of laureates. In the second edition of the Olympiad, which was held in the 2024/2025 school year, students from 65 schools took part in the school competitions, 998 students took part in the second stage, and 96 students took part in the third stage. In the second edition of the Olympiad, there were 6 finalists and 6 winners. The third edition of the competition, scheduled for the 2025/2026 school year, was in the process of being organised and conducted in first-level vocational schools at the time of writing.

Seventy-five schools from all over Poland took part in the school competitions, which were scheduled for 24 October 2025. Detailed data is presented in Table 1.

Table 1.
Course of the National Creative Advertising Competition in 2023-2026

	2023/2024	2024/2025	2025/2026
Number of schools registered for school competitions	52	65	75
Number of students qualified for second-level competitions	727	998	1105
Number of students qualified for third-level competitions	78	96	The text was written during preparations for the second stage of the competition*
Number of finalists	14	6	j.w
Number of winners	6	6	j.w.
* At the time of writing, the competition was in the post-school competition phase (school competitions were held on 24 October 2025 and second-stage competitions were scheduled for 15 January 2026).			

Source: own study based on documents from the Olympic Organising Committee entitled Creative in Advertising.

As shown in Table 1, interest in the National Olympiad entitled Creative in Advertising is growing. It should also be mentioned here that since 2023, this event has been included in the schedule of thematic competitions and Olympiads for subsequent school years and has been included in the Announcement of the Minister of Education and Science on the list of thematic competitions and Olympiads related to a selected field of knowledge entitling students to exemption from the written part of the vocational examination.

Materials and Methods

In order to achieve the research objective, which is to determine the role of the National Olympiad in shaping the career paths of its participants, a diagnostic survey method was used. This choice was dictated by the specific nature of the research group and the type of data sought. Diagnostic surveys are the most popular method in quantitative research. „It is a way of gathering knowledge about the structural and functional attributes and dynamics of social phenomena, opinions, views of selected communities, the intensification and directions of development of specific phenomena and any other phenomena that are not institutionally located, which have educational significance based on a specially selected group representing the general population in which the phenomenon under study occurs" (Piekarski, 2016, p. 89).

To structure the empirical logic of the study, the following research questions and testable hypotheses were formulated:

RQ1: To what extent does participation in the advertising-themed Olympiad correlate with the students' declaration of a professional career path in the industry?

RQ2: What are the primary motivators (pragmatic vs. developmental) for students to participate in this nationwide competition?

H1: The planned career path in the advertising field and the possibility of being exempted from the professional vocational examination are the dominant factors determining participation.

H2: Teachers' satisfaction with student outcomes and the perceived developmental benefits for the school motivate their long-term involvement in the Olympiad's subsequent editions.

The choice of a diagnostic survey to examine participants' attitudes and subject teachers' opinions was based on the following factors:

1. The participants in the competition constitute a group representing the population that may be interested in pursuing a career path in line with their education (the competition is open to students of schools offering training in advertising technology).
2. The Olympiad participants come from scattered locations, representing various cities and towns in Poland.
3. The quantitative nature of the study allows trends in career path creation to be identified.
4. The survey makes it possible to standardise variables and harmonise the responses obtained (reasons for participating in the competition, plans for the future, skills developed through participation in the competition).
5. Sense of anonymity – although the survey was conducted during the third stage of the Olympiad, participants were able to answer the questions in the questionnaire anonymously.

The survey method also allowed for effective and efficient outreach to event participants. Secondly, this method enabled the collection of standardised quantitative data. The use of this methodology allowed not only for the diagnosis of the actual state of affairs (which was dictated by participation in the Olympics), but also for learning the subjective opinions of participants regarding the usefulness of the competences acquired during the competition in their career plans. An audience survey was used as a research technique, which ensured that respondents felt anonymous and comfortable when answering questions. In addition, the organisers aimed to obtain a comprehensive, two-perspective assessment of the initiative and its impact on the socio-economic environment. The diagnostic survey study used two research tools: a questionnaire addressed to students participating in the competition and a questionnaire addressed to teachers.

In both editions of the competition held so far, a diagnostic survey was conducted among students and guardians/teachers who accompanied the participants during the third stage of the competition. The survey conducted among students concerned the organisation of the competition and the participants' career plans, while the survey conducted among teachers concerned, in addition to the organisation of the event, the assessment of the benefits that participation in the competition brought to students, the identification of the competences they were able to develop, and the thematic scope of the competition. In addition, teachers also evaluated a meeting with a representative of the Sector Council for Competences (Marketing Communication), which was organised for them during the competition at the Częstochowa University of Technology. Questionnaires were distributed to all students participating in the third-level competition and to teachers. Both questionnaires contained 10 questions and personal details (the questionnaires were authored by Agnieszka Widawska-Stanisz and Joanna Pikuła-Małachowska). The study assumed that the factors determining students' participation in the Advertising Knowledge and Skills Competition were their planned career in this field and the possibility of exemption from the vocational examination. Furthermore, it was assumed that teachers' satisfaction with the results and commitment of students in the current editions of the Olympiad would motivate them to actively include the school's participation in this event in their plans for the coming years. The survey was conducted during the two editions of the Olympiad organised so far – on 17 April 2024 and 16 April 2025.

In the first edition of the competition, 66 students returned correctly completed questionnaires, and in the second edition, 64 students did so. Not all of the questionnaires distributed were accepted for further analysis because they were not completed in full. Twenty-one teachers took part in the survey in the first edition, and 17 in the second edition.

Research Findings

The two editions of the Olympiad organized and conducted to date involved secondary school students. Women comprised the majority (76% in 2024 and 69% in 2025), while men accounted for 24% and 31%, respectively. In both editions, the majority of participants were aged 17-18, which may indicate that this age group is more likely to be interested in participating in Olympiads and competitions because they are better prepared (having already covered most of the curriculum in their final years of schooling) and are beginning to consider various scenarios for their career path or choice of field of study. Participants came from various cities across Poland. The largest number of finalists originated in the Silesian, Lesser Poland, Greater Poland, and Pomeranian Voivodeships.

In the first question, students talked about their career plans. As shown in figure 1, in 2025 there was an increase in the number of people who see their future in the advertising industry.

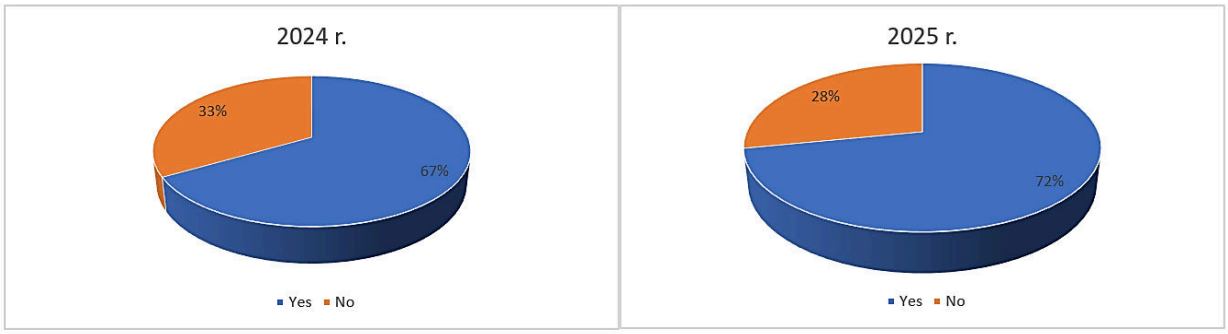


Figure 1. Intention to pursue a career in the advertising industry.
Source: own research based on conducted surveys.

In the next question, respondents were asked what had motivated them to take part in the Olympiad. In both editions, two answers stood out by far: the desire to compete and the opportunity to be exempted from the written part of the vocational exam. It is interesting to note that, compared to 2024, in this year's edition students were more likely to cite the development of their interests in advertising.

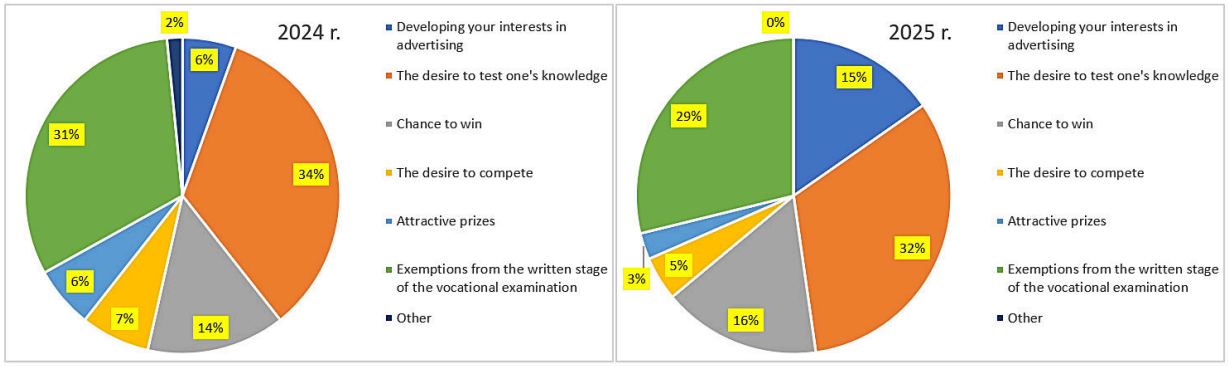


Figure 2. Reasons for participating in the Olympiad.
Source: own research based on conducted surveys.

In subsequent questions, students indicated their plans in the event of deciding to pursue higher education. In both editions, students indicated studying economics/management/ marketing at university, studying graphic design and multimedia, and some indicated other fields of study than those mentioned above. There were also those who were undecided. This question shows that most of the participants in the competition are thinking about further development and education, with individual responses concerning taking up employment immediately after school or deciding to take industry-specific courses. In the next question, the participants answered what benefits they gained from participating in the Olympiad. Most people believed that participating in the Olympiad allowed them to broaden their theoretical knowledge, helped them pass their professional examinations, and gave them the opportunity to test themselves in a competitive situation.

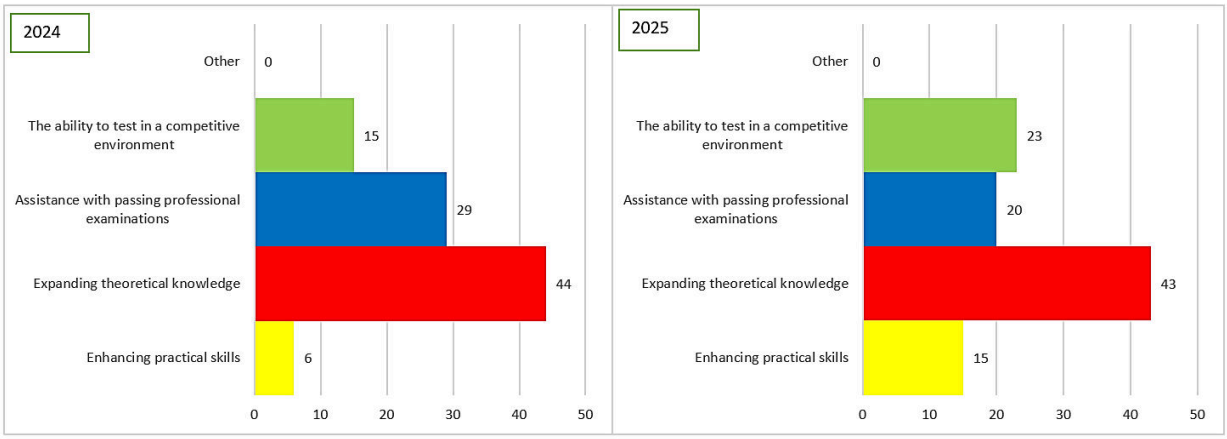


Figure 3. Benefits gained by participants from taking part in the competition.
Source: own research based on conducted surveys.

The students also indicated where they had heard about the Creative in Advertising Olympiad. The most common answer was that it was their vocational teacher (61 people in 2024 and 60 people in 2025). The organisers of the competition should therefore direct their promotional and publicity activities towards schools and subject teachers. In both editions, participants expressed a willingness to recommend the event to other students at their school – 83% (2024) and 91% (2025).

As the results of the study show, the participants who reached the third stage of the competition are people who:

1. see their future in the advertising industry,
2. participation in the competition allowed them to broaden their theoretical knowledge,
3. the students participating in the competition primarily wanted to compete with others and develop their interests related to advertising,
4. most of them would definitely recommend other students to participate in the competition,
5. the most important reason for participating was the opportunity to be exempt from the written part of the vocational examination.

Only students who reached the third stage of the competition took part in the study. The study group (third-stage competition participants) is highly selective and probably has unique characteristics that distinguish it from the average student (e.g. higher motivation, better skills, greater commitment, above-average knowledge in a given field). The above results should be treated as a pilot study (they show the results of research conducted only during the first two editions of the competition). It is also worth considering whether to send the questionnaire to all participants of the Olympiad (at all stages of the competition) in the future. However, there is a doubt as to whether those who only took part in the school competition will be able to answer all the questions as reliably as the participants of the final stage.

The second part of the survey conducted among teachers/guardians of the competition participants concerned, apart from the organisation of the event, the assessment of the benefits that the students gained from participating in the competition, the identification of the competences they were able to develop, and the thematic scope of the competition. In addition, teachers also evaluated a meeting with a representative of the Sector Council for Competences (Marketing Communication), which was organised for them during the competition at the Częstochowa University of Technology. The benefits for teachers resulting from the meeting with the Sectoral Competence Council were analysed using a categorisation approach in order to prioritise their needs. The identified benefits were grouped into three functional pillars, as shown in Table 2.

Table 2.
The benefits for teachers resulting from the meeting with the Sectoral Competence Council

Category	Specific Benefits Identified
Market Intelligence	Information on industry certifications (Dimaq), understanding evolving employer expectations, and information about the Industry Education Centre.
Networking & Integration	Building networks within the educational community, exchange of professional experiences, and integration of the academic and vocational environment.
Professional Growth	Opportunities to join the Sector Council and obtaining new teaching resources.

Source: own research based on conducted surveys.

Among the teachers surveyed, the majority were women (18 in 2024 and 14 in 2025) aged 31-40 and 41-50.

Conclusions

The results of this pilot study provide an initial insight into the role of the "Creative in Advertising" Olympiad in shaping career paths. However, the following limitations must be considered:

- Selective Sample: The study focused exclusively on finalists (third-stage participants). This group is highly selective and characterized by above-average motivation and commitment. Therefore, the findings represent a "talent subgroup" rather than the general population of vocational students.
- Pilot Nature: As a pilot study covering the first two editions (2024 and 2025), the results are a prelude to further analysis.
- Conclusion: While 70% of finalists declare a career in advertising, and the Olympiad serves as a facilitator of vocational education, these impact claims should be treated with caution. Future research will be expanded to include participants from the preliminary stages to mitigate selection bias and provide a broader perspective on the competition's impact.

References

1. Bańka, A. (2016). *Zawodoznawstwo, doradztwo zawodowe, pośrednictwo pracy.* SPiA.
2. Jeruszka, U. (2023). Kompetencje i zawody przyszłości. O (nie)dopasowaniu systemu edukacji do potrzeb rynku pracy. In: A. Piotrowska-Piątek (ed.), *System edukacji wobec zmian demograficznych.* Materiały z III Kongresu Demograficznego. Część 12. Warszawa.
3. Kwiatkowski, S.M. (ed.) (2018). *Kompetencje przyszłości*. FRSE.
4. Piekarski, M. (2016). Wybrane metody badania przydatności zawodowej pracownika. *Szkoła - Zawód - Praca, Nr 12*.
5. Santorski, J., Turniak, G. (2011). *Alchemia kariery. Bierz życie w swoje ręce*. Warszawa: Js & Co Dom Wydawniczy.
6. Smolbik-Jęczmień, A. (2017). *Kształtowanie własnej kariery zawodowej w kontekście wielopokoleniowości.* Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.
7. Wachowiak, P., Dąbrowski, M., Majewski, B. (eds.) (2007). *Kształtowanie postaw przedsiębiorczych a edukacja ekonomiczna.* Warszawa: Fundacja Promocji i Akredytacji Kierunków Ekonomicznych.
8. Wawro, F.W. (1999). Nauczyciel i szkoła jako zmienne warunkujące aspiracje edukacyjne młodzieży uzdolnionej (olimpijczyków), *Rocznik Nauk Społecznych, Tom XXVII, Zeszyt 2.* Lublin.
9. www1: Ogólnopolska Olimpiada Wiedzy i Umiejętności z Zakresu Reklamy pt. Kreatywni w reklamie, https://wz.pcz.pl/kreatywni-w-reklamie/o-olimpiadzie
10. www2: https://dimaq.pl/

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INCLUSIVE ORGANISATIONAL PRACTICES IN THE LOGISTICS INDUSTRY

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Purpose: The article was written within the framework of the research task of the project "The Role of an Inclusive Approach in Building Organisational Resilience: A Case Study of the TSL Sector (2023-2025)". Its aim is to indicate inclusive practices used by companies in the logistics industry.
Methodology: Comparative analysis of sustainable development reports from logistics industry companies available on the website www.raportyzr.pl, covering the period 2020-2025.
Findings: The analysed logistics sector companies differ in their approach to diversity management. In their sustainable development reports, they refer to team heterogeneity due to primary, secondary and organisational identity, differing among themselves in the number of employee identity characteristics mentioned. Inclusive practices applied by these companies can be assigned to the following categories: leadership and senior management engagement; organisational policies and practices; training and education; organisational culture; communication and dialogue. Universal inclusive practices were identified, namely Diversity & Inclusion indicators, which primarily relate to the aspects of diversity and equal opportunities (diversity in boards of directors and employees) as well as equal pay for women and men. The established and described inclusive practices have been defined as solutions at the meso-level – in terms of education and awareness-raising, building organisational culture and integration, inclusion-oriented HR processes and policies, and at the macro-level – in relation to public reporting of representation goals and DEI progress.
Research limitations: The study was based solely on data from reports (declarative level), without verification of compliance with reality in practice.
Practical implications: The research results may be useful for managers who are interested in implementing a Diversity, Equality and Inclusion policy in their companies.
Social implications: Building awareness about inclusive organisational practices.
Originality: The article has cognitive value for the development of management and quality sciences. It contributes to growing knowledge on inclusion from the perspective of human resource management.
Keywords: inclusion, inclusive practices, human resource management, inclusion & diversity, ESG reports, logistics.
Category of the paper: Research paper.

1. Introduction

Diversity and inclusivity are one of the megatrends in the area of social transformation and sustainable development (Sidor-Rządkowska, Sienkiewicz, 2023, p. 31). Since contemporary workplaces are more diverse than ever before, organisations need to adapt in order to remain competitive, innovative and fair (Gross-Gołacka, 2025, p. 15). The engagement of the organisation in shaping the work environment that promotes equal opportunities and respect for all employees, regardless of their diversity, is very important and involves numerous benefits such as increased innovativeness and better decision-making (Dernowska-Żaczyk, 2025, pp. 64-73).

Previous research results have shown, for instance, that inclusion can be treated as a critical determinant of organisational resilience to unforeseen events (Winnicka-Wejs, 2024) and that inclusion at work can be experienced positively in all modules: relational, emotional, behavioural, intellectual and sensory within the context of Employee Experience Management (Winnicka-Wejs, 2025).

In turn, the latest empirical research results on employee inclusivity and organisational climate emphasize the need to adopt a flexible, dynamic approach to human capital management that meets evolving needs and preferences of different generations while strengthening the importance of a people-centred approach in modern organisational strategies (Juchnowicz, Kinowska, 2024).

The latest findings of the analysis regarding inclusive solutions suitable for organisations in Poland deserve special attention. These are based on multiple case studies where an inclusive organisation model was developed, consisting of the following components: organisation characteristics, motivation, local conditions, sources of initiative, inclusive solutions and effects (Dudek, 2025).

In light of previous research, further exploration of issues related to inclusivity seems interesting, when narrowed down to a specific industry. The aim of this article is, therefore, to identify organisational inclusive practices applied by companies from the logistics industry, directed towards employees.

2. Methods

The study was based on the comparative analysis of sustainable development reports from companies in the "Transport and Logistics" industry, available on the website www.raportyzr.pl (2025). A selection of reports from the 2020-2025 period was chosen for the analysis. It should be noted that these reports are submitted as part of an annually organised competition,

the aim of which is to promote the ideas of responsible business (CSR), sustainable development, environmental protection and social engagement.

Table 1 presents a collection of reports which were subjected to analysis.

Table 1.
Collection of reports subjected to analysis in the study

Contest Edition	Company Name, Report Title
2025	– No reports.
2024	– Baltic Hub "Zrównoważony Rozwój 2023 w Baltic Hub" (Eng.*, "Sustainable Development 2023 in Baltic Hub"*), – Gdańsk Transport Company S.A. "2023 GTC raport zrównoważonego rozwoju" (Eng.*, "GTC Report on Sustainable Development 2023"*), – ROHLIG SUUS Logistics SUUSTAINABILITY ONE STEP AHEAD on the sustainability journey 2024".
2023	– ABC Czepczyński Sp. z o.o. Sp.k "Raport ESG Bilans Otwarcia 2023" (Eng., *"2023 ESG Opening Balance Report*"), – Gdańsk Transport Company S.A. "Raport Zrównoważonego Rozwoju 2022" (Eng.*, "Report on Sustainable Development 2022"*), – ROHLIG SUUS Logistics "SUUSTAINABILITY ONE STEP AHEAD on the sustainability journey 2023".
2022	– Prologis "Raport ESG 2021-22" (Eng., *"ESG Report 2021-22*"), – ROHLIG SUUS Logistics SUUSTAINABILITY REPORT 2022", – VGL Group *"*Raport CSR 2021 Razem Dostarczamy Więcej" *(*Eng.,*"CSR Report 2021 Together We Deliver More"),* – 7 R *"*Zrównoważony rozwój biznesu. Raport roczny 2021"(Eng., "*Sustainable Business Development. Annual Report 2021*"), – Gdańsk Transport Company *"*Raport Zrównoważonego Rozwoju 2021" (Eng.*, "Report on Sustainable Development 2022"*), – Grupa Kom-Eko *"*Raport ESG Grupy Kom-Eko za 2021 rok" (Eng., "*Kom-Eko Group ESG Report for 2021*").
2021	– Gdańsk Transport Company *"*Raport Zrównoważonego Rozwoju 2020" (Eng.*, "Report on Sustainable Development 2020"*), – Zarząd Transportu Metropolitalnego *"*Raport Społecznej Odpowiedzialności Zarządu Transportu Metropolitalnego za rok 2020" (Eng., "*Social Responsibility Report of the Metropolitan Transport Board for 2020")*, – Grupa Raben *"*Raport Zrównoważonego Rozwoju Grupy Raben 2020 Drive do Zrównoważonego Rozwoju" (Eng., *"Raben Group Sustainable Development Report 2020 Drive to Sustainable Development"*).
2020	– No reports.

Source: Author's own elaboration based on (https://raportyzr.pl/biblioteka-raportow/, 26.10.2025).

From Table 1, it appears that 15 reports on sustainable development from 10 logistics companies were analysed. The analysis was focused on answering the following research questions:

1. What dimensions of workforce diversity are included in the sustainable development reports of companies from the logistics industry?
2. What inclusive practices are used in the researched companies from the logistics industry?

3. Results

3.1. Dimensions of diversity considered in the analysed sustainability reports

In the researched companies, there is an effort to ensure equal opportunities in development and employment and to counteract all forms of discrimination and unequal treatment based on specific dimensions of identity (see Table 2).

Table 2.
Dimensions of diversity included in analysed sustainability reports

Company / Dimentionof identity	Baltic Hub	GTC	Rohlig SUUS	ABC Czapliński	Prologis	Grupa Kom-Eko	VGL	7R	Zarząd Transportu Metropolitalnego	Raben
Gender	+	+	+	+	+	+	+	+	+	+
Age	-	+	+	+	-	+	-	+	-	+
Race/ethnic origin	-	+	+	-	+	+	-	+	-	+
Sexual orientation/ gender identity	-	+	+	-	+	+	-	+	-	+
Disability	+	+	+	+	-	+	-	-	+	+
National or Social origin	+	+	+	+	+	-	-	+	-	+

(+) Dimension of diversity is included in the report; (-) Dimension of diversity is not included in the report.

Source: Author's own elaboration.

The data contained in Table suggest that the reports of the researched companies do not always explicitly state all dimensions of employee diversity. For example, in the Baltic Hub report, it has been indicated that all employees are ensured transparency of HR processes and career paths, while promoting a culture of equality and diversity – "We treat diversity broadly, as all aspects by which we differ from each other or are similar to each other" (Baltic Hub, 2023, p. 37). The company is aware that the industry is characterized by a higher number of employed men than women, therefore it appreciates women working at Baltic Hub by engaging them in campaigns such as "The Power of Womanhood", in which their work is presented (Baltic Hub, 2023, p. 37).

In some cases, it was diagnosed that the reports also referred to other dimensions of employee diversity, not included in Table 2, such as religious and ethical views (Rohlig SUUS, 7R, Raben), political views (Rohlig SUUS, Raben) as well as civil status, parental status, and union membership (Raben, 2020, p. 44). At GTC, in turn, a diverse team is created also in terms of thinking style or stage of family life (GTC, 2023, p. 22; GTC, 2022, p. 11; GTC, 2021, p. 14). The report of the Metropolitan Transport Board states that "strength lies in diversity – as ZTM employees, we combine different competencies and experiences, gained in working for the self-government administration as well as in business and the academic environment" (ZTM, 2020, p. 18), paying attention to organisational identity.

3.2. Inclusive practices employed within the researched companies in the logistics industry

3.2.1. Leadership and engagement of management

From the analysis of sustainable development reports, it appears that in some of the analysed companies, management promotes diversity and inclusivity. This is evidenced by the statements from logistics industry leaders cited within the reports. For instance, Torbjorn Nohrstedt, Chairman of GTC, a highway company, invokes the concept of DEI at the initial stage of their report: "The satisfaction, health and safety of our employees remain our highest priority. In this area, we have initiated actions focused on diversity, equality and inclusivity in our everyday life and while GTC's organisational values already support such behaviour, we believe that improving them is always possible" (GTC, 2023, p. 4). Similarly, at Prologis, at the very outset of the report, CEO Hamid R. Moghadam writes, "Our ESG report also details the progress we have made in the areas of inclusion and diversity promotion. Fifty percent of our workforce are women, and 32% of our US personnel are of non-white ethnic backgrounds – in both cases we exceed industry averages. To further advance in this area, we launched the Prologis Diverse Leaders programme last year" (Prologis, 2022, p. 4). The management at Prologis believes that diversity fosters good discussion and consideration of various perspectives (Prologis, 2022, p. 19). As part of its I&D commitment, the company is a signatory to the CEO Action for Diversity & Inclusion initiative (Prologis, 2022, p. 34).

In RohligSUUS's report, HR Manager Danuta Oleśkiewicz emphasizes that "We strive to meet all employee needs within SUUS. In 2024, we plan to implement the DEI Policy, which will help us to manage diversity even more effectively" (RohligSUUS, 2024, p. 26). Managers act in accordance with the company's culture and strategic objectives utilising a leadership engagment model that embodies specific values: humanity, cooperation, development, effectiveness (RohligSUUS, 2024, p. 47).

Undoubtedly, the cited examples from economic practice refer to a key element influencing the creation of an inclusive work environment, namely leadership and the involvement of management. Leaders publicly admit to the implementation of the DEI policy, serving as a model for their employees to follow.

3.2.2. Organisational policies and practices

In the analysed reports, there is frequent reference to employment policies. For example, at RohligSUUS, the key document is Work Regulations, which applies to everyone regardless of the type of work performed, the length of working hours, the type of contract concluded, or the position held. These regulations are supplemented by human resources management policies and procedures such as: Organisational Regulations; Payroll Regulations; Remote Work/Telework Regulations; Anti-Harassment Policies addressing bullying and discrimination; Training and Development Procedures; Internal Recruitment Regulations; a Procedure for Internal Meetings, a Procedure for Onboarding New Employees, a Physical and Environmental Safety Procedure; an Internal Communication Procedure, an Occupational

Health and Safety Policy, and a Data Protection Policy (RohligSUUS, 2024, p. 26). RohligSUUS enforces an unequivocal prohibition on forced labour, child labour, and all forms of discrimination while adhering to international norms and guidelines related to Human Rights, including The United Nations Guiding Principles on Business and Human Rights (UNGPs), the International Labour Organisation Declaration on Fundamental Principles and Rights at Work, and OECD Guidlines for Multinational Enterprises (RohligSUUS, 2024, p. 27).

At Prologis, in turn, in 2021, the Board updated the regulations as follows: "As part of a formal recruitment process for new directors, the Governance and Nominations Committee will consider and instruct an external recruitment firm to include candidates with diverse profiles in its searches, including on the preliminary shortlist individuals differing in gender and racial/ethnic origin" (Prologis, 2022, p. 19). The company clearly defines expectations regarding inclusive hiring practices towards coworkers and recruitment agencies, which includes a target of 50% diversity in each candidate pool. A portion of the annual bonus is allocated, dependent on the percentage of newly hired employees from underrepresented groups in positions related to property management services (Prologis, 2022, p. 34). Furthermore, an annual analysis of pay equality is conducted, encompassing gender and skin colour criteria, as well as remuneration components such as basic salary, annual bonus, and long-term incentives (Prologis, 2022, p. 34). Notably, the annual employee engagement survey for Prologis includes questions relating to inclusion and diversity ("In my team, diverse perspectives are valued and promoted"; "I have no problem expressing my own ideas and opinions, even if they differ from the ideas and opinions of others") (Prologis, 2022, p. 34).

At Kom-Eko, by contrast, there exists "Information for Employees Regarding Equal Treatment in Employment" (Grupa Kom-Eko, 2021, p. 39). According to the "Code of Ethics for Kom-Eko S.A. Employees", all members of staff are subject to the principle of equal treatment of all employees (Grupa Kom-Eko, 2021, p. 80).

The commitment to respecting human rights, providing equal opportunities in recruitment and employment is also present in the Raben's regulations. All recruitment processes are transparent and free from all forms of discrimination (Raben, 2020, p. 43).

ABC Czepczyński treats all members of staff equally, respecting their right to freedom and personal safety. The company complies with all applicable laws and regulations, including international treaties and standards (ABC Czepliński, 2023, p. 49). Its remuneration, bonus, and professional development procedures are clear, transparent, and promote equal opportunities (ABC Czepliński, 2023, p. 64).

Similarly, GTC promotes behaviours consistent with the Code of Ethics, not accepting any form of discrimination (GTC, 2023, p. 11). Diversity is listed as an important issue for the company and its stakeholders (GTC, 2022, p. 44), and a strategic goal is to create and implement the DEI (diversity, equality, inclusion) policy, where the training is followed by monitoring of actions (GTC, 2023, p. 22). It should be noted that well-designed policies and practices effectively reduce biases and promote equal opportunities.

3.2.3. Training and education

Training and education is another element influencing the creation of an inclusive work environment. However, it should be noted that it is not only about training programmes aimed at raising awareness of diversity and inclusivity in order to change employee attitudes and behaviours, but also about equal opportunities for professional development (see Winnicka-Wejs, 2017).

Thus, in RohligSUUS, every employee has the opportunity to expand their knowledge and skills, adapt to the constantly changing requirements of the environment, and receive assistance in developing their personality and professional qualifications (RohligSUUS, 2024, p. 44). When developing the competencies of the women and men working there, the training needs they report are taken into account. The company has a platform for managing training, on which the "Training Buffet" is published on a quarterly basis (RohligSUUS, 2024, p. 44). Diversity within the organisation was even among the topics addressed in projects undertaken by the company's interns (RohligSUUS, 2024, p. 49).

Meanwhile, ABC Czepliński provides "Accessibility Plus" training courses for all employees. The company, together with the CFF Foundation, implements the "ABC of Empathy" project, which aims to raise awareness among children and their parents about people with disabilities and illnesses (ABC Czepliński, 2023, p. 63). The topic of combating discrimination is also raised as part of the workplace Occupational Health and Safety training (Grupa Kom-Eko, 2021, p. 80).

Prologis recruits and develops employees with diverse backgrounds and views, creating an inclusive culture where everyone can present their abilities to the fullest (Prologis, 2022, p. 32). Priorities regarding training and professional development include supporting inclusivity and diversity. For example, in 2021, almost 500 employees completed a training course on team effectiveness using Insights Discovery assessment. To support talent and leadership development, the "Prologis Diverse Leaders" programme was launched, bringing together women and people from underrepresented minorities in middle management positions with mentors from senior management level. Participants spend together two to four hours a month (Prologis, 2022, p. 33). To provide training for employees in the area of inclusion and diversity, new training materials, programmes and toolkits were added. These include a new intranet I&D page, training on unconscious biases, as well as days and months in the year dedicated to specific topics (e.g. Black history, women's history, pride) (Prologis, 2022, p. 34).

For example, GTC has set itself the objective of ensuring that by 2030 all learners have acquired the knowledge and skills necessary for promoting sustainable development and fostering appreciation of cultural diversity. (GTC, 2020, p. 41).

3.2.4. Organisational culture

The analysis of the reports also indicates that the researched companies are striving to create inclusive organisational cultures that promote values such as "people first, openness and maintaining long-term relationships" (RohligSUUS, 2024, p. 28). At RohligSUUS, they seek to promote a diverse and integrative workforce (see RohligSUUS, 2023, p. 7), and the management team and all employees participate in building the organisational culture. In most employee-related projects, representatives from individual teams are involved to ensure that the projects are tailored to the needs of those concerned. For many years, a group of employee representatives has operated in the company, tasked with representing the needs, commenting on projects and actions for the benefit of employees (RohligSUUS, 2024, p. 29).

Building a motivating and engaging organisational culture that creates a good place to work and supports employee development, with a particular focus on ESG, is an example of an inclusive practice (see ABC Czepczyński, 2023, p. 13). Fair treatment and friendly workplaces are possible through integration and mutual respect, preventing the exclusion of minorities, a positive atmosphere and partnership, combating bullying and discrimination, building awareness, freedom of expression and openness of communication, as well as equal treatment of women (ABC Czepliński, 2023, p. 62).

The inclusion and diversity (I&D) agenda is a vital aspect of work also at Prologis and an important value of its corporate culture (Prologis, 2022, p. 13). This is evidenced by the words "Our people are committed to the ideas of inclusion and diversity, they listen, ask questions, engage and shape the future" (Prologis, 2022, p. 31); "The Prologis vision of Inclusion and Diversity aims to create an organisation where everyone is respected, feels part of the team and is treated fairly. We believe that inclusion and diversity has value for business: by including a wide range of perspectives, we can achieve better results for the company and our clients" (Prologis, 2022, p. 34). The company has established 5 support groups to promote the inclusion of Black, Asian-American, Hispanic, LGBTQIA+ employees, as well as women. The chairs of these groups are members of the global I&D steering committee alongside senior management leaders (Prologis, 2022, pp. 31, 34).

The foundation of 7R's corporate culture, based on respect and protection of diversity, is the "Code of Ethical Conduct". This document obliges all Prologis employees to oppose any manifestations of discrimination, harassment, persecution or humiliation of other people; it expresses respect for diversity and impartial attitude of employees towards political, religious and ethical views of other people; it ensures equal opportunities in the workplace, access to training and career development, equal treatment in terms of employment conditions and career advancement opportunities (7R, 2021, p. 41). It is noteworthy that diversity and an inclusive organisational culture is one of the five most important aspects of ESG identified within the 7R company (7R, 2021, p. 50).

3.2.5. Communication and dialogue

Open communication and dialogue with all employees are essential for building mutual understanding and trust within the company. At RohligSUUS, such communication is conducted via the company's intranet platform, where anyone can assess content and add their own comments. During regular "Don't Miss It" webinars with management, all employees can ask any questions, including anonymously. Managers do not refrain from difficult conversations and difficult questions, believing that only open communication can build a culture of trust within the organisation. Informal development conversations provide a space for dialogue with employees (RohligSUUS, 2024, p. 28). The company ensures that communications reach all employee groups, utilising a variety of channels and formats: direct briefings with Change Leaders / HR Business Partners; the online HR system; notice boards, posters, stickers, screens in kitchens and on warehouse floors (RohligSUUS, 2024, p. 29).

At VGL, in turn, dialogue with employees is supported by a range of communication tools: a corporate information platform, newsletters, a specially appointed "Engagement Team", comprising representatives from various departments and divisions of the company (VGL, 2021, pp. 14-15). The purpose of their operation is to make decisions on matters important to employees (VGL, 2021, p. 26). An annual "What's Important to You?" survey is conducted, whose findings indicate, among other things, that in 2021, 61% of the surveyed staff felt that the VGL Group offered the same opportunities to all employees (VGL, 2021, p. 29).

The communication strategies of the researched companies are not limited to internal operations. Some collaborate with various industry organisations to help develop career opportunities for underrepresented groups, or to provide charitable support for organisations working towards equality and inclusion (Prologis, 2022, p. 34). They also engage in dialogue with specific stakeholders, with diversity management being a key topic. This is the case with Raben, where diversity and inclusion are a cornerstone of its ESG strategy (Raben, 2020, pp. 13, 16).

3.2.6. Diversity & Inclusion Indicators

Diversity, equal treatment and inclusion of employees in organisations are monitored using D&I (Diversity & Inclusion) indicators, which can be measured in many aspects and at different levels, such as age, gender, seniority or disability (Morawiec-Bartosik, 2022, pp. 183-189). Table 3 presents the D&I indicators that are used in the analysed companies in the logistics industry.

Table 3.
Diversity & Inclusion indicators in the analysed companies in the logistics industry

Company Name	D&I indicators
Baltic Hub	– Percentage of newly hired employees (Baltic Hub, 2023, p. 36), – Employment structure by gender (Baltic Hub, 2023, p. 36), – Average number of training hours per year per employee by gender and employment category (Baltic Hub, 2023, p. 39).
GTC	– Board composition by gender, age group (under 30, 30 to 50, over 50), nationality (GTC, 2023, p. 6), – Employees of GTC S.A. by gender, age group (GTC, 2023, p. 23).
RohligSUUS	– Number of employees by gender (RohligSUUS, 2024, p. 31; 2022, p. 38), – Number of employees by country (RohligSUUS, 2024, p. 31), – Number of employees by country and gender (RohligSUUS, 2024, p. 32), – Number of employees by type of contract (RohligSUUS, 2024, p. 33), – Number of employees by type of contract broken down by country (RohligSUUS, 2024, p. 34), – Gender Distribution in Top Executives (RohligSUUS, 2024, p. 35), – Age structure of employees: under 30 years old, 30-50 years old, over 50 years old (RohligSUUS, 2024, p. 35; 2022, p. 38), – Number of employees with a disability certificate (RohligSUUS, 2024, p. 36), – Wage gap (RohligSUUS, 2024, p. 36), – Number of hours of training by position and gender (RohligSUUS, 2024, p. 45), – Number of training days for managers and other employees (RohligSUUS, 2023, p. 23).
ABC Czepliński	– Employment structure: women – men (2023, p. 61), – Type of contract: employment contract – cooperation contract (2023, p. 61), – Managerial positions: women-men (2023, p. 61), – Length of service: <3 years, 3-5 years, 5-10 years, 10-15 years, 15+ years (2023, p. 61), – KPIs: women in senior management positions; women in top management positions (C-Level); gender pay gap; members of the management board – women; management – age <30, age 31-50 (2023, p. 66).
Prologis	– Board diversity: men – women (2022, p. 19), – Board diversity: Caucasians – other people (2022, p. 19), – Seniority on the board: up to 5 years, 6-11 years, 12 years and more (2022, p. 19), – Equal pay, including gender and skin colour (2022, p. 34), – Achieving inclusion and diversity goals: women – all employees, managers, senior leaders; people of colour other than white – all employees, managers, senior leaders (USA) (2022, p. 35).
Grupa Kom-Eko	– Employment structure by type of employment: women – men (Kom-Eko Group, 2021, p. 39), – Employees on an employment contract broken down by full-time equivalent (Kom-Eko Group, 2021, p. 40), – Equal pay ratio (the sum of the annual salaries of men in full-time employment divided by the number of men employed full-time (A). The sum of the annual salaries of women in full-time employment divided by the number of women employed full-time (B). The value of the indicator calculated according to the following formula: (A-B) / B x 100) (Kom-Eko Group, 2021, p. 80), – Employees by gender, age and other diversity indicators: women, men, under 30 years old, 30-50 years old, over 50 years old, foreigners, people with disabilities (Kom-Eko Group, 2021, p. 81), – Composition of the Management Board and the Supervisory Board by gender and age (Kom-Eko Group, 2021, p. 82).
VGL	– Employment statistics by women and men (VGL, 2021, p. 18).

Cont. table 3.

7R	– Diversity in governing bodies: Management Board: <30, 30-50, >50 years / women, men. Supervisory Board: <30, 30-50, >50 years / women, men. All employees: <30, 30-50, >50 years old, including foreigners/women, men (7R, 2021, p. 41).
Metropolitan Transport Authority	– Total number of employees by type of contract and gender (ZTM, 2020, p. 19), – Total number of employees by type of employment and gender (ZTM, 2020, p. 19).
Raben	– Diversity index among management and employees (measured as the percentage of women in these groups) (Raben, 2020, pp. 61, 65), – Employed foreigners index (number of employed foreigners) (Raben, 2020, p. 61), – Total number of employees by type of contract, gender, geographical area (Raben, 2020, p. 60), – Total number of employees by type of work (women/men) (Raben, 2020, p. 60), – Total number of employees by gender and working time (Raben, 2020, p. 60) – Newly hired employees and employee turnover by age group and gender (Raben, 2020, p. 60).

Source: Author's own elaboration.

Data from Table 3 shows that compliance with the principle of diverse leadership and actions taken to ensure gender equality are information that is disclosed as part of CSR reporting.

"Diversity and equality of opportunities" indicators – the composition of management bodies and the workforce broken down by gender, age, ethnic minority status and other diversity indicators – as well as "gender pay equality" – the ratio of basic salary to remuneration of women and men broken down by employee categories and main locations of business operations (GRI, 2016, pp. 163, 165) are used almost universally across the analysed companies, although they are referred to by different names. Some D&I indicators also relate to foreign nationals and people with disabilities.

4. Discussion

The analysis of the first aspect concerning the dimensions of workforce diversity within logistics companies revealed that sustainability reports include characteristics relevant in the context of functioning in the workplace in Poland: gender, age, disability, race and ethnic origin, sexual orientation, and social class (cf. Dudek, 2025, pp. 26, 28). These characteristics are linked to team heterogeneity due to primary identity – visible: gender, age, physical ability, ethnic and racial affiliation, and secondary identity – invisible: sexual orientation, social status (cf. Jamka, 2011, p. 230).

The researched companies differed in the scope of referencing the above-mentioned features. For example, one of the companies referred solely to one identity feature, while three others referred to all six of the above-mentioned ones. In addition, some of the researched companies included in the reports also other categories of secondary identity, such as:

denomination/religion, lifestyle, family status, as well as categories of organisational identity: membership of trade unions, industry. This may indicate differences in the approach of the companies to team heterogeneity and their diversity management activities. These differences are strongly visible when comparing companies with Polish and foreign capital (cf. Waligóra, 2018, pp. 26-43).

The examined companies from the logistics industry engage in diversity by implementing specific inclusive practices. Inclusivity within these organisations relates to conscious actions aimed at creating a culture, policies and practices that support the DEI concept. The scope of these activities includes training, developing equality policies, promoting equal opportunities and eliminating discrimination - these are often cited in the literature on the subject (cf. Kuknor, Kumar, 2024, pp. 16-19).

Inclusive practices used in the researched companies from the logistics industry were categorized into the following categories: leadership and involvement of management, organisational policies and practices, training and education, organisational culture, communication and dialogue (see Gross-Gołacka, 2025, pp. 30-31) as well as Diversity & Inclusion indicators (see Morawiec-Bartosik, 2022, pp. 183-189; GRI Handbook of Applying the Guidelines, 2016, pp. 163-165).

This indicates that in the researched companies there are key elements influencing building an inclusive work environment, which can be classified as organisational factors determining inclusivity (see Gross-Gołacka, 2025, pp. 30-32). It should be emphasised that the inclusive practices described in detail in this article contribute to the achievement of specific United Nations Sustainable Development Goals, including: 3. Good Health and Well-being; 4. Quality Education; 5. Gender Equality; 8. Decent Work and Economic Growth; and 10. Reduced Inequalities (Sustainable Development Goals, 2025).

The D&I indicators identified in the researched companies from the logistics industry are universal inclusive practices which enable the assessment of progress in the area of DEI (cf. Dudek, 2025, p. 82). Most of the indicators primarily relate to key topics of the Global Reporting Initiative (GRI), namely the aspect of diversity and equal opportunities, i.e. the diversification of management bodies and employees, and the aspect of equal pay for women and men, which has recently been gaining importance due to the planned implementation in Poland of the EU Directive 2023/97 on strengthening the application of equal pay principles (Directive 2023/97).

It is observed that companies adopt diverse approaches to monitoring DEI activities. There is clear evidence that in the researched companies, where greater attention is paid to team heterogeneity, more D&I indicators are used, referring not only to women and men, but also to foreign nationals and people with disabilities, or specific age groups.

Unfortunately, analysing only the reports makes it difficult to determine the maturity level of inclusivity in the researched companies (cf. Karwowska, Tomczak, 2024; Gross-Gołacka et al., 2022; Lundy et al., 2021), as these are merely public declarations and records indicating

compliance with DEI obligations arising from applicable law. However, the established inclusive practices in the analysed companies can undoubtedly be described as solutions both at a meso level – in terms of education and awareness-raising, building organisational culture and integration, inclusive HR processes and policies, and at a macro level – in terms of public reporting of representation and DEI progress targets. It should be emphasised that these are key components of an inclusive organisational model in Poland (Dudek, 2025, pp. 192-198).

5. Summary

Research results are important as they enabled the indication of current inclusive organisational practices used actively in firms from the logistics industry. What is very important is that collections of activities and practices aiming at the implementation of goals set by companies from this industry while using heterogeneity of employees may be varied, less or more inclusive (see Leoński et al., 2020).

Conclusions from the study have both theoretical and practical implications. The article focuses on the less popular topic of inclusivity in the context of organization and human capital management, broadening theoretical knowledge in that area (cf. dimensions and levels of inclusion in: Pawlas et al., 2020, pp. 15-20), following the pragmatic research stream (cf. Rakowska, 2021, pp. 34-36).

The article can be an inspiration for managers, who are interested in the implementation of Diversity, Equity and Inclusion policy in their companies, who value creating diversified teams and inclusive organisations (cf. Fuller et al., 2022). Research results can also be useful for owners and managers of small and medium companies, who show worse preparation for inclusive management as compared to managers of large organisations (cf. Szydło et al., 2023, pp. 1-29).

This study has its limitations. Firstly, the analysis was based on historical reports (from 2021-2023), which may distort the actual and current picture of inclusive practices in the logistics industry, as these may have changed under the influence of current political and social conditions. Secondly, the analysis encompassed companies which submitted their sustainable development reports to competitions, and this fact may indicate a higher level of managerial awareness in the area of ESG, such as inclusion and diversity policies, compared to companies that do not undertake such initiatives. Thirdly, the dataset covered only selected companies and therefore it is not justified to generalise the results for the entire logistics industry. Finally, due to financial and time constraints, the study was based solely on data from reports, which means that the analysis was only conducted at a declarative level, without the perspective of managers' and employees' experience and verification of compliance with reality in practice.

Consequently, further research directions in the area of inclusive practices should assume the triangulation of data, researchers, theory, and methods (cf. Stańczyk, 2015, pp. 243-265). It is recommended to include a larger number of logistics companies in the study, as well as to adopt a different scope of entities covered, for example, companies of diversified classification of PKD – Polish Classification of Activities, corresponding to the EU NACE system, or public sector organisations. Undoubtedly, there are many research fields in this area worth deepening and exploring in order to expand knowledge about diversity and inclusivity in the context of human resource management and organisational practices in use.

References

1. *Cele Zrównoważonego Rozwoju*. Retrieved from: https://www.un.org.pl/, 31.10.2025.
2. Dernowska -Żaczyk, N. (2025). Człowiek w różnorodnym i inkluzywnym środowisku. In: B. Chomątowska, I. Janiak-Rejno, A. Smolbik-Jęczmień, A. Żarczyńska-Dobiesz (Eds.), *Człowiek w środowisku pracy Przyszłość jest teraz* (pp. 64-73). Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.
3. Dudek, A. (2025). *Analiza inkluzywnych rozwiązań stosowanych w organizacjach w Polsce. Praca doktorska.* Kraków: Uniwersytet Ekonomiczny w Krakowie.
4. *Dyrektywa 2023/970 w sprawie wzmocnienia stosowania zasady równości wynagrodzeń dla mężczyzn i kobiet za taką samą pracę lub pracę o takiej samej wartości za pośrednictwem mechanizmów przejrzystości wynagrodzeń oraz mechanizmów egzekwowania.* Retrieved from: https://sip.lex.pl/akty-prawne/dzienniki-UE/dyrektywa-2023-970-w-sprawie-wzmocnienia-stosowania-zasady-rownosci-72164952, 31.10.2025.
5. Fuller, P., Murphy, M., Chow, A. (2022). *Nieuświadomione uprzedzenia i stronniczość. Zrozum je, by uwolnić potencjał, tworzyć efektywne zespoły i inkluzywne organizacje.* Warszawa: MT Biznes.
6. *GRI G 4 Podręcznik Stosowania Wytycznych* (2016).
7. Gross-Gołacka, E. (2025). Różnorodność i inkluzywność w organizacji – w kierunku budowania inkluzywnego środowiska pracy. In: M. Gajda (Ed.), *Różnorodność i inkluzywność w miejscu pracy* (pp. 15-40). Warszawa: Wolters Kluwer.
8. Gross-Gołacka, E., Kupczyk, T., Wiktorowicz, J. (2022). Towards a Batter Workplace Environment – Empirical Masurement to Manage Diversity in the Workplace. *International Journal of nvironmental Research and Public Health, 19(23),* 15851.
9. Jamka, B. (2011). *Czynnik ludzki we współczesnym przedsiębiorstwie: zasób czy kapitał?* Warszawa: Oficyna a Wolters Kluwer Business.

10. Juchnowicz, M., Kinowska, H. (2024). Organizational Climate and Employee Inclusivity across Generations: Embracing a Human-Centric Management Approach. *Zarządzanie Zasobami Ludzkimi, Vol. 160, No. 6,* pp. 104-125.
11. Karwowska, E., Tomczak, M. (2024). Diversity, equality and inclusion maturity model: setting new standards in responsible business education – evidence from PRME reports. *Social Responsibility Journal, 21(2),* pp. 337-350.
12. Kuknor, S., Kumar, V.V. (2024). Impact of training and development interventions for diversity & inclusion: proposing an organizational schema. *Devlopment and Learning in Organizations: An International Journal, 38(1),* pp. 16-19.
13. Leoński, W., Pluta, A., Wieczorek-Szymańska, A. (2020). *Zarządzanie różnorodnością w organizacji*. Warszawa: CeDeWu.
14. Lundy, J., Kast, R., Farr-Wharton, B., Omari, M., Teo, S., Bentley, T. (2021). Utilising a capability maturity model to leverage inclusion and diversity in public sector organisations. *Australian Journal of Public Administration, 80(4),* pp. 1032-1045.
15. Morawiec-Bartosik, A. (2022). *Liczby w HR. Matematyczne ramy najbardziej ludzkiej części biznesu.* Gliwice: Onepress.
16. Pawlas, I., Talar, S., Dziembała, M., Czech, K. (2020). *Inkluzywna gospodarka światowa szanse i wyzwania.* Warszawa: PWE.
17. Rakowska, A. (2021). *Różnorodność zasobów ludzkich w organizacji: istota, dylematy wyzwania.* Lublin: Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej.
18. *Raporty Zrównoważonego Rozwoju*. Retrieved from: https://raportyzr.pl/biblioteka-raportow/, 26.10.2025:
    - ABC Czepczyński Sp. z o.o. Sp.k (2023). *Raport ESG Bilans Otwarcia 2023*.
    - Baltic Hub (2023). *Zrównoważony Rozwój 2023 w Baltic Hub*.
    - Gdańsk Transport Company (2020). *Raport Zrównoważonego Rozwoju 2020*.
    - Gdańsk Transport Company (2021). *Raport Zrównoważonego Rozwoju 2021.*
    - Gdańsk Transport Company (2023). *2023 GTC raport zrównoważonego rozwoju*.
    - Gdańsk Transport Company (2022). *Raport Zrównoważonego Rozwoju 2022*.
    - Grupa Kom-Eko (2021). *Raport ESG Grupy Kom-Eko za 2021 rok*.
    - Grupa Raben (2020). *Raport Zrównoważonego Rozwoju Grupy Raben 2020 Drive do Zrównoważonego Rozwoju.*
    - Prologis (2022). *Raport ESG 2021-22.*
    - ROHLIG SUUS Logistics (2022). *SUUSTAINABILITY REPORT 2022.*
    - ROHLIG SUUS Logistics (2023). *SUUSTAINABILITY ONE STEP AHEAD on the sustainability journey 2023.*
    - ROHLIG SUUS Logistics (2024). *SUUSTAINABILITY ONE STEP AHEAD on the sustainability journey 2024.*
    - VGL Group (2021). *Raport CSR 2021 Razem Dostarczamy Więcej*.

- Zarząd Transportu Metropolitalnego (2020). *Raport Społecznej Odpowiedzialności Zarządu Transportu Metropolitalnego za rok 2020.*
- 7 R (2021). *Zrównoważony rozwój biznesu. Raport roczny 2021*.

19. Sidor-Rządkowska, M., Sienkiewicz, Ł. (2023). *Cyfrowy HR. Organizacja w warunkach transformacji technologicznej.* Warszawa: Wolters Kluwer Polska.
20. Stańczyk, S. (2015). Triangulacja – łącznie metod badawczych i urzetelnienie badań. In: W. Czakon (Ed.), *Podstawy metodologii badań w naukach o zarządzaniu* (pp. 243-265). Warszawa: Oficyna a Wolters Kluwer business.
21. Szydło, J., Czerniawska, M., Rzepka, A., Fariñas, B.A. (2023). Inclusive Management in a Diversified Cultural Environment. *Ekonomia i Środowisko, No. 4(87),* pp. 1-29.
22. Waligóra, Ł. (2018). Zarządzanie różnorodnością w organizacjach. Prezentacja wybranych praktyk. *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach, No. 348,* pp. 26-43.
23. Winnicka-Wejs, A. (2017). Szkolenia pracowników jako element zarządzania różnorodnością. *Zeszyty Naukowe Uniwersytetu Ekonomiczngo w Krakowie, No. 4(964),* pp. 49-66.
24. Winnicka-Wejs, A. (2024). The Role of Inclusivity in Building Organizational Resilience. *Scientific Papers of Silesian University of Technology*, *No. 212,* pp. 623-637.
25. Winnicka-Wejs, A. (2025). Experiencing Inclusion by the Generation Z – Opportunities and Threats. *Scientific Papers of Silesian University of Technology, No. 227,* pp. 578-585.

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THE EVOLUTION OF E-SERVICE CONSUMPTION IN POLAND: A DECADE PERSPECTIVE

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Purpose: The purpose of this paper is to identify changes in e-service consumption in Poland between 2012 and 2024.
Design/methodology/approach: The study adopts a longitudinal research approach based on two quantitative surveys conducted in 2012 and 2024 using the CAWI method. Both surveys were carried out among Polish e-service consumers with comparable sampling criteria. The analysis focuses on changes in the frequency of using different categories of e-services, including social, leisure-related, and financial services.
Findings: The results indicate a significant expansion and diversification of e-service consumption in Poland. Between 2012 and 2024, consumer behaviour evolved from selective use of digital services to widespread and multidimensional adoption. The highest level of activity remains within the financial sector (online banking, electronic payments), yet the gap between this and other categories has clearly narrowed. Consumption of cultural e-services (films, music, audiobooks) and tourism services (online reservations and purchases) increased markedly, while moderate but steady growth was recorded in e-education and e-health.
Research limitations/implications: The study is subject to several methodological limitations. Although the CAWI method is well-suited to studying e-service users, it may exclude individuals with lower digital competences or limited internet access. Furthermore, the research does not account for consumers' digital maturity levels, which may influence e-service use. Future research should employ methodological triangulation.
Practical implications: The findings have practical value for service providers and policymakers. They highlight the need for further integration of digital services, improvements in usability, security, and personalization.
Social implications: The study reveals a growing level of digital inclusion among Polish consumers and the normalization of e-service use in everyday life. Widespread access to electronic services promotes convenience and time efficiency, while simultaneously raising challenges related to digital exclusion, data privacy and cybersecurity.
Originality/value: The paper offers a unique twelve-year perspective on changes in e-service consumption in Poland. It contributes to the growing body of research on e-consumer behaviour and e-service delivery in the digital economy. The study is addressed to scholars of the digital economy as well as practitioners in the e-service market.
Keywords: e-services; digital economy; e-consumer; longitudinal survey.
Category of the paper: Research paper.

1. Introduction

Technological change has become one of the key drivers of economic growth, exerting a significant influence on the innovativeness of market actors. This process is reflected in the ongoing virtualization of socio-economic life and the dynamic expansion of the market for electronically delivered services. The growth of e-services is closely linked to the evolution of the information society, in which both producers and consumers play an active role as co-creators of the digital economy. One of the indicators measuring the advancement of this process within the European Union is the Digital Economy and Society Index (DESI), which reflects the level of digitalization of economies and societies. In 2022, Poland, with a score of 40.5 points, ranked 24th in Europe. The widespread adoption of digital technologies has redefined the ways in which services are produced, delivered, and consumed, while also giving rise to new forms of interaction between providers and users. The consumption of e-services has become not only an expression of innovation but also a prerequisite for participation in a post-industrial society. As e-services increasingly integrate into everyday consumption practices, they have ceased to be a supplementary element and have become a permanent feature of the contemporary lifestyle.

There is a lack of long-term empirical studies examining changes in the consumption of different categories of e-services in Poland based on comparable data.

The purpose of this paper is to identify changes in e-service consumption in Poland between 2012 and 2024. The analyses aim to determine the directions and intensity of changes in e-consumer behaviour. The empirical basis consists of longitudinal research conducted using the CAWI (Computer-Assisted Web Interview) method in 2012 and 2024. Comparing the results from both measurement points makes it possible to capture the evolution of the digital consumption landscape within Polish society.

2. Literature review

The development of the e-services market was initiated by the emergence of new technological and organizational opportunities for providing services via the internet, which began to take shape in the final years of the twentieth century. In Western literature, the concept of e-services is defined in a multifaceted manner, encompassing various research perspectives - from process-oriented to relational approaches. Among the scholars who have examined this issue are K.K. Boyer, R. Hallowell and A.V. Roth (2002), R. Järvinen and U. Lehtinen (2004), K.D. Hoffman and J.E.G. Bateson (2007), A. Henten (2008), and Te-Hsin Liang (2011). In Polish literature, two approaches to defining e-services are particularly noteworthy. The first

emphasizes that e-services constitute "a new formula for providing services, and thus for meeting needs, through the use of the internet - from the moment of a company's first contact with a client (individual or institutional) to present an offer, through ordering and service delivery, up to post-sale communication" (Dąbrowska, 2008). The second defines e-services as "a form of service provision using the internet, encompassing in particular the presentation of a service, its ordering, payment, and online use, with the reservation that for some services the consumption stage takes place in the physical world" (Wolny, 2013).

The provision of e-services in Poland was legally regulated by the Act of 18 July 2002 on the Provision of Electronic Services. According to this act, an e-service is any service performed without the simultaneous presence of the parties - at a distance - through data transmission at the individual request of the recipient. This transmission takes place using devices for electronic data processing and storage, via a telecommunications network, with the entire process - from sending to receiving data - being digital in nature. This definition represents the implementation and extension of the provisions contained in Directive 2000/31/EC of the European Parliament and of the Council on electronic commerce and information society services.

The range of e-services available on the market is very broad, encompassing public, commercial, and social services. The literature most commonly distinguishes the following categories (Dąbrowska, 2008; Wolny, 2012a; Wolny, 2012b): e-government, e-banking, e-education, e-commerce, e-culture, e-tourism, e-insurance, and e-health. Other classifications group services according to functional criteria - for example, e-education and e-health are categorized as social e-services, while e-culture and e-sport are classified as leisure-oriented services (Fig. 1).

In economic practice, several types of e-services can be distinguished (Wolny, 2013, p. 13):

- services provided both traditionally and online, in which individual elements of the service process (presentation, ordering, payment, execution) may take place either in a traditional manner or within a digital environment,
- services provided exclusively online, where all stages - from presenting the offer, through ordering and payment, to actual use - are carried out entirely on the internet,
- services sold online but delivered traditionally, in which the stages of presentation, ordering, and payment are conducted digitally, while the actual consumption of the service occurs in the physical world.

The extent to which the internet is used in each phase of the service provision process depends on the nature of the service itself. Full digitalization of all stages (presentation, purchase, payment, and consumption) is possible in the case of e-banking, e-education, and e-sport.

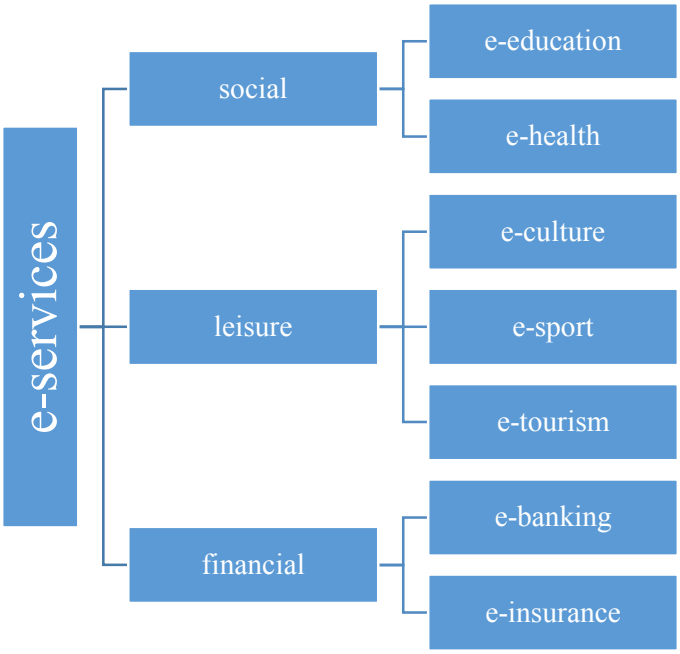


Figure 1. Classification of e-services.

Source: own elaboration based on: (Wolny, 2024).

For services such as e-insurance or e-tourism, part of the process - especially the use of the service - takes place outside the virtual environment. In the area of e-culture, the model of service provision is more diversified: some services (for example, film streaming or online concerts) are carried out entirely digitally (Table 1).

Table 1.
Internet elements of the e-service delivery process carried out via the internet.

Services		Possibilities of performing activities via the internet			
		Presentation	**Purchase/order**	**Payment**	**Use**
Social	e-education	yes	yes	yes	yes
	e-health	within the selected scope	yes	within the selected scope	within the selected scope
Leisure	e-culture	yes	yes	yes	within the selected scope
	e-sport	yes	yes	yes	yes
	e-tourism	yes	yes	yes	within the selected scope
Financial	e-banking	yes	yes	yes	yes
	e-insurance	yes	yes	yes	no

Source: own elaboration based on: (Wolny, 2013).

Others services (such as purchasing tickets for events) combine elements of both the online and offline worlds. In the case of e-health, the degree of digitalization is limited - the presentation of services and certain aspects of their delivery take place online, but most activities still have a traditional character.

E-services, like other goods and services available on the market, satisfy consumer needs and therefore constitute an object of consumption. In the literature, the consumption of services is defined as activities aimed at meeting various human needs through the use of assistance

provided by specialized individuals, institutions, or devices designed to perform specific service-related tasks (Olearnik, 1990). The specific nature of e-services, however, means that their consumption takes on a somewhat different form compared to traditional services. Depending on the nature of the e-service - whether it is delivered entirely online or only sold via the internet - the consumption process may occur either in the virtual space or in the physical world, following an online purchase, as discussed earlier.

In the context of the e-service market, defining the subject of consumption also becomes particularly important. The consumer of e-services is a person who actively uses digital technologies to satisfy their needs (Jaciow, Wolny, 2011a). This group includes:

- e-consumers: "a natural person who expresses and fulfils their consumption needs using products (goods and services) purchased on the internet" (Jaciow, Wolny, 2011b),
- m-consumers: "a natural person who expresses and fulfils their consumption needs using goods and services purchased through mobile devices" (Jaciow, Wolny, 2022),
- c-consumers: "a natural person who expresses and fulfils their consumption needs through personalized digital products purchased online" (Jaciow, Wolny, 2022).

A fully integrated participant in the consumption of e-services within the digital economy is the digital consumer (c-consumer).

3. Methods

In the analysis of socio-economic phenomena, repeated studies - longitudinal research - are of particular importance. Such studies make it possible not only to assess the current state of the examined phenomena but also to trace their changes over time. They involve multiple measurements of the same phenomena and characteristics, conducted on different samples drawn from the same population (Sagan, 2016). To capture changes in the consumption of e-services in Poland, longitudinal studies were carried out in 2012 and again in 2024. In both surveys, conducted using the same measurement scale, the frequency of e-service use was among the variables studied. The sampling criteria remained unchanged and included individual consumers who purchase or use e-services.

The 2012 survey was conducted using the CAWI (Computer-Assisted Web Interview) method between September 1 and September 30 on the SurveyMonkey.com platform. The study was nationwide in scope. After formal and substantive verification, 1200 fully completed questionnaires were qualified for further analysis. The 2024 survey was also conducted using the CAWI method, between November 18 and December 31, 2024, via SurveyMonkey.com. After verification, 1243 fully completed questionnaires were included in the final dataset. In both cases, the sample was controlled for gender, age, place of residence, household size, professional activity, and self-assessed financial situation. The use of the CAWI

method in both studies was justified by its broad reach and the ability to access respondents in line with predefined distributions. The CAWI technique is commonly applied in studies on consumption and consumer behaviour (Gajdzik et al., 2024; Olko, 2019; Fandrejewska et al., 2022; Gajdzik et al., 2025b).

In the 2012 survey, the sample included nearly equal proportions of women (50.3%) and men (49.7%). About 30% of respondents were aged up to 24 or between 25 and 34 years. Almost one in five was between 35 and 44, and roughly one in seven was over 45. The youngest participant was 18 years old, and the oldest was 68. Most respondents had higher education (60.9%), while nearly one-third had secondary education. Those with primary or vocational education accounted for only 3.2% of the sample. The majority lived in cities of various sizes (71.5%) and were employed (78.0%). Almost half rated their financial situation as good or very good, nearly one-third as satisfactory, and 17.4% as poor or very poor.

In the 2024 survey, 51.1% of participants were women and 48.9% men. One in ten respondents was aged 18-24, and one in three was aged 25-44. The remaining participants were over 45 years old. Most respondents had higher (49.2%) or secondary (38.1%) education, while those with vocational or primary education represented 15.7% of the sample. Nearly two-thirds of respondents were professionally active, while 37.6% were not working. Urban residents of various city sizes accounted for 60.8% of participants. Over 60% rated their financial situation as good or very good, almost one-third as satisfactory, and only a small share - 4.6% - described it as poor or very poor.

4. Results

The analysis of the 2012 and 2024 survey results makes it possible to identify significant changes in the frequency of using various categories of e-services in Poland. In both measurements, a five-point scale was applied, where 1 meant never, 2 – rarely, 3 – often, 4 – very often, and 5 – always.

In 2012, the structure of e-service consumption had a clearly selective character. Financial services were used most frequently: making online transfers and checking bank account balances were part of the everyday practices of a substantial share of respondents. The high proportion of very often and always responses confirms that electronic banking was, at that time, the most advanced segment of the e-service market. Other categories showed a noticeably lower level of user engagement. Educational services, such as thematic courses or foreign language learning, were used only occasionally. A similar pattern characterized the use of cultural e-services (reading e-books, watching films, listening to music or radio) and tourism-related services (purchasing tickets, booking accommodation). Health and insurance e-services

had even less importance, as the vast majority of respondents declared that they never or very rarely used them (Table 2).

Table 2.
Frequency of using e-services in 2012 (in %)

Items	1	2	3	4	5
Payments by bank transfer (e.g. rent)	8,8	28,7	18,9	15,9	26,8
Checking account balance and transaction history	7,8	12,0	29,3	31,1	19,8
Participation in training courses and thematic workshops	45,1	32,4	17,1	2,9	2,5
Learning a foreign language	58,2	20,8	10,8	3,6	6,7
Reading newspapers	27,7	16,2	17,8	18,8	19,5
Reading e-books	56,9	21,5	16,5	2,3	2,8
Watching films	25,7	11,5	23,0	20,3	19,6
Listening to the radio	31,8	10,9	18,3	8,1	30,9
Listening to music	53,4	19,3	10,8	12,7	3,8
Buying tickets for cinema/theatre/concerts	30,8	36,9	27,4	2,8	2,0
Buying train/bus/plane tickets	58,8	27,7	10,8	1,6	1,1
Purchasing domestic or international trips	64,0	32,5	2,3	1,0	0,3
Booking accommodation	54,1	41,9	2,8	0,6	0,6
Buying property/car insurance	73,0	24,3	1,6	0,5	0,6
Buying life/travel/accident insurance	82,4	15,2	1,9	0,3	0,3
Scheduling medical appointments	82,9	13,3	3,3	0,3	0,2
Using online medical consultations	89,0	7,7	2,3	0,5	0,5

Note: 1 – never, 2 – rarely, 3 – often, 4 – very often, 5 – always.
Source: own research.

The 2024 results indicate a significant expansion in both the scope and intensity of e-service use. In most of the analyzed categories, there was an evident increase in the share of responses such as often, very often, and always. This demonstrates the clear development and widespread adoption of e-service consumption. Financial services still recorded the highest level of user activity; however, the gap between this category and others has noticeably narrowed. While in 2012 e-banking and online payments were primarily used by the most technologically advanced consumers, by 2024 they had become a common practice and an integral part of everyday financial management (Table 3).

The conducted research also reveals an increase in the consumption of culture-related e-services. Watching films, listening to music, and using audiobooks have become activities performed frequently or very frequently by a large proportion of respondents. In the area of education, the level of engagement remains moderate; however, there has been a clear rise in the share of respondents declaring frequent or very frequent participation in online courses and language learning. Nevertheless, e-education services are still perceived mainly as complementary to traditional, in-person forms.

Table 3.
Frequency of using e-services in 2024 (in %)

Item	1	2	3	4	5
Payments by bank transfer (e.g. rent)	5,2	6,4	21,5	31,1	35,8
Checking account balance and transaction history	3,7	9,6	32,8	31,2	22,7
Participation in training courses and thematic workshops	25,2	33,4	23,2	13,4	4,9
Learning a foreign language	26,1	30,8	24,5	12,4	6,1
Reading newspapers	27,4	34,7	19,1	13,5	5,3
Reading e-books	36,7	27,8	19,4	11,0	5,1
Watching films	3,9	16,7	28,2	30,3	20,9
Listening to the radio	17,4	27,8	25,3	16,0	13,4
Listening to music	5,6	10,2	30,3	29,1	24,8
Buying tickets for cinema/theatre/concerts	32,7	26,8	20,4	13,1	6,9
Buying train/bus/plane tickets	12,1	30,7	28,5	15,5	13,2
Purchasing domestic or international trips	8,4	25,3	30,1	17,6	18,6
Booking accommodation	20,6	29,1	25,1	12,6	11,6
Buying property/car insurance	11,8	28,2	29,9	14,5	15,5
Buying life/travel/accident insurance	31,8	23,7	18,7	13,8	12,1
Scheduling medical appointments	32,0	26,3	17,2	14,2	10,2
Using online medical consultations	21,9	27,0	24,0	20,0	7,1
Korzystam z konsultacji lekarskich online	34,4	28,2	20,9	13,2	3,3
Filing taxes online	24,5	14,8	18,1	13,0	29,6
Signing documents with an electronic signature	29,3	23,7	25,2	14,2	7,5
Making payments using BLIK	11,5	7,7	23,8	39,0	17,9

Note: 1 – never, 2 – rarely, 3 – often, 4 – very often, 5 – always.
Source: own research.

A similar upward trend is observed in the sphere of e-tourism. Compared to 2012, the number of respondents purchasing tickets, booking accommodation, or organizing trips online has increased significantly. The same applies to e-insurance, where the share of individuals not purchasing insurance via the internet has markedly declined. In the field of e-health, the growing importance of digital channels is evident. More than 40% of respondents now book medical appointments online. Although remote consultations are not yet widespread, their use has increased several times compared to 2012.

A novelty in the 2024 study was the inclusion of additional categories of e-services that were either unavailable in 2012 (mobile BLIK payments, online tax settlements) or not yet common (electronic signature). The results in these areas show that the digitalization of administration and payment systems has reached a high level of social adaptation. BLIK mobile payments have become part of the daily routine for the majority of respondents, as has online tax filing, while the electronic signature - though used less frequently - is gradually becoming a standard tool in the lives of e-consumers.

5. Discussion

The obtained results confirm the ongoing evolution in the consumption of e-services in Poland. In 2012, although e-consumers were already relatively active in the e-service market, their engagement was rather selective. By 2024, however, the use of digital services had become widespread and multidimensional. The findings are consistent with global trends described in the literature, which emphasize the growing integration of electronic services into consumers' everyday lifestyles (Wolny, 2016a; Śledziewska, Włoch, 2020; Surmacz et al., 2024; Wolny, 2023; Zarzycka, 2021; Gajdzik et al., 2023; Gajdzik et al., 2025a; Wolny et al., 2025).

Similar to other studies conducted in recent years, the highest intensity of use was recorded in the area of financial services. The increase in the frequency of online transfers, electronic payments, and mobile transactions results not only from technological progress but also from changing attitudes toward digital trust and security. These findings align with the observations of Fandrejewska et al. (2022), who demonstrated that the COVID-19 pandemic permanently increased consumers' openness to digital channels. Other studies also confirm that people adopt new digital technologies and modify their behaviour in the e-banking market (Grigorescu et al., 2023).

The growing importance of e-services in the field of e-culture (or, more broadly, e-entertainment) corresponds with the findings of Szewczyk (2014) and Słaby and Bazydło-Egier (2021), who observed that the digitalization of cultural and entertainment goods has become one of the main dimensions of modern consumption. Watching films, listening to music, or using audiobooks online increasingly shapes the lifestyle of contemporary consumers, particularly among younger generations (Szojda, 2024; Wolny, 2016b). Over the past decade, the share of consumers in Poland who read or download online magazines has increased nearly fourfold, while the share of those watching on-demand television has risen sevenfold. It can therefore be concluded that digitality is no longer, as it was at the beginning of the 21st century, an addition, but rather an integral component of cultural institutions and their audiences (Wolny, 2023).

Meanwhile, the moderate increase in the use of e-education services aligns with the findings of Wierzbicka (2019), who emphasized that despite the development of e-learning tools, online education continues to play a complementary role to traditional teaching forms. Similar conclusions were drawn by Jackowski, whose results indicate that remote learning, if implemented, tends to take the form of blended learning - that is, as a supplement rather than a replacement (Jackowski, 2023).

The observed increase in the use of e-health services, including online medical appointments and consultations, reflects a broader trend toward the digitalization of healthcare. As noted by Bukowska-Piestrzyńska (2021), e-health represents a response to the logistical challenge of ensuring sufficient healthcare resources amid long waiting times for medical

services. Although these services have not yet reached the level of mass adoption, their growth confirms the ongoing transition toward a patient-centered digital health model.

6. Conclusion

The conducted research allows for the formulation of several important conclusions regarding the evolution of e-service consumption in Poland over the past decade. Between 2012 and 2024, a clear shift can be observed - from selective and cautious use of digital services toward their widespread and diversified adoption. E-services have become a permanent element of Polish consumers' everyday practices, as evidenced by both the increased frequency of use and the broader range of service categories.

Financial e-services enjoy the greatest popularity, having reached a high level of social acceptance by 2024. The development of mobile payment systems such as BLIK demonstrates a strong internalization of digital innovations in consumer behaviour. A dynamic rise has also been observed in the area of e-culture, where the consumption of audiovisual and multimedia content has become one of the key dimensions of modern lifestyles. The moderate yet consistent growth of e-education, along with the significant increase in the use of e-health services, points to the consolidation of hybrid models of service consumption that combine the online and offline spheres. The findings are consistent with recent European research, which indicates that the digital transformation of consumption is redefining the role of the consumer - from a passive recipient of services to an active co-creator and participant in the digital ecosystem.

From both theoretical and practical perspectives, the results confirm that the development of the e-services market in Poland is part of a broader process of technological and social convergence, in which the digital consumer (c-consumer) becomes the central link in the service system. This transformation is continuous and evolutionary in nature, and its further trajectory will depend, among other factors, on the level of consumers' digital competence and the state of cybersecurity.

Despite the broad scope of the study and the use of quantitative methods, the presented analyses are subject to several important methodological and cognitive limitations. The research employed the CAWI method, which, while appropriate for studying individuals who use e-services, may have excluded certain groups of respondents. Another limitation is the lack of consideration of consumers' digital maturity levels, including their digital skills, which may influence the extent of e-service consumption. Differences in digital maturity could modify the observed relationships and should therefore be taken into account in future studies.

Future research could consider the use of methodological triangulation, complementing declarative data with alternative sources of information, such as behavioural data or digital activity tracking. Moreover, comparative studies are planned to broaden the research scope, including the exploration of additional motives and determinants of e-service consumption.

References

1. Boyer, K.K., Hallowell, R., Roth, A.V. (2002). E-services. Operations strategy – a case study and a method for analyzing operational benefits. *Journal of Operations Management*, *Vol. 20,* pp. 175-188.
2. Bukowska-Piestrzyńska, A. (2021). Multikanałowość w ochronie zdrowia a e-zdrowie. In: C. Mańkowski, L. Reszka (Eds.), *Modelowanie procesów i systemów logistycznych*. Gdańsk: Wydawnictwo Uniwersytetu Gdańskiego.
3. Dąbrowska, A. (2008). *Rozwój rynku usług w Polsce – uwarunkowania i perspektywy.* Warszawa: SGH.
4. Dyrektywa 2000/31/WE Parlamentu Europejskiego i Rady z dnia 8 czerwca 2000 roku w sprawie niektórych aspektów prawnych usług społeczeństwa informacyjnego, w szczególności handlu elektronicznego w ramach rynku wewnętrznego (Dyrektywa o handlu elektronicznym), *EUR-Lex* (2000). Retrieved from: https://eur-lex.europa.eu/legal-content/PL/ALL/?uri=CELEX%3A32000L0031, 11.11.2025.
5. Fandrejewska, A., Chmielarz, W., Zborowski, M. (2022). The Impact of the COVID-19 Pandemic on the Perception of Globalization and Consumer Behavior. *Sustainability*, *Vol. 14, No. 9575,* doi: https://doi.org/10.3390/su14159575
6. Gajdzik, B., Bartuś, K., Jaciow, M., Wolniak, R., Wolny, R., Grebski, W.W. (2024). Evolution of Polish E-Consumers' Environmental Awareness and Purchasing Behavior over Ten Years. *Sustainability*, *Vol. 16, No. 11,* pp. 4686, doi: https://doi.org/10.3390/su16114686
7. Gajdzik, B., Jaciow, M., Mosora, L., Stolecka-Makowska, A., Wolniak, R., Wolny, R. (2025a). Collaborative Consumption and Its Implication for Sustainable Consumption of Generation Z in Ukraine. *Sustainability*, *17*(10), 4456.
8. Gajdzik, B., Jaciow, M., Wolny, R. (2023). Types of E-Consumers and Their Implications for Sustainable Consumption – A Study of the Behavior of Polish E-Consumers in the Second Decade of the 21st Century. *Sustainability*, *Vol. 15, No. 16,* p. 12647, doi: https://doi.org/10.3390/su151612647
9. Gajdzik, B., Jaciow, M., Wolny, R. (2025b). Value Creation for the Digital Consumer. A Management Guide. In: A. Jabłoński, M. Jabłoński (eds.), *Effect of Digital and Climate Changes in the Business Models of Companies* (pp. 62-78). Boca Raton: Taylor & Francis Group, CRC Press.

10. Grigorescu, A., Oprisan, O., Lincaru, C., Pirciog, C.S. (2023). E-Banking Convergence and the Adopter's Behavior Changing Across EU Countries. *Sage Open*, *Vol. 13, No. 4*, doi: https://doi.org/10.1177/21582440231220455
11. Henten, A. (2008). Services, e-services and nonservices. In: A. Scupola (Ed.), *Cases on Managing E-Services*. London: Idea Group Publishing.
12. Hoffman, K.D., Bateson, J.E.G. (2007). *Services Marketing. Concepts, Strategies & Cases.* USA: Thompson South-Western.
13. Jaciow, M., Wolny, R. (2011a). *Polski e-konsument. Typologia, zachowania.* Gliwice: Helion.
14. Jaciow, M., Wolny, R. (2022). *Polski e-konsument. Dekada zmian.* Gliwice: Helion.
15. Jaciow, M., Wolny, R. (2011b). *E-consumer in Poland: Behaviours & Typology*. University of Economics in Katowice. Department of Markets and Consumption the Centre of Research and Expertise.
16. Jackowski, M. (2023). E-edukacja – eksperyment dydaktyczny czy nowa forma nauczania. *Dydaktyka informatyki*, *Vol. 18, No. 18*, pp. 128-136.
17. Järvinen, R., Lehtinen, U. (2004). Services, e-Services and e-Service Innovations – Combination of Theoretical and Practical Knowledge. *Frontiers of E-Business Research.* Tampere: University of Technology and University of Tampere.
18. Liang, T.-H. (2011). The Awareness and Want Matrix with Adoption Gap Ratio Analysis for e-Service Diffusion Effect. *Cyberpsychology, Behavior and Social Networking*, *Vol. 14, No. 3*, pp. 131-140.
19. Olearnik, J. (1990). *Konsumpcja usług w Polsce. Diagnoza – Modelowanie – Kształtowanie.* Katowice: Wydawnictwo Akademii Ekonomicznej im. K. Adamieckiego.
20. Olko, S. (2019). Theoretical and Practical Approaches to Analysing Sharing Economy Business Models – Intercultural Perspective. *International Journal of Innovation and Economic Development*, *Vol. 5,* pp. 48-56.
21. Sagan, A. (2016). *Metodologia badań ekonomicznych.* Kraków: Wydawnictwo Uniwersytetu Ekonomicznego w Krakowie, p. 114.
22. Słaby, T., Bazydło-Egier, D. (2021). *Zarządzanie produktami na rynku e-rozrywki. Zmiany strategii.* Warszawa: Aspra-JR.
23. Śledziewska, K., Włoch, R. (2020). *Gospodarka cyfrowa. Jak nowe technologie zmieniają świat.* Warszawa: Wydawnictwo Uniwersytetu Warszawskiego.
24. Surmacz, T., Wierzbiński, B., Kuźniar, W., Witek, L. (2024). Towards Sustainable Consumption: Generation Z's Views on Ownership and Access in the Sharing Economy. *Energies*, *Vol. 17, No. 14*, p. 3377, doi: https://doi.org/10.3390/en17143377
25. Szewczyk, A. (2014). Analiza usług elektronicznych branży rozrywkowej i działalności kulturalnej. *Zeszyty Naukowe Uniwersytetu Szczecińskiego. Studia Informatica*, *No. 35 (Zastosowania informatyki w e-gospodarce: rozwiązania, narzędzia, metody),* pp. 165-187.

26. Szojda, G. (2024). The Development of the E-Culture Market: Perspectives from Polish Consumers. *Zeszyty Naukowe. Organizacja i Zarządzanie, No. 204*. Politechnika Śląska, pp. 609-623.
27. *Ustawa z dnia 18 lipca 2002 roku o świadczeniu usług drogą elektroniczną*, *ISAP* (2002). Retrieved from: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=wdu20021441204, 11.11.2025.
28. Wierzbicka, A. (2019). *Dydaktyczne i komunikacyjne aspekty e-edukacji akademickiej*. Łódź: Wydawnictwo Uniwersytetu Łódzkiego.
29. Wolny, R. (2012a). E-usługi jako przedmiot badań ekonomicznych. In: B. Iwankiewicz-Rak, A. Panasiuk, K. Rogoziński (Eds.), Usługi w Polsce 2012. Teoria usług – Funkcjonowanie sektora usługowego – Kształcenie w usługach. *Zeszyty Naukowe, nr 772, Ekonomiczne Problemy Usług, nr 95*. Szczecin: Uniwersytet Szczeciński.
30. Wolny, R. (2012b). Polski e-konsument na rynku usług. *Konsumpcja i rozwój*, *1(2),* pp. 117-129.
31. Wolny, R. (2013). *Rynek e-usług w Polsce – funkcjonowanie i kierunki rozwoju.* Katowice: Uniwersytet Ekonomiczny w Katowicach.
32. Wolny, R. (2016a). Zmiany w zachowaniach nabywczych polskich e-konsumentów. *Studia Ekonomiczne*, *270*, pp. 285-293.
33. Wolny, R. (2016b). Use of ICT Among Consumers on the Cultural Market in Poland. In: G. Mazurek, J. Tkaczyk (Eds.), *The Impact of the Digital World on Management and Marketing* (pp. 369-382). Warszawa: Poltext.
34. Wolny, R. (2023). Konsument i jego ślad w gospodarce cyfrowej. In: M. Jaciow, R. Wolny (Eds.), *Cyfrowy ślad konsumenta*. Katowice: Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach. https://www.sbc.org.pl/dlibra/publication/719652/, 11.11.2025.
35. Wolny, R. (2023). Rynek kultury w Polsce w XXI wieku w świetle analizy danych statystycznych – stagnacja czy zmiana? In: M. Sobocińska (Ed.), *Konsument i rynek – Badania marketingowe – Strategie i działania marketingowe. Księga jubileuszowa z okazji 50-lecia pracy twórczej prof. zw. dr hab. Krystyny Mazurek-Łopacińskiej* (pp. 352-364). Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.
36. Wolny, R. (2024). E-usługi. In: M. Jaciow (Ed.), *Pomiar gospodarki cyfrowej*. Katowice: Uniwersytet Ekonomiczny w Katowicach, doi: 10.22367/uekat.9788378759133
37. Wolny, R., Kol, J., Stolecka-Makowska, A., Szojda, G. (2025). Digital Consumer Behavior in Poland and Its Environmental Impact Within the Framework of Sustainability. *Sustainability*, *Vol. 17, No. 10*, p. 4691, doi: https://doi.org/10.3390/su17104691
38. Zarzycka, A.M. (2021). Konsument cyfrowy a postcyfrowy – próba identyfikacji. In: M. Johann (Ed.), *Gospodarka cyfrowa i postcyfrowa a przedsiębiorstwo*. Warszawa: Oficyna Wydawnicza SGH.

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ANALYSIS OF SECTORAL EMPLOYMENT DYNAMICS IN EU COUNTRIES IN THE YEARS 2009-2024

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Purpose: The study aims to understand how similar the trajectories of changes in the average rate of employment are among EU countries and how this similarity changes over time, which is intended to reveal different paths of structural transformation.
Design/methodology/approach: The study covered all member states of the European Union and 17 selected employment sectors. The analysis concerned two comparative periods: 2009-2019 and 2019-2024. The average rate of change in employment in individual sectors was calculated for both periods. Czekanowski's diagram was used to examine the similarities in the average rates of employment change in EU countries.
Findings: The analysis showed that on the scale of the entire EU between 2009 and 2024, there were no major changes in the average rate of employment change in most sectors. Significant changes were recorded in 4 sectors. The vulnerability of countries to employment changes caused by the COVID-19 pandemic varied, which translated into the grouping of countries in both periods.
Research limitations/implications: Limitations: The application of a different grouping method may potentially yield different grouping results. Further research: It is worth extending the analysis to include other factors and examining public policies that contributed to mitigating or accelerating the changes. Comparing the results with other grouping methods is also suggested.
Practical implications: The study enables reliable analysis of trends and prediction of future changes. The conclusions are key for public policies, pointing out sectors with dynamic growth and countries with the greatest sensitivity to global economic shocks.
Social implications: The study provides information for public policy on the impact of strong shocks (pandemic) and long-term trends on the employment structure. This can support decisions regarding social security policies.
Originality/value: The value of the article lies in the application of Czekanowski's diagram to analyze changes in the structure of sectoral employment dynamics in EU countries in the context of major economic shocks. Literature indicates that the average rate of employment change in the EU is not precisely researched. The application of Czekanowski's diagram allows for reliable analysis of trends and visualization of results.
Keywords: Czekanowski's diagram, employment dynamics, COVID-19 pandemic.
Category of the paper: Research paper.

1. Introduction

The structure of sectoral employment in European Union countries has undergone significant changes in the last two decades. The 2008/2009 global financial crisis, which caused severe economic disruptions, credit freezes, demand slowdowns, and significant declines in industrial and construction sectors, presented many EU countries with the necessity of restructuring the production sector. Subsequently, the COVID-19 pandemic (starting from late 2019/2020) acted as another powerful impulse changing the structure of the labor market, through both temporary standstills and permanent changes in demand and service delivery methods (e.g., remote work, mobility restrictions, reduced demand in sectors related to personal interaction). The escalation of the war in Ukraine could also significantly influence changes in the employment structure in some EU countries. Simultaneously, long-term factors—digitization, automation, energy transition and green economy, increasing qualification requirements, demographic pressures (population aging, migration)—are affecting sectoral employment models.

In these conditions, it becomes essential to understand not only *how* employment has changed in individual sectors, but also *how similar* or *different* the trajectories of these changes are among EU countries and how this similarity changes over time. Such comparisons can reveal different paths of structural transformation. Czekanowski's diagram was used to illustrate these trajectories. Thanks to it, groups of countries with similar dynamics of employment changes in the analyzed economic sectors can be easily identified.

The main goal of this article is therefore to examine changes in the structure of sectoral employment dynamics in EU countries in the years 2009-2024, taking into account the impact of the COVID-19 pandemic. Secondary goals include: identifying groups of countries with similar sectoral change dynamics, analyzing how the similarity of the employment structure changes between EU countries over time, and examining which countries "shift" between groups.

2. Literature review

Analyses of employment changes in Poland and EU countries over the last two decades focus on identifying long-term structural trends and short-term economic shocks. The period 2009-2019 was characterized by moderate sectoral restructuring, a decline in industrial employment, and the growing importance of the services sector. In contrast, the years 2019-2024 brought the pandemic shock and economic recovery under new structural conditions,

accompanied by the increasing importance of digitization and the green energy transition (OECD, 2024; ILO, 2022; World Bank, 2019).

In the context of labor market polarization, studies by Goos and Manning (2007) and Autor, Dorn, and Hanson (2013) show that developed countries experience an increase in jobs in low- and high-skilled sectors, and a decrease in middle-skilled sectors. Poland experienced similar trends, although at a slower pace, with a visible increase in the importance of market services and a decrease in the share of industry in employment (GUS, 2020; Kowalik, Magda, 2021).

Between 2009 and 2019, employment in the industrial sector in EU countries increased slightly, while market services saw a marked increase. After 2019, the COVID-19 pandemic caused sharp declines in contact-intensive industries (tourism, gastronomy), followed by recovery with a shift in employment towards logistics and digital services (ILO, 2020; WEF, 2020).

Simultaneously, a new current of research has emerged in the literature concerning the energy transition and its impact on the employment structure (OECD, 2024; World Bank, 2019). It is indicated that sectors with high CO_2 emissions will lose jobs, while employment in green and technological sectors will increase (PIE, 2024). Wójcik (2013) applied Czekanowski's diagram to study the similarities of EU countries regarding the acquisition of energy from renewable sources, which is also significant in the analysis of changes in employment structure in modern and ecological sectors. This method allows for visualizing the degree of similarity and differences between research units, which can be used to assess the rate of employment change in various economic sectors.

Miśkiewicz-Nawrocka (2015) analyzes the threat of unemployment in Polish provinces in the years 2005-2012, indicating significant regional variation. These studies suggest that the rate of employment change is strongly dependent on the specifics of local labor markets, the level of education, and the economic structure of a given region, which can be applied to different countries. Additionally, Polish literature points to specific challenges for the labor market, such as a low share of employment in the modern business services sector, the growing importance of remote work (Król, 2022), and the phenomenon of unstable forms of employment and temporary contracts (PARP, 2022). PIE (2024) studies and MRPiPS (2020) reports indicate that structural changes in employment in Poland are increasingly related to demographics, energy transition, and digitization.

Conclusions from the literature review indicate that the average rate of employment change in Poland and the EU is not precisely researched. Since it is sectorally and regionally diversified, and economic shocks, such as the pandemic, have a significant impact on the employment structure, it is worth looking closely at this. The application of a tool such as Czekanowski's diagram allows for reliable analysis of trends and prediction of future changes.

3. Research methodology

The analysis covers all member states of the European Union (EU-27). The study considers two comparative periods:

- 2009-2019 (the period covered by recovery after the 2008/09 crisis and the decade preceding the pandemic),
- 2019-2024 (the period covering the beginning of the COVID-19 pandemic and the subsequent recovery / transformation period).

The year 2009 appears in both studied periods because it marks both the end of the pre-pandemic period and the beginning of the pandemic. Analyzing the employment structure, 17 sectors with the largest employment were taken into account. They are presented in Table 1.

Table 1.
Selected employment sectors

Symbol	Sector	Symbol	Sector
S1	Legal and accounting activities	S10	Specialised construction activities
S2	Services to buildings and landscape activities	S11	Wholesale and retail trade and repair of motor vehicles and motorcycles
S3	Public administration and defence; compulsory social security	S12	Wholesale trade, except of motor vehicles and motorcycles
S4	Education	S13	Retail trade, except of motor vehicles and motorcycles
S5	Human health activities	S14	Land transport and transport via pipelines
S6	Residential care activities	S15	Food and beverage service activities
S7	Crop and animal production, hunting and related service activities	S16	Computer programming, consultancy and related activities
S8	Manufacture of fabricated metal products, except machinery and equipment	S17	Financial service activities, except insurance and pension funding
S9	Construction of buildings		

The shares of employment in individual sectors were calculated based on employment data in individual sectors and total employment data in individual EU countries originating from the Eurostat website (Eurostat, 2025). For all employment sectors, in all EU countries, the average rate of change was calculated for the years 2009-2019 and 2019-2024, using the formula (Ostasiewicz et al., 2001):

$$\bar{\imath}_G = \sqrt[n-1]{in_{/n-1} * i_{n-1/n-2} * ,,,* i_{2/1}}, \quad (1)$$

where: $in_{/n-1} = \frac{y_n}{y_{n-1}}$.

To find out in which countries the average rate of change in individual sectors was similar, Czekanowski's diagram was created. This was done twice, for the average rate of change in the years 2009-2019 and 2019-2024.

The creation of Czekanowski's diagram (Czekanowski, 1913) is one of the oldest taxonomic methods that allows to determine the relationships between objects and to visualize the relationships and similarities between them. The diagram is a visualization of the distance matrix between these objects. The objects most similar to each other are closest to the main diagonal of the distance matrix. The farther from the main diagonal the objects are less similar to each other (Jaskulski, Sołtysiak, 2004; Sołtysiak, Jaskulski, 1999).

The diagram is drawn according to the following stages (Heffner, Gibas, 2007):

- defining the data matrix,
- standardization or unitization of variables,
- selection of the measure of similarity,
- estimation of taxonomic distance matrices,
- determination of the minimum and maximum value in the taxonomic distance matrix,
- estimation of class intervals for taxonomic distances based on the determined empirical variability area,
- developing a disordered Czekanowski diagram,
- organizing Czekanowski's diagram,
- interpretation of obtained results.

Standardization of variables can be performed according to the formula (Dziechciarz, 2012):

$$z_{ij} = \frac{x_{ij} - \overline{x_{ij}}}{s_j}, \tag{2}$$

where:

z_{ij} - standardized variable x_j for the i-th object,

x_{ij} - variable x_j for the i-th object,

$\overline{x_{ij}}$ - arithmetic mean of the variable x_j ,

S_j - standard deviation of the variable x_j .

However, the similarity distance matrix is determined using the Euclidean metric.

4. Empirical analysis

The purpose of the article is to examine the changes occurring in the employment structure in selected sectors in EU countries, so we are interested in the rate of change, not just the employment shares in individual sectors in EU countries.

Figure 1 presents the average rates of employment change in individual sectors during the pre-pandemic period (2009-2019) and the period of the pandemic and immediately thereafter (2019-2024) across the entire EU. In almost all sectors, there were no major changes in the average rate of change. 4 sectors deserve attention:

- services to buildings and landscape activities (S2) and residential care activities (S6), where the trend changed from upward to downward,
- construction of buildings (S9), where the decline in employment shares was halted,
- computer programming, consultancy and related activities, where the already large increase in employment shares was significantly amplified (increase in the average rate of change from 1.04 to 1.08).

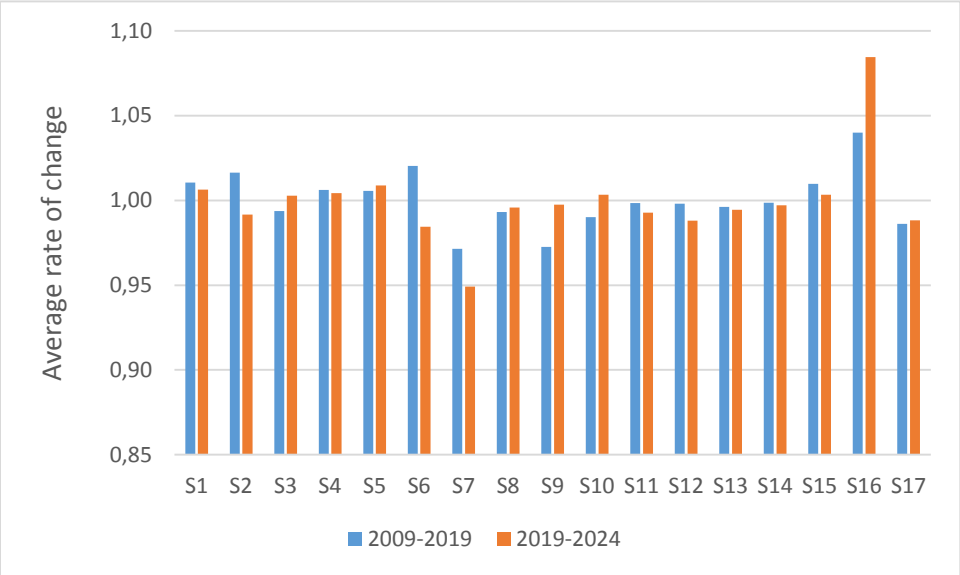


Figure 1. Average rate of change in employment shares in selected sectors across the entire EU.
Source: Own calculations.

How did the changes in the average rate of change in selected sectors look in individual countries? Due to the multitude of both countries and sectors, not all statistics are presented, only selected ones. Table 2 shows only the countries where the largest changes in the average rate of employment change occurred in selected sectors.

Table 2.
Countries with the largest changes in the average rate of employment change in the periods 2009-19 and 2019-2024, in selected sectors

Sector	Largest decreases		Largest increases	
S1	Latvia	-0,158	Netherlands	0,069
S2	Bulgaria	-0,183	Hungary	0,050
S3	Greece, Hungary	-0,019	Netherlands	0,069
S4	Croatia	-0,031	Netherlands	0,037
S5	France	-0,023	Luxembourg	0,048
S6	Lithuania	-0,101	Greece	0,041
S7	Romania	-0,087	Luxemburg	0,108
S8	Slovenia	-0,077	Greece	0,102
S9	Germany	-0115	Greece	0,179

Cont. table 2.

S10	Latvia	-0,100	Greece	0,122
S11	Malta	-0,075	Luxembourg	0,089
S12	Germany	-0,083	Slovenia	0,125
S13	Slovenia	-0,075	Luxembourg	0,063
S14	Lithuania	-0,074	Malta	0,044
S15	Estonia	-0,076	France	0,022
S16	Estonia	-0,056	Cyprus	0,164
S17	Slovenia	-0,049	Hungary	0,134

We can draw several conclusions from Table 2. Firstly, the range of changes in individual sectors was very diverse, from 0.068 in Sector 4 to 0.294 in Sector 9. Secondly, the COVID-19 pandemic did not have an equally strong impact on changes in the average rate of employment change in individual sectors in all countries. There are several countries that appear quite often in Table 2, meaning the changes in these countries were the most abrupt. These include: Greece, Luxembourg, and Slovenia. 13 countries did not appear in Table 2 at all, which may indicate a smaller impact of the pandemic on the rate of employment change in individual sectors in these countries. To precisely answer the question of which countries experienced sharp changes in the rate of employment change and which experienced minor ones, the average modules of differences in the average rates of change in individual countries were calculated, which are presented in Table 3.

Table3.
Averages of the modules of differences in the average rates of change in EU countries in the years 2009-19 and 2019-2024

Country	**Mean**	**Country**	**Mean**	**Country**	**Mean**
Spain	0,017	Poland	0,024	Lithuania	0,034
France	0,018	Slovakia	0,025	Ireland	0,034
Finland	0,018	Hungary	0,026	Bulgaria	0,035
Sweden	0,019	Portugal	0,027	Germany	0,036
Austria	0,019	Netherlands	0,027	Croatia	0,037
Denmark	0,022	Romania	0,030	Malta	0,038
Czechia	0,023	Slovenia	0,030	Greece	0,038
Italy	0,024	Cyprus	0,033	Luxembourg	0,046

From Table 3, we can conclude that indeed the countries that appeared in Table 2 are generally characterized by greater vulnerability to employment changes caused by the COVID-19 pandemic. The largest changes in the average rate of employment change occurred in Luxembourg, Greece, and Malta. Conversely, the smallest changes were observed in Spain, France, and Finland.

Figure 2 presents Czekanowski's diagram for the average rates of employment change in individual sectors in the years 2009-19. Czekanowski's diagram allowed for the distinction of countries where the average rate of employment change during the pre-pandemic period was similar.

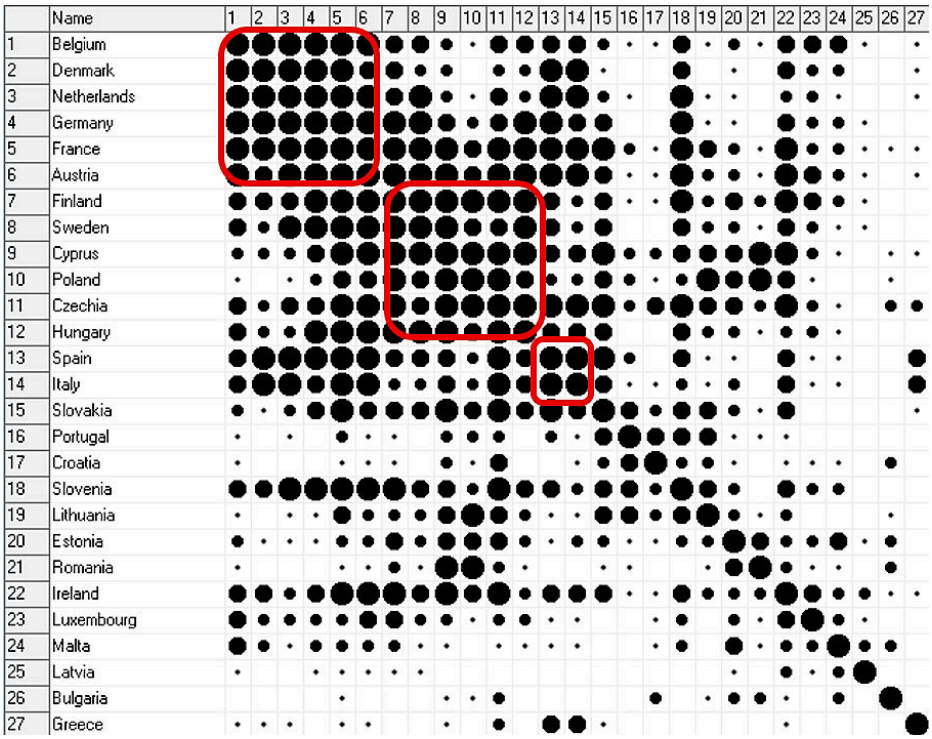


Figure 2. Czekanowski's diagram for the average rate of change in employment in individual sectors in the years 2009-2019.

Source: Own calculations.

In the years 2009-19, three groups of countries with a similar average rate of change in individual sectors were distinguished. It might seem very natural that in certain groups of countries, employment changes proceed similarly—certain economic sectors lose importance while others gain. The first group included: Belgium, Denmark, Netherlands, Germany, France, and Austria. Group 2 included: Finland, Sweden, Cyprus, Poland, Czechia, and Hungary. The last group included Spain and Italy. The first group consists of neighboring countries, while the third group consists of countries where tourism plays an important role. Group 2 is the most diverse, including 2 countries from the northern part of the EU besides Central European countries.

Countries in Group 1 are characterized by a large increase in employment in services related to building maintenance (S2) (an average of 3% annually) and an equally large decrease in employment in agriculture (S7) and construction (S9). In contrast, Group 2 saw a rapid increase in employment in the IT industry (an average of 6% annually) and a large increase in legal and accounting activities (S1) (an average of 3% annually), while employment in agriculture (S7) decreased, similar to Group 1, by an average of 3% annually. Spain and Italy during this period were characterized by a large increase in employment in the IT sector (S16) (an average of 4% annually) and residential care (S6) (an average of 3% annually). The remaining countries did not form groups, meaning the average rate of change in sectors in those countries was not similar to other countries.

In 2019, the COVID-19 pandemic erupted in China. In 2020, the pandemic spread globally, including Europe. Undoubtedly, the pandemic had a significant impact on the economy of EU countries, and how it affected employment in individual sectors, specifically how it affected the similarity of the average rate of employment change in EU countries, is shown in Figure 3.

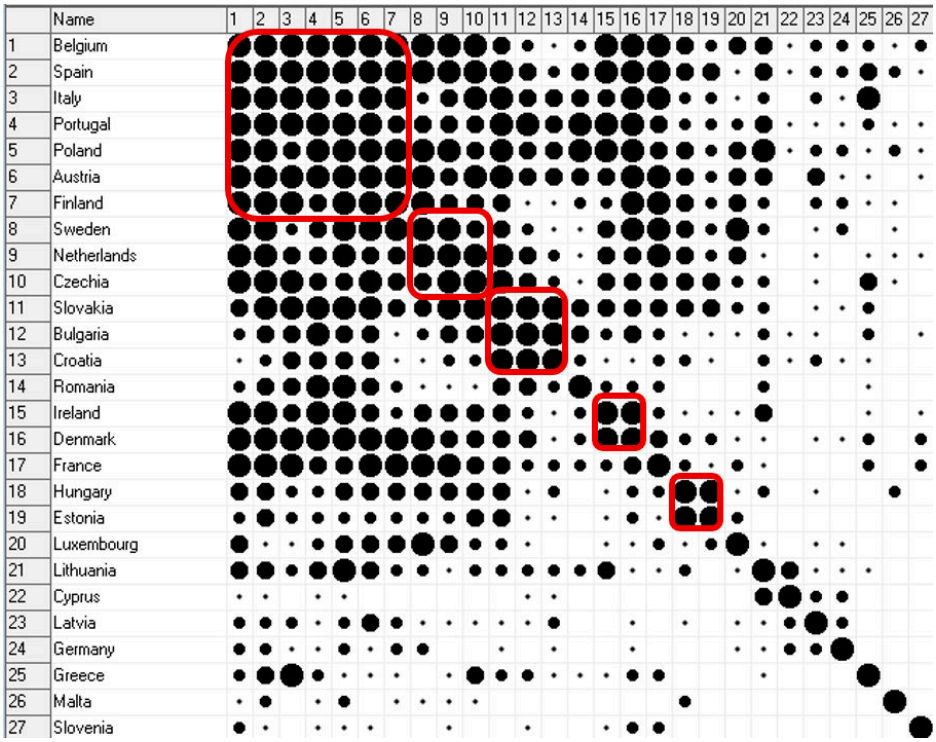


Figure 3. Czekanowski's diagram for the average rate of change in employment in individual sectors in the years 2019-2024.

Source: Own calculations.

Already at first glance, it is visible that a completely different division of countries into groups with similar average rates of employment change in the studied sectors was made. Five groups were distinguished, with the first group containing as many as 7 countries, and the remaining 4 groups containing three or two countries each.

Group 1 included: Belgium, Spain, Italy, Portugal, Poland, Austria, and Finland. This group is characterized by a very large increase in employment in the IT sector (S16) (an average of 8% annually) and a large decrease in employment in agriculture (S7) (an average of 4% annually). A large increase in employment in the IT sector (an average of 6% annually) also occurred in the countries of Group 2: Sweden, Netherlands, and Czechia. These countries were also characterized by a large increase in employment (an average of 4% annually) in Sector 1 related to legal and accounting activities and a large decrease in employment (an average of 3% annually) in the sector related to the manufacture of fabricated metal products (S8). In Slovakia, Bulgaria, and Croatia (Group 3), the largest increase in employment in the IT sector occurred in the years 2019-2024 among all distinguished groups, amounting to an average of 13% annually. Although this is a very large increase, it was significantly higher in Cyprus,

where the average rate of change in this sector in the years 2019-2024 was 1.24. This means that employment in this sector almost doubled in slightly over three years.

Countries in Group 3 are also characterized by a large increase in specialized construction activities (S10) (an average of 5% annually) and in legal and accounting activities (S1) and trade (S11) (an average of 4% annually). In this group, a large increase in employment occurred in as many as 4 sectors, and only in activities related to building maintenance (S2) did a large decrease in employment occur, by an average of 4% annually. Ireland and Denmark (Group 4) felt the effects of the pandemic most strongly among all groups. In as many as 4 sectors, the average rate of employment change adopted a value significantly lower than 1. In agriculture (S7) (0.94), in the manufacture of fabricated metal products (S7) and trade (S11) (0.96), and in activities related to building maintenance (S2) (0.97).

In the last distinguished group, which includes Hungary and Estonia, average annual employment decreases of at least 3% were not recorded. Large increases in employment were noted in financial service activities (S17) (an average of 9% annually), in the IT industry (S16) (an average of 7% annually) and in specialized construction activities (S10) (an average of 4% annually).

10 countries did not form groups with other countries. In these countries, the average rates of employment change in individual sectors are not similar to employment changes in other countries, or those other countries belong to different groups.

5. Summary

The purpose of this article was to examine changes in the structure of sectoral employment dynamics in European Union (EU) countries in the years 2009-2024, with particular emphasis on the impact of the COVID-19 pandemic. The study aimed to identify groups of countries with similar dynamics of sectoral changes and to analyze the evolution of the similarity of the employment structure among these countries over time.

The analysis of the rate of employment change in 17 selected sectors (based on Eurostat data) across two comparative periods (2009-2019 and 2019-2024) led to several key empirical findings:

1. Fundamental shift in sectoral trends in the EU: Significant changes in the average rate of change were recorded across the entire EU in four sectors.
   The sectors of services to buildings (S2) and residential care activities (S6) recorded a change in trends from upward to downward.
   In construction (S9), the downward trend in employment shares was halted.
   In the computer programming sector (S16), the already large increase in employment (rate 1.04) was significantly amplified (rate 1.08).

2. Varied vulnerability of countries to changes: Not all EU member states felt the impact of the COVID-19 pandemic with the same intensity.
   Countries such as Luxembourg (0.046), Greece (0.038), and Malta (0.038) were characterized by the greatest vulnerability to changes in the rate of employment (measured by the average modules of differences in the average rates of change).
   The smallest changes in the average employment rate were recorded in Spain (0.017), France (0.018), and Finland (0.018).
   A particularly abrupt change occurred in Cyprus in Sector S16, where the average rate of change was 1.24, meaning employment in this sector almost doubled in slightly over three years.
3. Change in similarities between countries: The application of Czekanowski's diagram revealed fundamental shifts in the grouping of countries during the studied period. While three groups were distinguished in 2009-2019, as many as five new groups were distinguished in the 2019-2024 period.
   For example, Slovakia, Bulgaria, and Croatia (Group 3) recorded the largest increase in employment (as a group) in sector S16 (an average of 13% annually).
   Ireland and Denmark (Group 4) felt the effects of the pandemic most strongly, as the average rate of employment change adopted a declining value in as many as 4 sectors.

The results confirm the theses of Goos and Manning (2007) as well as Autor, Dorn, and Hanson (2013) regarding the growing importance of high-skilled sectors. This is demonstrated by a sharp increase in the computer programming sector (S16), where the rate of change rose from 1.04 to 1.08. In Cyprus, employment in this sector nearly doubled within just three years.

In contrast to the period 2009-2019, the years 2019-2024 brought a reversal of trends in building maintenance services (S2) and residential care services (S6), shifting from growth to decline. This finding is consistent with ILO (2020) reports indicating sharp contractions in contact-intensive industries.

The contribution of this article lies in the application of the Czekanowski diagram to the analysis of trajectories of change in sectoral employment dynamics, enabling a robust assessment of trends and offering potential for forecasting future developments. This methodology allows for the straightforward identification of groups of countries exhibiting convergent employment dynamics. Future research could extend the analysis to additional factors (e.g., education levels, rising skill requirements, migration) and examine which public policies have contributed to mitigating or accelerating these changes.

The authors acknowledge that the application of alternative clustering methods may yield different grouping results. Even within the diagram, assigning a country to one group or another may be problematic; therefore, further research may also pursue the use of alternative clustering techniques and compare their outcomes with those obtained in this study. The analysis is planned to be extended to include factors such as education levels, migration, and the impact

of digitalization on sectoral models. It is also advisable to investigate specific public policies that, across different countries, have contributed to mitigating or accelerating the ongoing structural changes.

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References

1. Autor, D.H., Dorn, D., Hanson, G. (2013). The China syndrome: Local labor market effects of import competition in the United States. *American Economic Review, 103(6),* 2121-2168. https://doi.org/10.1257/aer.103.6.2121
2. Czekanowski, J. (1913). Zarys metod statystycznych w zastosowaniu do antropologii. *Prace Naukowego Towarzystwa Warszawskiego, 5*. Warszawa
3. Dziechciarz, J. (2012). *Ekonometria. Metody, przykłady, zadania*. Wrocław: WUE.
4. *Eurostat*. Retrieved from: https://ec.europa.eu/eurostat, 10.08.2025.
5. Główny Urząd Statystyczny (2020). *Zatrudnienie i wynagrodzenia w gospodarce narodowej w 2019 roku.* Warszawa: GUS. ISBN 978-83-7027-734-1
6. Goos, M., Manning, A. (2007). Lousy and lovely jobs: The rising polarization of work in Britain. *Review of Economics and Statistics, 89(1),* 118-133.
7. Heffner, K., Gibas, P. (2007). *Analiza ekonomiczno-przestrzenna*. Katowice: WWU.
8. ILO (2020). *World Employment and Social Outlook: Trends 2020. Geneva: International Labour Organization*. ISBN 978-92-2-031812-7.
9. ILO (2022). *World Employment and Social Outlook: Trends 2023. Geneva: International Labour Organization*. ISBN 978-92-2-035697-5.

10. Jaskulski, P., Sołtysiak, A. (2004). Diagram Czekanowskiego: pomysł, historia, zastosowania. *Prace Naukowe AE we Wrocławiu. Taksonomia, t. 11, nr 1022, Klasyfikacja i analiza danych – teoria i zastosowania,* pp. 374-383.
11. Kowalik, Z., Magda, I. (2021). Rynek pracy w Polsce – przemiany i wyzwania (2006-2019). *Studia Ekonomiczne, 375*, 45-64.
12. Król, M. (2022). Rynek pracy zdalnej w Polsce w latach 2020-2022. *Studia i Prace Kolegium Zarządzania i Finansów SGH, 183*, 89-108.
13. Kukołowicz, P. (2024). *Konsekwencje zmian demograficznych dla podaży pracy w Polsce.* Warszawa: Polski Instytut Ekonomiczny (PIE). ISBN 978-83-66660-86-4.
14. Ministerstwo Rodziny, Pracy i Polityki Społecznej (2020). *Rynek pracy w Polsce w 2019 roku.* Warszawa: MRPiPS. ISBN 978-83-66181-30-8.
15. Miśkiewicz-Nawrocka, M. (2015). Ocena zagrożenia bezrobociem w województwach Polski w latach 2005-2012. *Zeszyty Naukowe UEK, 4(940),* 145-161.
16. OECD (2024). *OECD Employment Outlook 2024: The Net-Zero Transition and the Labour Market.* Paris: OECD Publishing. https://doi.org/10.1787/empl_outlook-2024-en
17. Ostasiewicz, S., Rusnak, Z., Siedlecka, U. (2001). *Statystyka. Elementy teorii i zadania.* Wydawnictwo AE we Wrocławiu.
18. Polska Agencja Rozwoju Przedsiębiorczości (2022). *Polski rynek pracy – procesy i zjawiska.* Warszawa: PARP. ISBN 978-83-7633-498-7.
19. Sołtysiak, A., Jaskulski, P. (1999). *Czekanowski's Diagram. A Method of Multidimensional Clustering. New Techniques for Old Times. CAA 98. Computer Applications and Quantitative Methods in Archaeology.* Proceedings of the 26th Conference, Barcelona, March 1998, J.A. Barceló, I. Briz, A. Vila (eds.). BAR International Series, 757. Oxford, pp. 175-184.
20. Wójcik, A. (2013). Zastosowanie diagramu Czekanowskiego do badania podobieństwa krajów Unii Europejskiej pod względem pozyskiwania energii ze źródeł odnawialnych. *Zarządzanie i Finanse, 11(4),* 353-365.
21. World Bank (2019). *World Development Report 2019: The Changing Nature of Work.* Washington, DC: World Bank. ISBN 978-1-4648-1328-3.
22. World Economic Forum (2020). *The Future of Jobs Report 2020*. Geneva: World Economic Forum. ISBN 978-2-940631-16-8.

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INNOVATIVENESS OF POLISH COMPANIES – PRELIMINARY RESEARCH RESULTS

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Purpose: The purpose of this study is to examine the approach to implementing innovations and investing in research and development in enterprises. It also takes into account differences depending on the size of the enterprise and attempts to preliminarily define the innovation strategies used in them.
Design/methodology/approach: The research was carried out among 278 companies between March and September 2025 using a CATI method. Entities that invested in product and process innovation were intentionally selected for the research.
Findings: The research allowed to determine the respondents' approach to the development of innovation policy and the diversity of expenditure on innovation activities, as well as the number and type of innovations implemented. Respondents also indicated whether they use internal or external sources of innovation. A preliminary analysis of the survey results indicates significant variation in the data, which may characterised the innovation strategies used by the surveyed companies.
Research limitations: Researching the innovativeness of enterprises using a questionnaire survey is difficult due to the limited possibilities of comparing innovative activities in terms of the scale of innovations implemented, which is the result of considerable subjectivity. The research took into account data from companies for the years 2022-2024, which, unfortunately, in many industries were affected by the crisis caused by the COVID pandemic and later by the Russia-Ukraine war and the related disruption of supply chains. This may significantly affect the research results.
Practical implications: The results obtained cannot be generalised due to the intentional selection of entities for the research. In the future researches, it is advisable to use stratified sampling, so that it would be possible to further verify whether the industry is relevant to the company's innovation performance. With this approach, the results obtained could, to a large extent, form the basis for creating innovation policy.
Originality/value: The originality of the research is related to the consideration of the strategic orientation of the respondents in the area of innovation, the types of innovation introduced in companies and the impact of public subsidies on the results achieved.
Keywords: Innovativeness of companies, results of innovations, innovation profiles of enterprises.
Category of the paper: Research paper.

1. Introduction

In line with J.A. Schumpeter's concept of creative destruction, companies through innovation are capable of creating breakthroughs in the development of new products, technologies leading to increased productivity, expanding to new markets and building competitive advantage (Zagóra-Jonszta, 2015).

According to the study's findings, innovation plays a crucial role in driving economic growth, enabling firms and countries to increase profits and social welfare, respectively (Koç, et al., 2025, p. 15).

Innovation was addressed in endogenous models of economic development, but its role was defined somewhat differently. In Romer's model, in which growth is driven by the accumulation of knowledge, the role of innovation is highlighted. Although new knowledge is characterized by diminishing returns at the company level, it can have positive impact through the technological development of other companies (Romer, 1986). According to Romer, investments in physical capital can trigger learning by doing and knowledge spillovers, as a result of which technology becomes a public good. The phenomenon of knowledge diffusion is the primary justification for the use of public support.

Later models that did not consider R&D and the resulting innovations as a by-product assumed two approaches to product innovation. The first, which is presented in the Grossman and Helpman's model, describes horizontal innovation. New products do not replace those that already exist, but expand the range of products available (Grossman, Helpman, 1991a, 1991b).

The second group of models focuses on vertical innovation and assumes that they have an impact on improvement in the quality of existing products. As a result, it is emphasised that new varieties of these products replace those already on the market. In particular, in the Aghion and Howitt's model, the authors point to the importance of Schumpeter's creative destruction through the creation of changes within products.

Many authors emphasise the benefits that companies can derive from the effective implementation of innovation. Ongoing research confirms that investments in research and development and other forms of innovation bring tangible benefits to companies, which include increased competitiveness and productivity, higher market value and a long-term rate of return. The rate of return can be high and may exceed other ways of investing. The knowledge spillovers effect prompts the public sector to create innovation policies using various forms of support, including even non-refundable public grants, which may cause concerns about distorting free market mechanisms and favour the supported entities to some extent. It is also emphasised that problems related to the effectiveness of intellectual property protection and the significant risk of failure may negatively affect the level of private investment in innovation development (Hall et al., 2009). However, ongoing meta-analyses show that it is possible to achieve a significant return on investment, which, according to studies compiled for the UK,

is around 14%, although when factors that may influence its underestimation are taken into account, it is estimated at around 20% (Frontier Economics). The latest research results confirm the positive impact of implementing innovation in companies. They emphasise the correlation between R&D intensity and productivity, and the results confirm the key role of innovation in increasing the efficiency of companies and maintaining competitive advantage in developed economies (Saharti, 2025; Mohen, 2019).

Assessing the impact of innovation implementation in companies also has its limitations, which include the fact that there may be significant delays in results in relation to the expenditure incurred, which may be as long as several years, and the varying capacity of entities for endogenous growth, as companies in a better financial position may increase their R&D investments. Another problem is sectoral diversity and the aforementioned diffusion of innovation, through which benefits can be transferred to other entities.

2. Research methodology

According to M. Romanowska, it is necessary to conduct intensive scientific research into the innovativeness of Polish companies. She points out that it is important to understand the phenomenon of innovation in Polish companies, or rather the lack thereof. The previous article in the series points precisely to the relatively low level of innovation in the Polish economy, which is both a result and a cause of the orientation of Polish companies. Research focuses more often on the external determinants of innovation development in business entities than on addressing entrepreneurship, cultural resources and corporate strategy (Romanowska, 2017). In her study, M. Romanowska proposed a diagnostic profile that treats the innovation more broadly. They were the direct inspiration for the research discussed in this study.

The approach to innovation is important not only in terms of its development, but also in terms of its successful implementation. Innovation often fails, and this is particularly true of new product launches. Focusing on the products themselves can often be the very reason for failure. A systematic approach to products using analysis of what other innovators are doing and their effects can lead to improvements in the efficiency and effectiveness of a company's innovation activities (Keeley et al., 2013). This may mean that strategic orientation in areas of innovation development is one of the most important success factors.

The research carried out for the purpose of this study seeks to identify model profiles of innovative companies and those that can promote positive long-term performance.

The research was carried out among 248 companies between March and September 2025 using a CATI method. Entities that invested in product and process innovation were purposively selected for the research.

The following variables were taken into account during the research: innovation expenditures (as a percentage of sales revenues), employment in R&D (as number of enterprises, as a percentage of enterprises and as a percentage of total employment), sources of innovation financing (own resources, EU funds, national public funds), number of innovations developed and implemented in the last 3 years, novelty of innovations, type of implemented innovations (product, process), main reason for undertaking innovative activity, benefits from innovation implementation, existence of a separate innovation unit in the structure, and innovation strategy model.

3. Results and discussion

Of the companies considered, 26% were large, 36% were medium-sized and the rest were small companies. There is considerable variation in the innovation expenditure, ranging from close to 0% of turnover to 11,5% of sales revenues. Almost half of large enterprises (close to 48%) employ R&D staff, as do a small percentage of medium-sized companies (18%), but small companies only occasionally do (below 11%).

Own resources are most often used for funding innovation in companies. Funds from the European Union budget or the state budget were used much less frequently.

All companies declared that they had carried out innovative activities during the researched period. No significant differences were found with regard to process innovation related to company size or the industry represented. There is a clear difference in terms of product innovation implementation depending on the size of the company. Large companies are the most active (66%), while medium-sized companies show less involvement (49%%). The small companies were less likely to engage in product innovation (less than 29% of them indicated such activity). Multiple answers were permitted for this question, as companies may implement both product and process innovations during the period under review. In most cases, these innovations consisted of significant modifications to existing products rather than the introduction of completely new ones on the market.

As regards the sources of innovation, the majority of companies use external sources, implementing solutions available on the market (66% of innovation-active large companies, 65% of medium-sized companies and over 77% of small companies active in the area of innovation implementation in the period concerned). As multiple responses were permitted in the survey, since companies may use both sources of innovation simultaneously, they do not add up to 100%. Large enterprises are more likely to indicate that they use internal sources of innovation. This may be due to investing more funds and employing staff in the area of R&D. There were no significant differences between medium-sized and small enterprises.

The study also took into account the number of innovations in companies over the last three years. In this area, large companies have a slight advantage over others. Companies that employ research and development staff introduced more innovations, which can be seen in every size category.

The structure of the research sample and the results of the research are presented in the table (Table 1).

Table 1.
Preliminary results of a business survey

Item	Size of the enterprise		
	large enterprises	**medium-sized enterprises**	**small enterprises**
number of enterprises	65	89	94
percentage of enterprises	26,21%	35,89%	37,90%
employment in R&D activities			
number of enterprises with employees in R&D activities	31	16	10
percentage of enterprises with employees in R&D activities	47,69%	17,98%	10,64%
innovation expenditure			
average R&D expenditure as a percentage of sales revenues	3,41	2,19	2,02
average R&D expenditure as a percentage of sales revenues in enterprises employing R&D personnel	5,08	3,55	4,19
average R&D expenditure as a a percentage of sales revenues in other enterprises	1,89	1,90	1,76
standard deviation	2,80	1,66	1,73
number of innovations in the last 3 years			
average	1,55	1,29	1,26
average in enterprises employing R&D personnel	1,87	1,81	2,20
average in other enterprises	1,26	1,18	1,14
standard deviation	0,87	0,53	0,59
type of innovation*			
product innovation	66,15%	49,44%	28,72%
process innovation	95,38%	93,26%	92,55%
sources of innovation*			
internal	61,54%	31,46%	29,79%
external	66,15%	65,17%	77,66%

Note. Own research.

* Multiple responses were permitted.

The high standard deviation indicates significant diversity among the surveyed companies in terms of innovation expenditure and the number of innovations introduced. Further research will aim to refine the results obtained in terms of differences in the innovation strategies of the surveyed companies.

Similar indications were given regarding the benefits of innovation. Most often, respondents pointed to process improvements, cost reductions and increased efficiency. Large companies also pointed to the strengthening of their market position and the improvement of product attractiveness. Companies also noted a general improvement in opinion and ease of acquiring contractors.

Responses regarding the motives for undertaking innovative activities indicate that companies understand the need to do so, but this is often a requirement of the market and competitive conditions.

The results obtained do not differ from those obtained in other similar researches. It was noted that the innovation profile of companies in the comparable researches and the benefits of innovation were similar. This applies in particular to the reasons why companies undertake innovative activities, which are primarily the expected increase in the company's competitiveness. The research carried out indicates the positive impact of innovation strategies on competitiveness (Agazu, Kero, 2024; Xue et al., 2025; Bogetoft et al., 2024; Oksanych, 2021).

Preliminary results at the current level of analysis indicate that the respondents are more likely to reach for familiar solutions and adapt to market requirements, as similar measures are already being implemented. This reduces the risk of implementing innovation. The higher involvement is characteristic of large companies, especially in the industrial sector.

The commitment to research and development and innovation implementation declared by the surveyed companies may result from their awareness of the role these activities play in the development of the enterprise. Better results in this area in large enterprises may, in turn, be caused by the more stable financial situation of the enterprise.

One issue that should be noted is that respondents declaring that they conduct innovative activities and classifying them may have more likely done so subjectively. It would therefore be important to carry out similar research in the future including audits, which, in more detail, would allow a more objective classification of the activities. Unfortunately, research and development is often protectesurprisd by companies, so there are frequent refusals to participate in studies. Research on innovation can be prone to errors. Even in the case of quantitative measures of innovation, there is a problem of errors in variables, as they are subjective, not always clearly defined, and the moment when their effects appear is difficult to capture when innovation is defined over a three-year period (Jaumandreu, Mairesse, 2017).

For the final part of the publication series, the results obtained will be subjected to advanced statistical analyses to verify further research hypotheses formulated prior to the research. It will present detailed analyses of the motives for undertaking innovative activities, address the benefits gained by companies, and discuss in detail their innovation strategies depending on the size of the company and the industry in which it operates. For the final part of the publication series, the results obtained will be subjected to advanced statistical analyses to verify further research hypotheses formulated prior to the research. It will present detailed analyses of the motives for undertaking innovative activities, address the benefits gained by companies, and discuss in detail their innovation strategies depending on the size of the company and the industry in which it operates.

4. Conclusions

The research confirmed the diversity of companies in the area of innovation, particularly in terms of their size and the industry they represent.

Large enterprises are more likely to invest in innovation and research and development than small and medium-sized enterprises. The reasons for this approach are important. Respondents often indicated that, in their opinion, innovation improves work efficiency and the quality of a company's products. Entrepreneurs count on unique products and more efficient processes that will enable dynamic growth through higher profits. A detailed analysis of their responses, together with an indication of the relevant links with other variables, will be the subject of the next part of the publication series.

What distinguishes large companies surveyed is their approach to conducting R&D. A significant proportion of them (nearly half) employed staff conducting research and development work in the company. This may be a significant argument in favour of the fact that these companies are not looking for ways to reduce costs by outsourcing R&D work, but are carrying it out themselves in order to exploit the potential offered by its results. This is important in light of available research findings, which indicate that conducting R&D independently has a significant impact on a company's technical efficiency (González-Blanco et al., 2024). A much smaller proportion of companies in other size categories employed such staff. All enterprises declared that they had carried out innovative activities during the period under review. This may be a sign of high awareness of the role that innovation plays in building competitiveness. In terms of product innovation, large enterprises were also more active among the respondents. The focus on external sources of innovation, which was primarily declared by small enterprises, may indicate that they are keen to seek ready-made solutions that are already known on the market but implemented in enterprises in order to meet market requirements.

As has been demonstrated based on a review of the literature and preliminary results of empirical research, innovation plays a significant role in creating the foundations for the functioning and growth of companies and the economy, but there are still problems associated with assessing the results of its implementation. Therefore, it is necessary to conduct continuous research and improve its methodology. A multi-dimensional research approach should be used in order to capture the various aspects of innovation.

Literature reviews have shown that companies should develop strategies that take into account projects with different time horizons in order to better manage liquidity and achieve long-term growth. It is also important to bear in mind the possibility of short-term fluctuations in financial indicators, which occur even in well-prepared and implemented innovation projects. It is possible to mitigate the negative effects related to the development of innovation by, among others, using various sources of financing, including public instruments such as subsidies and tax breaks, which can improve the profitability of risky innovation projects, especially when

significant knowledge spillover effects are expected. The manner in which research and development work is carried out is particularly important. The literature contains research findings confirming that seeking to reduce costs by outsourcing research and development work does not contribute to improving a company's innovation potential.

Small and medium-sized enterprises are a particularly supported area in terms of innovation in the European Union. However, it is worth noting that it is large companies that have the capacity to create innovation thanks to their expenditure. These innovations can then be implemented in smaller entities thanks to the effect of knowledge spillovers. This means that all categories of enterprises should be supported in accordance with their role and capabilities in order to create optimal conditions for the creation and transfer of innovation.

References

1. Agazu, B.G., Kero, Ch.A. (2024). Innovation strategy and firm competitiveness: a systematic literature review. *Journal of Innovation and Entrepreneurship*, *Vol. 13*, pp. 1-17, DOI: 10.1186/s13731-024-00381-9
2. Aghion, P., Howitt, P. (1992). A model of growth through creative destruction. *Econometrica*, *Vol. 60, No. 2,* pp. 323-351.
3. Aghion, P., Howitt, P. (1998). *Endogeous Growth Theory.* Cambridge M.A.: MIT Press.
4. Bogetoft, P., Kroman, L., Smilgins, A., Sørensen, A. (2024). Innovation strategies and firm performance. *Journal of Productivity Analysis*, *Vol. 62,* pp. 175-196, https://doi.org/10.1007/s11123-024-00727-1
5. Frontier Economics (2023). *Rate of return to investment in R&D.* A report for the Department for Science, Innovation and Technology.
6. González-Blanco, J., del Mar Rodríguez-Domínguez, M., Guisado-González, M. (2024). Innovation Strategies and Technical Efficiency. *European Research on Management and Business Economics*, *Vol. 30, Iss. 2*, https://doi.org/10.1016/j.iedeen.2024.100243
7. Grossman, G., Helpman, E. (1991). *Innovation and Growth in the Global Economy.* Cambridge M.A.: MIT Press.
8. Grossman, G.M., Helpman, E. (1991). Trade, knowledge spillovers, and growth. *European Economic Review*, *Vol. 35, Iss. 2-3,* pp. 517-526.
9. Hall, B.H., Mairesse, J., Mohnen, P. (2009). *Measuring the Returns to R&D.* Working Paper, 15622. Cambridge: National Bureau of Economic Research.
10. Jaumandreu, J., Mairesse, J. (2017). Disentangling the effects of process and product innovation on cost and demand. *Economics of Innovation and New Technology*, *26*, pp. 150-167. https://doi.org/10.1080/10438599.2016.1205276

11. Keeley, L., Pikkel, R., Quinn, B., Walters, H. (2013). *Ten Types of Innovation*. Hoboken, New Jersey: The John Wiley & Sons, Inc.
12. Koç, S., Uctu, R., Essop, H., Mercan, B. (2025). The impact of innovation on economic growth: A dynamic panel data analysis using system GMM approach. *International Journal of Innovation Studies*, https://doi.org/10.1016/j.ijis.2025.09.003, 10.10.2025.
13. Møen, J., Thorsen, H.S. (2017). Publication Bias in the Returns to R&D Literature. *Journal of the Knowledge Economy*, *Vol. 8*, pp. 987-1013.
14. Mohnen, P. (2019). *R&D, innovation and productivity.* MERIT Working Papers 2019-016. United Nations University - Maastricht Economic and Social Research Institute on Innovation and Technology (MERIT).
15. Oksanych, O. (2021). Innovation strategy and its impact. *Organization and Management*, *Vol. 2, No. 54,* pp. 125-140, DOI: 10.29119/1899-6116.2021.54.8
16. Romanowska, M. (2017). Profil diagnostyczny jako narzędzie badania innowacyjności przedsiębiorstw. *Studia Oeconomica Posnaniensia*, *Vol. 5, No. 9,* pp. 107-122, DOI: 10.18559/SOEP.2017.9.7
17. Romer, P.M. (1986). Increasing Returns and Long-Run Growth. *The Journal of Political Economy*, *Vol. 94, No. 5,* pp. 1002-1037.
18. Saharti, M. (2025). R&D and Innovation and Its Impact on Firm Performance and Market Value: Panel Evidence from G7 Economies. *Economies*, *No. 13(9),* 254, https://doi.org/10.3390/economies13090254
19. Ugur, M., Churchill, S.A., Luong, H.M. (2020). What do we know about R&D spillovers and productivity? Meta-analysis evidence on heterogeneity and statistical power. *Research Policy*, *Vol. 49(1),* 103866.
20. Ugur, M., Trushin, E., Solomon, E., Guidi, F. (2016). R&D and productivity in OECD firms and industries: A hierarchical meta-regression analysis. *Research Policy*, *Vol. 45(10),* pp. 2069-2086.
21. Xue, F., Tan, Y., Anwar, S. (2025), Innovation strategy, digital transformation and competitive advantage of manufacturing enterprises: evidence from China. *European Journal of Innovation Management*, *Vol. 28, No. 8*, pp. 3395-3417, doi: https://doi.org/10.1108/EJIM-09-2023-0786
22. Zagóra-Jonszta, J. (2015). Teoria rozwoju gospodarczego i „twórczej destrukcji" Schumpetera oraz jej aktualność. *Optimum. Studia Ekonomiczne*, *No. 3,* pp. 20-31, doi: 10.15290/ose.2015.03.75.02

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BLOCKCHAIN INTEGRATION IN SUSTAINABLE SUPPLY CHAINS: MEASURING CONTRIBUTION TO CIRCULAR ECONOMY GOALS

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Purpose: This paper addresses the lack of systematic frameworks for assessing blockchain technology's contribution to circular economy goals in supply chains. It develops a comprehensive conceptual model integrating blockchain capabilities with CE performance metrics to enable rigorous evaluation of blockchain implementations.
Design/methodology/approach: The study employs a conceptual-analytical research design based on systematic literature review across three domains: blockchain technology, circular economy metrics and supply chain visibility. The methodology includes systhematic analysis, structured conceptual model development following established information systems frameworks, and secondary analysis of industry case studies to inform model design.
Findings: The framework comprises four integrated layers: Blockchain Technical Capabilities, CE Performance Metrics, Assessment Frameworks combining Visibility Evaluation with Blockchain Affordance Analysis and Multi-Tier Implementation. The model articulates seven critical relationships demonstrating how blockchain capabilities translate into actionable affordances and enable credible metric measurement.
Research limitations/implications: The primary limitation is absence of empirical validation; the model remains conceptual and untested in real-world implementations. Future research should focus on empirical testing through case studies, sector-specific adaptations, and integration with emerging technologies.
Practical implications: The framework provides decision-support for supply chain managers evaluating blockchain investments, design guidance for technology developers, a foundation for policymakers developing standardized assessment protocols, and due diligence tools for sustainable finance investors. The multi-tier structure enables realistic expectation-setting and phased implementation strategies.
Originality/value: This is one of the first comprehensive frameworks systematically integrating blockchain technical affordances with established CE measurement metrics through multi-layered assessment mechanisms. It moves beyond descriptive accounts to establish theoretical linkages between technology capabilities and measurable sustainability outcomes, providing both researchers and practitioners with actionable tools for evaluating blockchain-CE implementations.
Keywords: circular economy, blockchain technology, sustainable supply chain.
Category of the paper: research paper.

1. Introduction

In the face of growing challenges related to the depletion of natural resources, climate change and social pressure for sustainable development, the circular economy is gaining importance as a model for the transformation of production and consumption systems. A key element of effective CE implementation is ensuring full transparency, effective resource management and cooperation between supply chain participants. In this context, blockchain technology, thanks to its unique features such as data immutability, decentralization and the possibility of automating processes using smart contracts, is becoming a promising tool supporting the goals of the circular economy.

This article focuses on the development and presentation of a conceptual model for assessing the impact of blockchain integration in sustainable supply chains on the achievement of CE goals. This model combines the technical capabilities of blockchain with key circularity metrics and a framework for assessing the visibility and affordability of the technology, enabling multi-level analysis of the effects of implementations - from operational efficiency, through process automation, to systemic transformation. The goal is to provide a tool that will allow both researchers and business practitioners to measure and monitor the real contribution of blockchain to the transition towards a circular economy.

2. Materials and methods

This study adopts a conceptual-analytical research design aimed at developing a novel theoretical framework for assessing blockchain technology's contribution to circular economy goals in sustainable supply chains. The research recognizes that the integration of blockchain with circular economy principles is an emergent, socially constructed phenomenon requiring synthesis of multiple theoretical perspectives. The choice of a conceptual modeling approach, as opposed to purely empirical research, is justified by the nascent stage of blockchain-CE integration. Given the limited number of mature, large-scale implementations and the heterogeneity of existing pilots, a premature focus on empirical validation could result in context-specific findings with limited generalizability. Instead, this study prioritizes the development of a comprehensive theoretical foundation that can guide future empirical investigations across diverse contexts.

The literature review followed a systematic approach to ensure comprehensive coverage while maintaining flexibility appropriate for an emerging research domain. The review spanned three interconnected domains: blockchain technology capabilities and applications, circular

economy frameworks and performance metrics, supply chain visibility and traceability systems. Research strings used in the research were as follows:

- Blockchain domain: ("blockchain" OR "distributed ledger" OR "DLT" OR "smart contract*") AND ("supply chain" OR "logistics" OR "traceability").
- Circular economy domain: ("circular economy" OR "circularity" OR "closed-loop" OR "resource efficiency" OR "4R" OR "waste reduction") AND ("metric*" OR "indicator*" OR "measurement" OR "assessment").
- Integration domain: ("blockchain" AND "circular economy") OR ("blockchain" AND "sustainability" AND "supply chain").

The construction of the model proposed by the author in the second part of the article is the result of literature analysis, case studies observed in business reality and conceptual work.

3. Circular economy and blockchain technical capabilities

A sustainable supply chain is defined as a system that integrates environmental, social, and economic considerations into supply chain management, aiming to minimize negative impacts while maximizing benefits for all stakeholders (Negri et al., 2021). This approach is essential for achieving sustainable development goals and involves complex interactions among various actors, emphasizing the need for innovative practices and technologies to enhance efficiency and transparency. Key components of sustainable supply chains include environmental responsibility, social equity and economic viability (Gao et al., 2024; Fernando et al., 2022; Makprang, 2024).

Circular economy however is an economic model that aims to minimize waste and maximize resource reuse by closing material loops (Kara et al., 2022). In contrast to the traditional linear “take-make-throw” model, CE is based on the 4R principles: reduce, reuse, recycle, and recover (Sehrawat, 2025). The goal is to create a system in which products, materials, and resources remain in circulation for as long as possible, which contributes to reducing pressure on the natural environment and increasing economic efficiency (Ghisellini et al., 2016). The key objectives of the CE focus on sustainability, resource efficiency, and the integration of forward and reverse logistics (Mishra et al., 2023). CE aims to create a closed-loop system where products are designed for longevity, repairability, and recyclability, thereby minimizing waste and maximizing resource use (Kara et al., 2022). This transition necessitates a rethinking of logistics strategies to accommodate new material flows and business models (Aarikka-Stenroos et al., 2022). In practice, the circular economy requires a comprehensive approach to product design, supply chain management and cooperation between different stakeholders (Amir et al., 2023). Transparency of processes and the ability to monitor the flow

of materials are key here, which allows for the identification of areas for improvement and the effective implementation of circular strategies (Nascimento et al., 2019).

A number of metrics have been identified in the scientific literature and industry reports to assess the degree of circularity in organizations and supply chains (Corona et al., 2019). The most important include the materials circularity rate, supply chain visibility, waste reduction and carbon footprint (Calzolari et al., 2022). These metrics allow for a quantitative assessment of the effectiveness of circular activities and provide a basis for making informed strategic decisions. Table 1 shows a synthetic summary of the most commonly used circular economy metrics, which will be used later in the article to assess the impact of blockchain integration on the achievement of CE goals.

Table 1.
Circular Economy Metrics – a synthetic summary

Metric	Description	Source
Materials Circularity Rate	Share of recycled/reused materials in total input	Janik, Ryszko, 2017
Supply Chain Visibility	Traceability of materials/products through lifecycle	Kofos et al., 2022
Waste Reduction	Waste minimized/diverted from landfill or incineration	Domenech, Borrion, 2022
Carbon Footprint	Total greenhouse gas emissions	Gao, Liu, Wang, 2014
Resource Productivity	Economic output per unit of material input	Duflou et al., 2012
Percentage of Recycled Material Used	Proportion of recycled content in products/processes	Parchomenko et al., 2019
Product Recyclability	Share of product materials that can be recycled/reused	Okumura, 2022
Circular Water Consumption	Proportion of water reused in operations	Smol, Adam, Preisner, 2020
Product Longevity	Average lifespan of products	Bakker et al., 2021
Industrial Symbiosis Indicators	Use of waste/by-products as inputs for other processes	Domenech et al., 2019

Source: own elaboration based on sources indicated in the Table.

Integrating blockchain technology with the principles of the circular economy seems to be a natural and promising direction for the development of sustainable supply chains. The characteristic features of blockchain - such as decentralization, data immutability, consensus mechanisms, security, material tracking and programmability - perfectly meet the needs of transparency, credibility and process automation, which are key to the effective implementation of the circular economy model. In turn, circularity metrics allow not only to measure progress in closing material cycles, reducing waste or limiting emissions, but also provide specific reference points that can be linked to blockchain functionalities. Combining these two areas - technology and circularity indicators - allows for the creation of a comprehensive model that not only identifies the potential of blockchain, but above all allows for measuring and monitoring its actual impact on achieving the goals of the circular economy.

Blockchain is a technology that has attracted a lot of interest from circular economy experts due to its ability to precisely track the flow of materials and increase the transparency of information exchange in the network (Rehman Khan et al., 2022). The foundation of blockchain

is decentralized architecture, which eliminates the need for a central controlling entity, which increases the system's resistance to manipulation and failures (Shrimali, Patel, 2022). Each transaction is recorded in a block, which, after being approved by network participants, becomes immutable, which guarantees the durability and authenticity of data (Thakre, Yadav, 2024). Consensus mechanisms are key to ensuring the consistency and trustworthiness of records in a distributed network (Lashkari, Musilek, 2021). They allow network participants to jointly approve transactions, eliminating the risk of forgery and double spending (Zhou et al., 2023). The security of the blockchain system is based on cryptography and the distribution of data, which protects it from unauthorized access and attacks (Idrees et al., 2021). Traceability, or the ability to track the origin and flow of materials in the supply chain, is one of the most important features of blockchain used in the circular economy (Centobelli et al., 2022). Thanks to the transparent and immutable record of information, it is possible to accurately monitor the life cycle of products, which supports the responsibility of producers and consumers and allows for the verification of environmental declarations (Luo et al., 2024). Blockchain programmability, implemented by smart contracts, among others, allows for the automation of processes such as the implementation of contracts for returns, recycling or financial incentive systems (Sen Gupta et al., 2021). This increases operational efficiency and supports the implementation of business models based on the principles of the circular economy (Upadhyay et al., 2021). The next section of the article will present a conceptual assessment model that integrates the technical capabilities of blockchain with key metrics of the circular economy, creating a tool to support both researchers and practitioners in the transformation of sustainable supply chains.

4. Measuring Blockchain's Contribution to Circular Economy Goals – the model proposal

The proposed model for assessing the impact of blockchain technology on achieving circular economy goals is conceptualized as an interdisciplinary framework integrating three main components: blockchain technical capabilities, circular economy performance indicators, and a framework for assessing supply chain visibility. The model is based on an extensive analysis of scientific literature and supported by the analysis of case studies from industrial practice that illustrate real blockchain applications in the context of circularity. Key blockchain features have been selected as technical foundations that enable the implementation of CE goals.

The construction of the proposed model

A) Identification of Model's Foundational Layers

The model construction began with the identification of two foundational layers: blockchain technical capabilities and circular economy performance indicators. These constructs were selected based on both their theoretical relevance and their practical observability in real-world pilots and industry use cases. The starting point for defining the first layer of the model was the analysis of the basic technological features of blockchain technology presented in the earlier part of the article. The proposed basic variant of the model took into account transparency and traceability, usability of smart contracts, decentralized verifiability and tokenization. Using the model in practice allows for the use of a wider range of blockchain technology features that have the potential to impact the goals of the circular economy.

In the practical use of the model, the first step is to identify those blockchain functionalities that are actually present or actively used in the analyzed project. Such identification should be carried out on the basis of a technical and functional analysis of the solution using the following approaches:

- analysis of technical documentation and system architecture,
- evaluation of implemented blockchain feature,
- interviews or use case analysis,
- checklist and analysis of the occurrence of features.

The model includes four key CE performance indicators: material circularity rate, supply chain visibility, waste reduction, and carbon footprint. These indicators were selected due to their widespread recognition in the literature and their direct verifiability and monitoring using blockchain data. Their selection allows for a comprehensive assessment of the blockchain's impact on various aspects of circularity – from material efficiency, through process transparency, to environmental impact. Similarly to the first element, using the model in practice allows for the use of a wider range of circularity indicators that are impacted by the usage of blockchain technology. In practice, this layer of the model should be refined by selecting indicators that relate to the circular economy objectives and can be measured or observed in the context of the project being analysed. This selection should be supported by:

- review of strategic documents, project objectives and scope of activity,
- reference to literature and industry standards,
- data availability analysis,
- industry and organizational context,
- validation of indicators with project stakeholders.

B) A Framework for Assessing Blockchain Affordability and Circular Economy Visibility

The model uses a visibility assessment layer, adapted from the existing CE visibility assessment frameworks, which examine the blockchain's ability to monitor and integrate data from multiple sources. In parallel, blockchain affordance analysis allows for linking specific technology features to circular economy goals, allowing for the identification of mechanisms through which blockchain improves circularity. In order to effectively assess the impact of blockchain technology on achieving circular economy goals, it is necessary to combine two perspectives: technical (blockchain features) and measurement (CE metrics). The technological capabilities themselves, constitute a potential that must be linked to specific, measurable effects in the field of circularity. For this purpose, the model introduces two complementary layers: a visibility assessment framework and a blockchain affordance analysis.

Visibility Assessment Framework

Supply chain visibility is a fundamental element enabling monitoring and verification of the flow of materials, their condition and interactions between participants in the system. Blockchain, thanks to its decentralized and immutable nature, increases the level of this visibility by integrating data from various sources. An important point of reference for this layer is the Circular Economy Visibility Evaluation Framework, which indicates that without high-quality, integrated and reliable data, it is not possible to reliably monitor and assess circularity (Kofos et al., 2022). The authors of this approach emphasize that blockchain platforms, by integrating data from many stakeholders and sources, can significantly increase the visibility of material flows throughout the supply chain, which is a necessary condition for effective management and reporting of CE indicators. This enables reliable tracking of materials throughout the product life cycle, allowing for accurate measurement of indicators such as Material Circularity Rate or Waste Reduction. This visibility is essential for eliminating problems such as greenwashing and for ensuring transparency and reliability of data used in reporting and decision-making.

Blockchain Affordability Analysis

The affordance of technology refers to what actions and capabilities technology makes available to users and systems. Analyzing blockchain affordance allows to understand how specific features of the technology translate into the realization of circular economy goals. For example:

- Transparency and traceability enable verification of recycled content, which translates into a reliable Material Circularity Rate (Kouhizadeh, Zhu, Sarkis, 2023).
- Smart contracts automate incentive and material recovery processes, which increases operational efficiency and supports Waste Reduction (Pattanayak et al., 2025).

- Decentralized verification eliminates the need to trust individual entities, which strengthens data credibility and reduces the risk of greenwashing (Cerchione, 2025).
- Tokenization introduces incentive mechanisms, e.g. rewards for pro-environmental activities, which facilitates the involvement of various stakeholders in circular practices (Pattanayak et al., 2025).

Such a link between blockchain functions and specific CE effects enables not only the identification of potential benefits of the technology, but also their measurement and monitoring over time. Combining the visibility assessment framework with affordance analysis creates a coherent mechanism that allows us to move from abstract technology features and metrics to a practical tool for assessing the impact of blockchain on supply chain circularity. Visibility provides data and information, while affordance indicates how this data can be used to achieve CE goals through specific mechanisms and processes.

C) Multi-level impact and implementation assessment

The model considers different levels of blockchain impact – from short-term operational efficiency improvements (e.g., material tracking, waste reduction), through medium-term process automation (e.g., smart contracts), to long-term systemic transformation (e.g., decentralized secondary markets, full product lifecycle responsibility). This approach allows for the assessment of both direct and indirect effects of blockchain implementations in the context of CE. This approach is also based on the assumption that the transformation towards a circular economy is a multi-stage and multi-dimensional process, requiring actions at different organizational and systemic levels.

Short-term improvement in operational efficiency

At the lowest level, blockchain primarily supports operational improvements, such as tracking materials and components in the supply chain and reducing waste. Thanks to the transparency and immutability of data, blockchain enables accurate recording of material flows, which allows for better resource management and reduction of losses. Examples include systems for monitoring electronics recycling or secondary raw materials, which gain credibility and efficiency thanks to blockchain. Such activities fit into the 4R, which is the basis of many CE strategies.

Medium-term process automation

In the medium term, blockchain enables the automation of processes through smart contracts that can independently implement the terms of contracts for material returns, recycling, or financial incentives. This automation increases operational efficiency and reduces transaction costs, while strengthening incentive mechanisms for supply chain participants.

Examples include buy-back programs that are automatically triggered after scanning QR codes or tokenization of incentives for system participants.

Long-term systemic transformation

At the systemic level, blockchain has the potential to fundamentally change the structure and functioning of supply chains and secondary markets. For example, decentralized platforms for the exchange of materials and products (peer-to-peer marketplaces) can reduce dependence on traditional intermediaries and increase resource efficiency. In addition, blockchain supports the concept of "chain of responsibility", or full responsibility for the life cycle of products, which promotes the design of products for ease of recycling and reuse.

This approach is consistent with systems theory, which emphasizes the interconnectedness and feedback between elements of the economic and environmental systems. The transformation of the circular economy therefore requires actions at multiple levels, from operational to strategic, which the model reflects through a multi-level assessment of the impact of blockchain.

D) Model validation and adaptation

The model is designed with verification and scalability in mind, with the purpose of using case studies from real-world implementations and audit mechanisms based on immutable blockchain ledgers in the future. Additionally, integration with AI and IoT technologies is planned, which will allow for the development of predictive tools for managing materials and product life cycles. The model also takes into account challenges such as data standardization, technology scalability, and regulatory compliance. Implementing the model in practice requires taking into account several important challenges:

- Data standardization and interoperability - for blockchain to effectively integrate data from different sources and platforms, common data standards and communication protocols must be developed. The lack of standardization makes it difficult to scale solutions and implement them widely.
- Technology scalability - blockchain, especially in public versions, struggles with limitations in transaction throughput and energy consumption. Hybrid solutions, private or consortium blockchains, and the development of technologies such as proof-of-stake can mitigate these limitations.
- Regulatory compliance - data protection, privacy, and environmental certification regulations must evolve to take into account the specifics and capabilities of blockchain. Cooperation with regulators is key to building trust and acceptance of the technology.

It is planned that validation and adaptation of the model will be based on the synergy of practical implementations, audits based on immutable blockchain data, and integration with modern AI and IoT technologies. At the same time, successful implementation requires

overcoming challenges related to standardization, scalability, and regulations. This approach ensures that the model is not only theoretically consistent, but also practically useful and scalable in different circular economy contexts. The proposed model, the design assumptions of which are presented in the above fragment of the article, takes the graphical form shown in Figure 1.

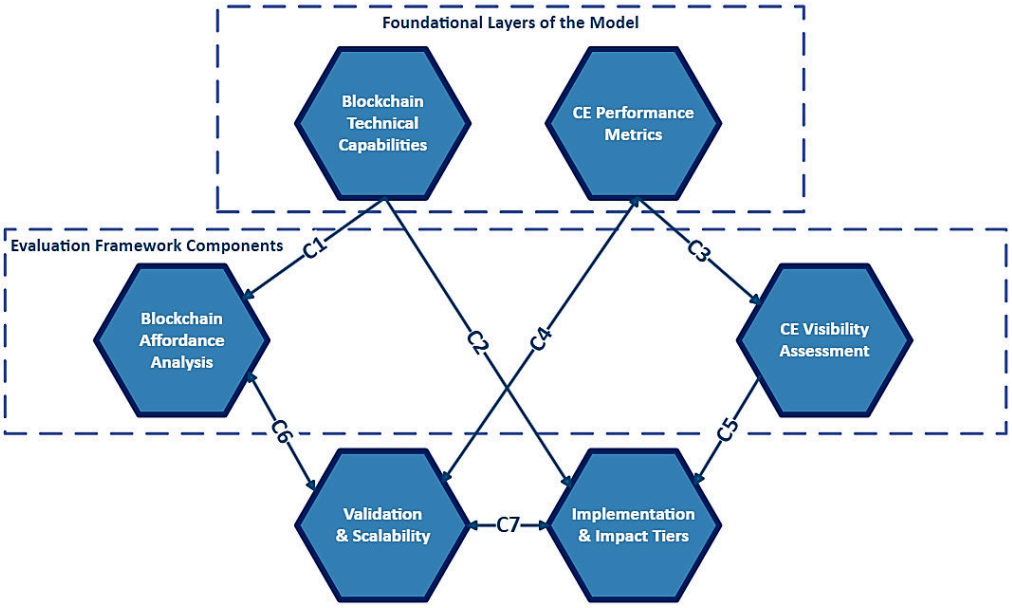


Figure 1. The Model Measuring Blockchain's Contrubution to Circular Economy Goals.
Source: own elaboration.

Figure 1 presents the basic structural elements of the model and indicates 7 connections between them. The characteristics of the individual connections are presented below.

C1 – Blockchain Technical Capabilities -> Blockchain Affordance Analysis

Demonstrates how technical features of blockchain enable specific CE outcomes. This link highlights the functional translation of blockchain tools into CE affordances. For example, transparency enables verification of recycled content, while tokenization supports user engagement in take-back schemes.

C2 – Blockchain Technical Capabilities - > Implementation & Impact Tiers

Shows how practical CE implementations rely on the technical foundation provided by blockchain. As impact tiers evolve, blockchain capabilities such as decentralized verification or smart contracts become critical enablers. This link reinforces the cyclical nature of innovation and capability development.

C3 – CE Performance Metrics -> CE Visibility Assessment

Illustrates how performance indicators are dependent on robust visibility mechanisms to ensure accurate measurement and monitoring. Without visibility, performance metrics such as the material circularity rate or carbon reduction cannot be credibly validated. Visibility ensures traceability across the value chain, enabling real-time tracking and reporting.

C4 – CE Performance Metrics -> Validation & Scalability

Ensures that performance metrics are backed by credible, auditable, and standardized data sources. Validated and scalable systems allow metrics to be recognized across industries and regulatory systems.

C5 – CE Visibility Assessment -> Implementation & Impact Tiers

Represents how visibility supports implementation stages and helps scale CE initiatives by identifying process bottlenecks and material flows. Visibility tools provide the necessary infrastructure to gradually implement CE solutions, from short-term traceability to long-term product lifecycle accountability.

C6 – Blockchain Affordance Analysis <-> Validation & Scalability

Emphasizes the importance of validating how blockchain-enabled CE capabilities perform in real-world contexts and can be scaled sustainably. Each affordance needs to be tested for impact, audited for credibility, and proven scalable across industries. This includes considering energy use, transaction costs, and data standardization.

C7 – Validation & Scalability <-> Implementation & Impact Tiers

Highlights the need to evaluate and validate CE implementations before scaling them across industries or regions. Each implementation must be assessed for actual impact and replicability. Case studies, verified indicators, and interoperability tests are critical to moving from pilot to scaled solutions.

The model described in this article could be a useful tool which can be used in various ways, such as:

- evaluation of specific blockchain-based pilot projects in logistics, industry, or waste management,
- comparison of alternative solutions — to decide which blockchain implementation better supports CE goals,
- verification of technological maturity of a given blockchain-based solution,
- decision-making support for public and private stakeholders looking to invest in technologies that promote circularity.

The practical application of the model described conceptually in this article will be the subject of further work by the author. Subsequent articles will focus on model validation, presentation of practical research results using it, and the development potential of the proposed tool.

5. Conclusion

This study addresses a critical gap at the intersection of blockchain technology and circular economy research by developing a comprehensive conceptual framework for measuring blockchain's contribution to circular economy goals in sustainable supply chains. The proposed model integrates blockchain technical capabilities, circular economy performance metrics, assessment frameworks, and multi-tiered implementation impacts into a coherent system that enables systematic evaluation and optimization of blockchain deployments for circularity outcomes. The research makes three primary theoretical contributions. First, the model provides a structured integration of affordance theory with circular economy measurement frameworks, explicitly connecting blockchain's technical features to their action possibilities for achieving circular economy objectives. Second, the framework introduces a multi-layered visibility and credibility mechanism addressing one of the circular economy's most persistent challenges: reliable measurement and verification of circularity performance. By demonstrating how blockchain-enabled visibility supports the credibility of CE metrics, the model articulates a pathway to overcome greenwashing concerns and establish trust among supply chain stakeholders. Third, the model's temporal dimension—distinguishing between short-term operational improvements, medium-term process automation, and long-term systemic transformation—provides a framework for understanding blockchain adoption as an evolutionary process rather than a binary implementation. This perspective aligns with systems theory and organizational change literature.

The framework offers substantial value for multiple stakeholder groups. Supply chain managers and sustainability officers gain a structured decision-support tool for evaluating blockchain investments, enabling assessment of whether proposed solutions align with circularity objectives before committing resources. Technology vendors and blockchain developers receive guidance on critical design priorities, with the affordance perspective highlighting that systems must enable and encourage specific circularity-enhancing actions. Policymakers and standard-setting bodies obtain a foundation for developing standardized assessment protocols for blockchain-CE implementations. Investors and financial institutions focused on sustainable finance gain a framework for due diligence on blockchain-enabled circular economy ventures, helping direct capital toward genuinely impactful innovations.

Despite its contributions, this study has several important limitations. The most significant limitation is the absence of primary empirical validation; the model has not been tested through real-world implementations. While grounded in extensive literature review and informed by secondary case study analysis, its practical utility, completeness, and accuracy remain to be verified in diverse organizational contexts. The selection of four primary CE metrics, while justified by their widespread recognition and measurability, may not capture the full spectrum of circularity objectives, particularly social dimensions of circular economy. The model is

designed to be extensible to additional metrics, but the current formulation has inherent scope boundaries. Technological dynamism presents another challenge. Blockchain technology is evolving rapidly, with ongoing developments in scalability solutions, consensus mechanisms, and interoperability standards. The model may require periodic updating to reflect technological advances and integration with other emerging technologies. Data availability and quality assumptions may limit applicability. The model assumes reliable, granular data about material flows and environmental impacts, which may be scarce in many supply chains, particularly in developing regions or informal sectors. Finally, the framework focuses primarily on technological and measurement dimensions, giving less attention to organizational and governance challenges such as power dynamics, resistance to transparency, and competing economic interests among supply chain actors, which could be an interesting future research area.

The transition to a circular economy represents one of the most critical challenges of the 21st century, requiring fundamental transformation of production and consumption systems. Blockchain technology holds significant promise as an enabler of this transformation, yet realizing this promise requires moving beyond technological optimism to develop rigorous frameworks for designing, implementing, and evaluating blockchain solutions in service of measurable circularity outcomes. This study contributes to that endeavor by providing a theoretically grounded, practically oriented conceptual framework that bridges blockchain capabilities with circular economy performance measurement. The framework is not an endpoint but a foundation—a structured starting point for empirical research, practical implementation, and ongoing refinement. As blockchain technology matures and circular economy principles become increasingly embedded in business strategy and public policy, tools like the proposed model will be essential for ensuring that technological innovation genuinely advances sustainability goals.

References

1. Aarikka-Stenroos, L., Chiaroni, D., Kaipainen, J., Urbinati, A. (2022). Companies' circular business models enabled by supply chain collaborations: An empirical-based framework, synthesis, and research agenda. *Industrial Marketing Management, 105*, pp. 322-339.
2. Amir, S., Salehi, N., Roci, M., Sweet, S., Rashid, A. (2023). Towards circular economy: A guiding framework for circular supply chain implementation. *Business Strategy and the Environment, 32(6)*, pp. 2684-2701.
3. Bakker, C.A., Mugge, R., Boks, C., Oguchi, M. (2021). Understanding and managing product lifetimes in support of a circular economy. *Journal of cleaner production, 279*, 123764.

4. Calzolari, T., Genovese, A., Brint, A. (2022). Circular Economy indicators for supply chains: A systematic literature review. *Environmental and Sustainability Indicators, 13*, 100160.
5. Centobelli, P., Cerchione, R., Del Vecchio, P., Oropallo, E., Secundo, G. (2022). Blockchain technology for bridging trust, traceability and transparency in circular supply chain. *Information & Management, 59(7),* 103508.
6. Cerchione, R. (2025). Design and evaluation of a blockchain- based system for increasing customer engagement in circular economy. *Corporate Social Responsibility and Environmental Management, 32(1),* 160-175.
7. Corona, B., Shen, L., Reike, D., Carreón, J.R., Worrell, E. (2019). Towards sustainable development through the circular economy—A review and critical assessment on current circularity metrics. *Resources, Conservation and Recycling, 151*, 104498.
8. Domenech, T., Borrion, A. (2022). Embedding circular economy principles into urban regeneration and waste management: Framework and metrics. *Sustainability, 14(3),* 1293.
9. Domenech, T., Bleischwitz, R., Doranova, A., Panayotopoulos, D., Roman, L. (2019). Mapping Industrial Symbiosis Development in Europe_ typologies of networks, characteristics, performance and contribution to the Circular Economy. *Resources, conservation and recycling, 141,* pp. 76-98.
10. Duflou, J.R., Sutherland, J.W., Dornfeld, D., Herrmann, C., Jeswiet, J., Kara, S., Kellens, K. (2012). Towards energy and resource efficient manufacturing: A processes and systems approach. *CIRP annals, 61(2),* pp. 587-609.
11. Fernando, Y., Halili, M., Tseng, M.L., Tseng, J.W., Lim, M.K. (2022). Sustainable social supply chain practices and firm social performance: Framework and empirical evidence. *Sustainable Production and Consumption, 32*, pp. 160-172.
12. Gao, J.Q., Li, D., Qiao, G.H., Jia, Q.R., Li, S.R., Gao, H.L. (2024). Circular economy strategies in supply chains, enhancing resource efficiency and sustainable development goals. *Environmental Science and Pollution Research, 31(6),* pp. 8751-8767.
13. Gao, T., Liu, Q., Wang, J. (2014). A comparative study of carbon footprint and assessment standards. *International Journal of Low-Carbon Technologies, 9(3),* pp. 237-243.
14. Ghisellini, P., Cialani, C., Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner production, 114,* pp. 11-32.
15. Idrees, S.M., Nowostawski, M., Jameel, R., Mourya, A.K. (2021). Security aspects of blockchain technology intended for industrial applications. *Electronics, 10(8),* 951.
16. Janik, A., Ryszko, A. (2017). *Towards measuring circularity at product level–Methodology and application of material circularity indicator*. 7th Carpathian Logistics Congress-CLC.
17. Kara, S., Hauschild, M., Sutherland, J., McAloone, T. (2022). Closed-loop systems to circular economy: A pathway to environmental sustainability? *CIRP Annals, 71(2),* pp. 505-528.

18. Kofos, A., Ubacht, J., Rukanova, B., Korevaar, G., Kouwenhoven, N., Tan, Y.H. (2022). Circular economy visibility evaluation framework. *Journal of Responsible Technology, 10,* 100026.
19. Kouhizadeh, M., Zhu, Q., Sarkis, J. (2023). Circular economy performance measurements and blockchain technology: an examination of relationships. *The International Journal of Logistics Management, 34(3),* pp. 720-743.
20. Lashkari, B., Musilek, P. (2021). A comprehensive review of blockchain consensus mechanisms. *IEEE access, 9,* pp. 43620-43652.
21. Luo, Y., Shen, J., Liang, H., Sun, L., Dong, L. (2024). Supporting building life cycle carbon monitoring, reporting and verification: A traceable and immutable blockchain-empowered information management system and application in Hong Kong. *Resources, Conservation and Recycling, 208,* 107736.
22. Makprang, K. (2024). Sustainability in supply chains: strategies and practices for a greener future. *RMUTT Global Business Accounting and Finance Review, 8(1),* pp. 85-108.
23. Mishra, A., Dutta, P., Jayasankar, S., Jain, P., Mathiyazhagan, K. (2023). A review of reverse logistics and closed-loop supply chains in the perspective of circular economy. *Benchmarking: an International Journal, 30(3),* pp. 975-1020.
24. Nascimento, D.L.M., Alencastro, V., Quelhas, O.L.G., Caiado, R.G.G., Garza-Reyes, J.A., Rocha-Lona, L., Tortorella, G. (2019). Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal. *Journal of manufacturing technology management, 30(3),* pp. 607-627.
25. Negri, M., Cagno, E., Colicchia, C., Sarkis, J. (2021). Integrating sustainability and resilience in the supply chain: A systematic literature review and a research agenda. *Business Strategy and the Environment, 30(7),* pp. 2858-2886.
26. Okumura, S. (2022). Reuse-efficiency model for evaluating circularity of end-of-life products. *Computers & Industrial Engineering, 171*, 108232.
27. Parchomenko, A., Nelen, D., Gillabel, J., Rechberger, H. (2019). Measuring the circular economy-A Multiple Correspondence Analysis of 63 metrics. *Journal of Cleaner Production, 210*, pp. 200-216.
28. Sehrawat, M., Nandwani, A., Rohila, M., Jain, A. (2025). Redefining Consumer Behaviour in a Circular Economy: Strategies for Sustainable Living. In: *Social System Reforms to Achieve Global Sustainability* (pp. 391-420). IGI Global Scientific Publishing.
29. Rehman Khan, S.A., Yu, Z., Sarwat, S., Godil, D.I., Amin, S., Shujaat, S. (2022). The role of block chain technology in circular economy practices to improve organisational performance. *International Journal of Logistics Research and Applications, 25(4-5),* pp. 605-622.
30. Sen Gupta, Y., Mukherjee, S., Dutta, R., Bhattacharya, S. (2022). A blockchain-based approach using smart contracts to develop a smart waste management system. *International Journal of Environmental Science and Technology*, *19*(8), pp. 7833-7856.

31. Shrimali, B., Patel, H.B. (2022). Blockchain state-of-the-art: architecture, use cases, consensus, challenges and opportunities. *Journal of King Saud University-Computer and Information Sciences, 34(9),* pp. 6793-6807.
32. Smol, M., Adam, C., Preisner, M. (2020). Circular economy model framework in the European water and wastewater sector. *Journal of Material Cycles and Waste Management, 22*, pp. 682-697.
33. Thakre, B., Yadav, U. (2024). Evaluation of Data Management in Blockchainbased Systems. In: *Data Management and Security in Blockchain Systems* (pp. 1-37). Bentham Science Publishers.
34. Upadhyay, A., Mukhuty, S., Kumar, V., Kazancoglu, Y. (2021). Blockchain technology and the circular economy: Implications for sustainability and social responsibility. *Journal of cleaner production*, *293*, 126130.
35. Zhou, S., Li, K., Xiao, L., Cai, J., Liang, W., Castiglione, A. (2023). A systematic review of consensus mechanisms in blockchain. *Mathematics*, *11*(10), 2248.

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IT'S NOT WHAT YOU KNOW, BUT WHO YOU KNOW: NETWORKING ABILITY LINKING POLITICAL WILL AND JOB PERFORMANCE

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Purpose: This study examines the causal mechanism linking political will (PW) and job performance (JP). Specifically, it investigates whether political skill (PS) dimensions mediate the relationship between benevolent and self-serving dimensions of PW and task/contextual performance as dimensions of JP. By adopting a process-oriented perspective, the study moves beyond traditional interaction-based approaches to political behavior.
Design/methodology/approach: A quantitative study was conducted on 370 senior and middle managers in medium and large enterprises operating in Poland. Data were analyzed using path analysis with maximum likelihood estimation and bootstrapping. The explanatory variables included the dimensions of PW; the dimensions of PS were analyzed as parallel mediators, while task and contextual performance served as dependent variables. Measurement scales with established validity and reliability were used to assess all constructs.
Findings: Networking ability emerged as the exclusive mediator linking self-serving PW to both task and contextual performance. Contrary to expectations, social astuteness, interpersonal influence, and apparent sincerity did not serve as mediators. Furthermore, benevolent PW showed a direct negative relationship with task performance. These findings highlight the unique behavioral leverage of networking in the association between political motivation and performance outcomes.
Research limitations/implications: The cross-sectional nature of data requires caution with regard to conclusions concerning causality. Future research should implement longitudinal studies and more diverse samples to examine the temporal ordering and stability of the observed associations over time. The use of self-report measures also suggests the need for multi-source designs in future studies.
Practical implications: The findings suggest that organizations may benefit from channeling employees' self-serving ambitions into constructive networking behaviors, as these are positively associated with performance. Strengthening political competencies—particularly networking—may therefore serve as a high-impact lever in leadership development.
Originality/value: This paper challenges the assumption that all political skills function similarly by identifying networking ability as the critical dimension linking motivation (PW) and action. It offers empirical evidence for a differentiated, association-based model of political behavior in organizations.

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Keywords: political will, political skill, organizational politics, political behaviors, job performance.
Category of the paper: research paper.

1. Introduction

The workplace is intrinsically political, requiring individuals to cultivate skills in persuasion, influence, and control – abilities collectively referred to as political skill (PS) (Mintzberg, 1983, 1985). Engagement in political behavior is a common feature of professional life (Kapoutsis et al., 2017). It's scope and strength depend on the individual's encouragement and determination to exert effort toward achieving political objectives, referred to as political will (PW) (Mintzberg, 1983). Importantly, political will operates as an internal motivational force, reflecting not only the intention to act politically but also the direction of this intention, which may be benevolent (pro-organizational) or self-serving (self-oriented).

Our study expands the domain of political influence research by shifting the focus from the interaction of these constructs to the causal mechanism linking them. While existing literature often conceptualizes PW and PS as interactive forces – where skill is necessary to activate the benefits of will (e.g. Maher et al., 2018; Treadway et al., 2005) – there is still limited research examining the processual nature of this relationship. Specifically, we propose that PW serves as the motivational antecedent that drives the development and deployment of specific PS, which in turn facilitate higher job performance (JP). In this framework, political will represents the motivational energy ("want to"), political skill reflects the behavioral competence ("know how"), and job performance captures the observable outcomes of political behavior ("what gets done"), illustrating a coherent motivational–behavioral–performance pathway.

Consequently, the primary objective of this study is to investigate the mediating role of PS dimensions (social astuteness, interpersonal influence, networking ability, and apparent sincerity) in the relationship between PW (both benevolent and self-serving) and JP (task and contextual). By adopting a detailed approach, we aim to move beyond global assessments of these constructs to identify precisely which specific political competencies act as the behavioral vehicles for translating political motivation into organizational effectiveness. This approach addresses calls for more nuanced empirical examinations of political dynamics in the workplace (Kapoutsis et al., 2017) and offers a clearer understanding of how motivation and skill combine to shape employee outcomes. Moreover, by identifying the particular skill dimensions through which political will translates into performance, this study provides insights that may support leadership development, managerial training, and HRM practices centered on strengthening constructive political competencies in organizations.

1.1. The Motivation: Political Will

According to Treadway (2012, p. 533), PW is "the motivation to engage in strategic, goal-directed behavior that advances the personal agenda and objectives of the actor that inherently involves the risk of relational or reputational capital." PW is a necessary trait for navigating the political dynamics of the workplace (Mintzberg, 1983). Treadway further contends that PW incorporates both self-serving motives – such as individual need for achievement, power, and Machiavellian tendencies, and benevolent motives, which are linked to need for affiliation, organizational citizenship behavior, and voice behavior.

While theoretical perspectives highlight PW's significance in managing workplace politics and influencing others (e.g., Treadway, 2012), empirical studies on this topic remain limited (Treadway, 2012). Existing evidence suggests that PW often operates simultaneously in both forms, meaning that self-serving and benevolent motives can co-exist within the same individual rather than forming opposite ends of a single continuum (Kapoutsis et al., 2017). For instance, Kapoutsis et al. (2017) identify PW as a fundamental driver of personal and organizational resources toward political goals. Another study by Semadar et al. (2006) suggests that interpersonal competencies are key predictors of managerial performance. Taken together, existing literature positions PW as the motivational precursor of political behavior, yet it remains less understood how this motivation translates into concrete behavioral expressions—a gap that underscores the need to examine its relationship with political skill.

1.2. The Behavioral Mechanism: Political Skill

Ferris et al. (2005, p. 127) define PS as "the ability to effectively understand others at work and to use such knowledge to influence others to act in ways that enhance one's personal and/or organizational objectives". This concept, frequently examined within the fields of organizational behavior and leadership, is recognized as a crucial trait for being an effective leader and for achieving organizational success. It involves the capacity to understand and influence others to accomplish specific goals (Ferris et al., 2005).

Political skill has been described as a core element of social effectiveness at work, conceptually related to but distinct from broader constructs such as emotional intelligence or self-monitoring (Ferris et al., 2007; Semadar et al., 2006). PS is understood as a multidimensional construct that includes four core components: social astuteness, interpersonal influence, networking ability, and apparent sincerity (Ferris et al., 2000, 2005). Social astuteness pertains to individuals' ability to perceive and adapt to subtle social cues in their environment (Blass, Ferris, 2007). Interpersonal influence is characterized by the ability to effectively bring about changes in others' attitudes or behaviors (Bing et al., 2011). Networking ability refers to forming and leveraging relationships, alliances, and coalitions to one's advantage (Pfeffer, 1993). Apparent sincerity reflects the capacity to convey authenticity and trustworthiness in social interactions, such that others are inclined to ascribe positive intent even when behavior is strategically managed (Blass, Ferris, 2007).

In contemporary work settings, attributes like social astuteness, organizational positioning, and political savvy often outweigh intelligence and diligence as determinants of performance, effectiveness, and career advancement. Ferris et al. (2006) argue that PS is among the most critical competencies for leaders in modern organizations. Consistent with this view, prior research has linked political skill to higher supervisor-rated performance, organizational citizenship behavior, and career success (Blickle et al., 2013; Semadar et al., 2006; Treadway et al., 2007). Building on these findings, we conceptualize PS as the key behavioral mechanism through which political will is translated into job performance in our study.

1.3. The Outcomes: Job Performance

The construct of job performance has long been explored in scientific literature, however there is still little consensus on its conceptual framework. Instead, its definition largely depends on the context and research approach. Yet, different terms are used to refer to job performance, such as productivity, efficiency, and effectiveness, but their meanings are not always distinct, and they are frequently used interchangeably (Tangen, 2005). In management studies, job performance is typically associated with the challenge of maximizing employee productivity (Luthfiyana et al., 2024; Viswesvaran, Ones, 2000). Moreover, it remains a key and widely utilized outcome measure in occupational research.

Crucially for modern organizational research, job performance is widely recognized as a multidimensional construct. Borman and Motowidlo (1993, 1997) proposed a fundamental distinction between task performance and contextual performance. Task performance refers to the proficiency with which individuals perform activities that are formally part of their job description and contribute to the organization's technical core. This includes activities that directly transform raw materials into goods and services or replenish the supply of these materials (Motowidlo, Van Scotter, 1994). Conversely, contextual performance – often referred to as Organizational Citizenship Behavior (OCB) – encompasses behaviors that support the broader organizational, social, and psychological environment in which the technical core must function. These behaviors include volunteering for activities not formally prescribed, helping and cooperating with others, and endorsing organizational objectives (Borman, Motowidlo, 1993). Distinguishing between these two dimensions is essential, as they may have different antecedents and are likely differentially influenced by political dynamics within the organization.

Research consistently shows that task and contextual performance differ not only in content but also in their antecedents, with contextual performance more strongly influenced by interpersonal processes, social effectiveness, and political behavior (Blickle et al., 2013; Ferris et al., 2007). This distinction is particularly relevant for the present study, as it provides a theoretical basis for expecting political will and political skill to differentially impact these two facets of performance.

1.4. Integrative Theoretical Framework: Political Skill as a Mediating Mechanism

Research suggests that both PW and PS significantly enhance task and contextual performance, as individuals with high levels of both are uniquely equipped to address workplace challenges, build alliances, and influence others effectively. Yukl (2008), examining how top management and other leaders can influence the financial performance of a business organization, confirmed that leaders' ability to adapt, be flexible, and innovate – skills fostered by political will – enhances organizational effectiveness and helps organizations survive and thrive in turbulent and uncertain environments. Although these perspectives underscore the importance of PW and PS, they predominantly treat the constructs as independent contributors to performance, offering limited insight into the mechanisms by which political motivation is translated into effective political behavior.

Despite the arguments highlighting the importance of PW and PS, empirical research examining their interaction and relationship remains scarce (Maher et al., 2018). While some studies suggest an interactive effect, where PW has a positive effect on job performance only when PS is high (Ferris et al., 2019), a growing body of theoretical work suggests a causal, process-oriented relationship. According to the Theory of Planned Behavior (Ajzen, 2011), Social Cognitive Theory, SCT (Bandura, 2001), and other models of social influence, motivation (PW) serves as the antecedent that drives the acquisition and deployment of specific competencies (PS). Treadway (2012) posits that PW provides the necessary energy and determination to engage in political behavior, but it is the PS that serves as a tool through which this motivation is translated into effective action. In organizational behavior research, similar motivation→skill→behavior pathways have been demonstrated in studies on proactive behavior, leadership development, and social effectiveness (DeRUE & Ashford, 2010; Grant, Ashford, 2008), reinforcing the plausibility of a mediating mechanism.

In this view, PW is not merely a moderator but a precursor to PS. Individuals driven by self-serving motives (e.g., need for power or achievement) or benevolent motives (e.g., organizational benefit) are more likely to invest effort in developing their social astuteness, interpersonal influence, networking ability, and apparent sincerity to achieve their goals. For instance, an employee with a strong self-serving will to advance their career is likely to actively cultivate a professional network (networking ability). Consequently, this enhanced networking ability allows them to access resources and information more efficiently, thereby improving their task performance (Bing et al., 2011). Similarly, individuals with benevolent PW may utilize interpersonal influence and apparent sincerity to foster a supportive work environment, directly enhancing contextual performance.

Importantly, treating PW and PS as interacting predictors (as in the moderation model) provides an incomplete explanation of political behavior because it assumes that skill is a static attribute that merely amplifies motivation. In contrast, a mediational perspective conceptualizes PS as the behavioral expression of political will – an interpretation better aligned with

motivational theory and with empirical findings showing that social competencies develop in response to goal-directed striving (Kanfer, 2012; Latham, Pinder, 2005). This approach also addresses critiques that prior research has not sufficiently traced how political motivation is enacted within organizations (Kapoutsis et al., 2017).

Therefore, rather than viewing these constructs as interacting separate entities, it is reasonable to posit that PS acts as the behavioral mechanism that transmits the effects of PW onto JP. Without the requisite PS, PW remains a latent potential or untapped energy; it is the execution of PS that ultimately impacts organizational outcomes. This reasoning is consistent with process models in organizational psychology, which hold that motivation influences performance only when it is expressed through specific behaviors (Mitchell, Daniels, 2003). This theoretical framework leads to the proposition that PS mediates the relationship between PW and JP and to the following general hypothesis:

Dimensions of PS (social astuteness, interpersonal influence, networking ability, apparent sincerity) statistically mediate the relationship between the dimensions of PW (benevolent and self-serving) and job performance (task and contextual performance).

The complete list of specific hypotheses (H1-H16) required to fully test this general hypothesis is presented in Table 5 in Appendix.

2. Research method

Procedure and sample

The empirical study targeted middle and senior managers employed in medium-sized (50-250 employees) and large (over 250 employees) companies operating in Poland. Company contact details were obtained from the Polish Central Statistical Office (GUS). A purposive non-probability sampling strategy was applied, with the inclusion criterion that only middle and senior managers were eligible to participate.

The research was conducted in two stages. The pilot study, carried out from October to December 2021, yielded 113 completed questionnaires. The main study was conducted from January to December 2022. In the first quarter of 2022, invitations to participate in the survey were sent by email to entities randomly selected form the GUS's list, followed by reminders after three and six months. In addition, telephone calls were made to representatives of some of the enterprises in order to increase the response rate. The survey questionnaire was administered via an online survey platform (CAWI methodology). The invitations assured respondents of complete anonymity and that the data would only be used in aggregate form. The main study collected an additional 365 completed questionnaires.

A total of 478 surveys were collected, of which 108 were rejected for not meeting the criteria (respondents outside the target group or companies with fewer than 50 employees). A total of 370 complete questionnaires were qualified for analysis (N = 370), which exceeded the minimum required sample size as determined using the "Sample selection calculator" available on https://www.naukowiec.org/dobor.html website and allowed the empirical material obtained to be considered sufficient for further statistical analysis.

Of the study sample 189 were women and 181 were men. The largest group of respondents fell within the 46-50 years age bracket. A total of 153 respondents (41.4%) were under 40 years of age, while 217 respondents (58.6%) were over 40 years of age. Regarding professional experience, the largest cohort (169 individuals, 45.7%) reported having at least 10 years of work experience. A total of 146 individuals (39.5%) had up to 5 years of work experience, whereas 224 individuals (60.5%) had 5 or more years of work experience. The majority of the respondents were employed at a middle management level. Most respondents worked in organizations employing 50–250 people. In terms of the sector of economy, the highest percentage of respondents worked in the manufacturing industry (63 people, 17%). Overall, 207 participants (55.9%) were employed in the industry, manufacturing, and trading sectors, while 163 participants (44.1%) were employed in sectors related to intangible services.

Measures

In this study, a Polish version of the measurement tool was developed to assess the constructs outlined above. This tool was based on validated and reliable measurement scales. A 5-point Likert scale was used, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The following scales were used to construct the questionnaire:

- **Political Will Scale (PWS):** Developed by Kapoutsis et al. (2017), this scale has a Cronbach's α of 0.88 and includes 8 items. Sample questions are: "When I am right I am willing to act politically" and "I would engage in politics to preserve my self-esteem".
- **Political Skill Inventory (PSI)**: Developed by Ferris et al. (2005), this scale has a Cronbach's α of 0.80 and consists of 18 items. Sample questions are: "I spend a lot of time and effort at work networking with others" and "I am able to communicate easily and effectively with others".
- **The Individual Work Performance Questionnaire (IWPQ)**, developed by Koopmans et al. (2014). This instrument assesses employee performance through distinct subscales (18 items in total). In the present study, the Cronbach's alpha coefficient for contextual performance was 0.79, indicating good reliability. For task performance, the alpha value was 0.62. This reliability level is common in short subscales and acceptable provided that factor loadings meet recommended thresholds (Hair et al., 2019).

Sample questions are: “I kept in mind the results that I had to achieve in my work”, “I took on challenging work tasks, when available” and “I focused on the negative aspects of a work situation, instead of on the positive aspects”.

All instruments were translated into Polish ensuring conceptual and linguistic equivalence with the original scales.

3. Results

The empirical analysis contained in this section is presented in two main steps. First, descriptive statistics and reliability coefficients for the measurement scales are provided to assess data distribution and quality. Second, to establish the relationship between the variables, path analysis based on the maximum likelihood method was used. The independent variables included the dimensions of PW; dimensions of PS were analyzed as parallel mediators, while work performance dimensions were analyzed as dependent variables. Statistical significance of the mediation effects was verified using the bootstrapping method. Prior to estimating the structural model, confirmatory factor analysis (CFA) was conducted to verify the adequacy of the measurement model. All factor loadings exceeded recommended thresholds and global fit indices indicated good model fit.

Table 1 presents the descriptive statistics for the analyzed interval variables, i.e., mean values, standard deviations, minimum and maximum values, and the values of skewness and kurtosis measures. The summary is supplemented with the values of Cronbach's alpha reliability coefficients.

Table 1.
Descriptive statistics for interval variables analyzed

Variables	M	SD	min	max	S	K	α
Political will							
Benevolent	12.37	3.46	4	20	-0.36	-0.51	0.81
Self-serving	8.92	3.42	4	18	0.35	-0.60	0.87
Political skill							
Social astuteness	17.86	2.72	9	25	-0.04	0.25	0.76
Interpersonal influence	15.31	2.17	8	20	-0.24	0.26	0.76
Network ability	20.12	3.42	9	30	-0.25	0.05	0.75
Apparent sincerity	12.29	1.38	7	15	-0.04	0.88	0.57

Note. M – average value; SD – standard deviation; min – minimum value; max – maximum value; S – measure of skewness; K – measure of kurtosis; α - value of the Cronbach measurement reliability coefficient α.

Source: own study.

The skewness values fell within the range typical of a normal distribution (i.e. -1 to 1), indicating that the distribution of analyzed variables is approximately normal. All kurtosis values also fell within the acceptable ±2 range, further supporting the assumption of

approximate normality. This is important as it justifies the use of parametric statistical tests and enhances the generalizability of the study's findings.

The relationships between variables were analyzed using path analysis based on the maximum likelihood method. The explanatory variables included the dimensions of PW: the benevolent dimension and the self-serving dimension. Indicators of PS – namely, social astuteness, interpersonal influence, networking ability, and apparent sincerity – were analyzed as parallel mediators, while work performance indicators, including task performance and contextual performance, were analyzed as dependent variables. Figure 1 presents the hypothesized empirical model of relationships between the study variables. Correlations among the four political skill dimensions and, separately, between the two work performance indicators were included in the model estimation but are omitted from the figure for clarity.

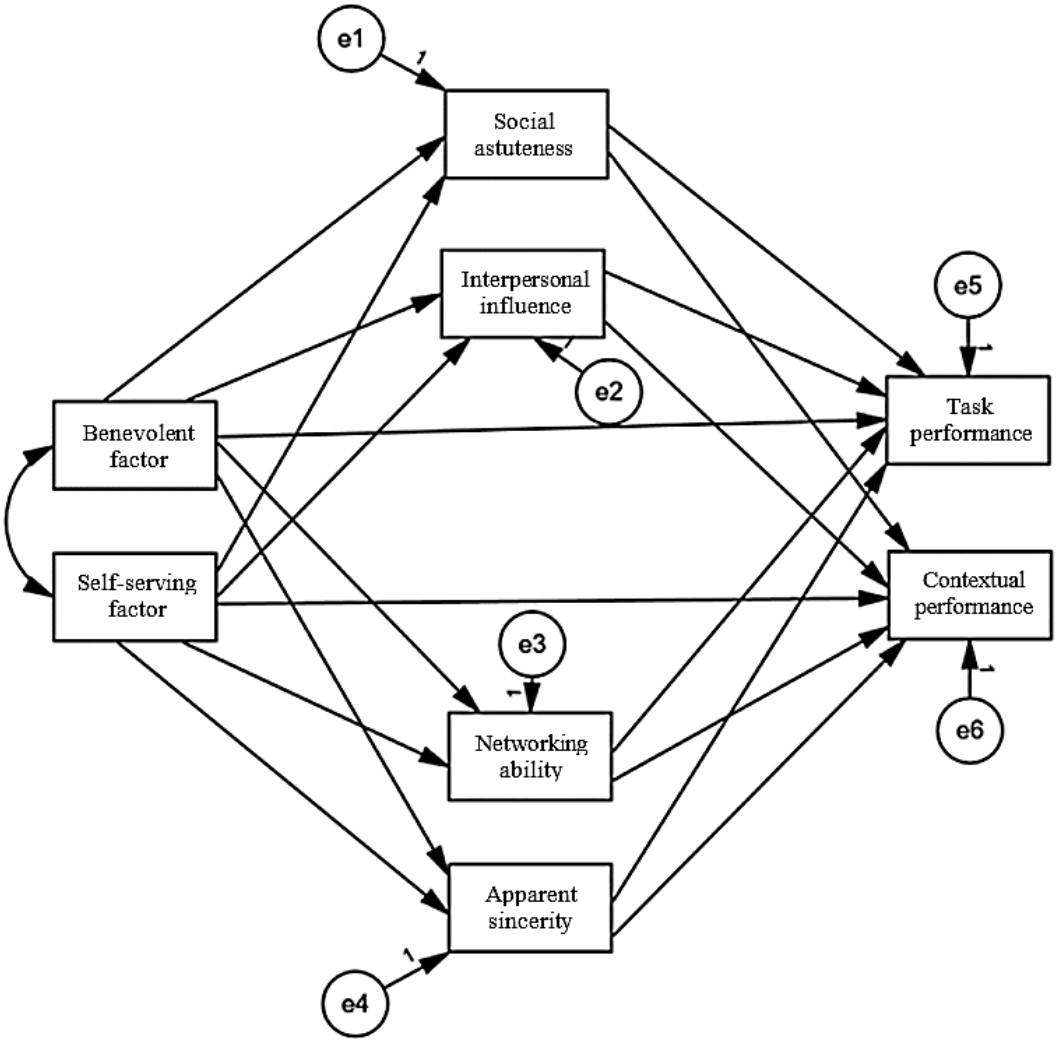


Figure 1. Hypothesized empirical model of relationships between the variables.

Source: own study.

The fit index values for the empirical model were optimal, with NFI = 0.99, CFI = 0.99, and RMSEA = 0.06. However, several relationships in the empirical model were not statistically significant. Table 2 presents the values of correlation coefficients. All variables

demonstrated adequate variability, with means and standard deviations consistent with prior research using these scales.

Table 2.
Values of correlation coefficients

Variables	M	SD	α	1.	2.	3.	4.	5.	6.	7.
Job Performance										
1. Task performance	19.45	2.79	0.62	--						
2. Contextual performance	27.86	6.11	0.79	0.315**	--					
Political will										
3. Benevolent Factor	12.37	3.46	0.81	-0.112*	0.072	--				
4. Self-serving Factor	8.92	3.42	0.87	-0.129*	0.009	0.559**	--			
Political skill										
5. Social astuteness	17.86	2.72	0.76	0.103*	0.214**	0.153**	0.179**	--		
6. Interpersonal influence	15.31	2.17	0.76	0.102*	0.184**	0.086	0.069	0.510**	--	
7. Networking ability	20.12	3.42	0.75	0.142**	0.334**	0.184**	0.209**	0.484**	0.519**	--
8. Apparent sincerity	12.29	1.38	0.57	0.105*	0.181**	0.054	-0.042	0.377**	0.455**	0.327**

Note. M – average value; SD – standard deviation; α - value of the Cronbach measurement reliability coefficient α; * p<0,05; ** p<0,01.

Source: own study.

No statistically significant relationships were found between the benevolent dimension of PW and interpersonal influence, social astuteness, networking ability, or apparent sincerity. Similarly, no statistically significant relationships were observed between the self-serving dimension of PW and apparent sincerity, interpersonal influence, or contextual performance. Social astuteness, interpersonal influence, and apparent sincerity were not statistically significantly related to task or contextual performance. After removing the non-significant relationships, the fit index values improved to NFI = 0.96, CFI = 0.98, and RMSEA = 0.05. Non-significant paths were removed following standard model-trimming procedures (Kline, 2016), provided that such modifications were theoretically justified and improved global model fit. Indirect effects were examined using 5000 bootstrap samples with bias-corrected confidence intervals to ensure robust estimation of mediation effects. The final empirical model after removing all non-significant paths is presented in Figure 2.

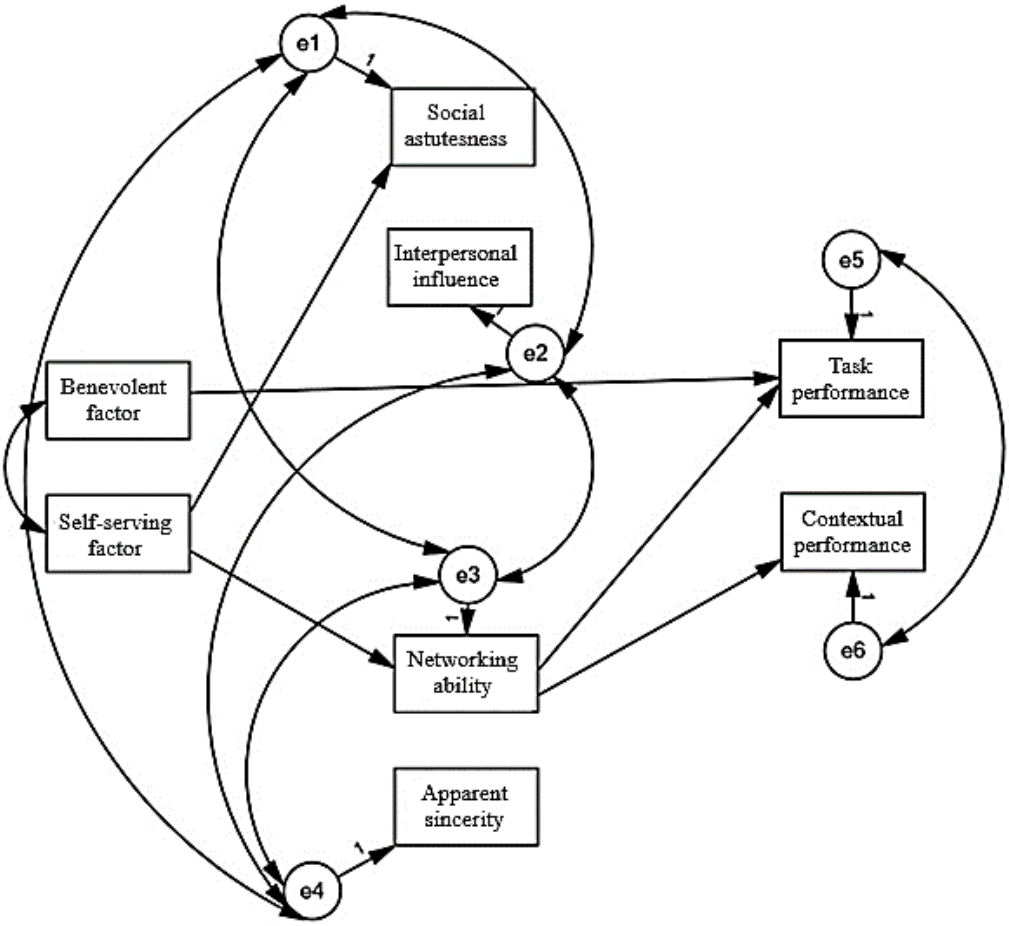


Figure 2. Final model of relationships between the variables.

Source: own study.

Table 3 presents the values of regression coefficients and correlation coefficients obtained in the final model.

Table 3.
Values of regression coefficients and correlation coefficients obtained in the final model

Relationship			*Beta/r*	*p*
Networking ability	<---	Self-serving factor	0.18	0.001
Task performance	<---	Networking ability	0.17	0.001
Contextual performance	<---	Networking ability	0.33	0.001
Social astuteness	<---	Self-serving factor	0.16	0.001
Task performance	<---	Benevolent factor	-0.15	0.003
Benevolent factor	<-->	Self-serving factor	0.56	0.001
Task performance	<-->	Contextual performance	0.29	0.001
Social astuteness	<-->	Interpersonal influence	0.51	0.001
Apparent sincerity	<-->	Networking ability	0.34	0.001
Social astuteness	<-->	Apparent sincerity	0.39	0.001
Social astuteness	<-->	Networking ability	0.47	0.001
Apparent sincerity	<-->	Interpersonal influence	0.46	0.001
Interpersonal influence	<-->	Networking ability	0.52	0.001

Note. Beta - standardized regression coefficient; r - Pearson's correlation coefficient; p - statistical significance.

Source: own study.

Both dimensions of PW—the benevolent and the self-serving—were positively correlated. Task performance was positively correlated with contextual performance, and all indicators of PS were also positively correlated with each other. The strong correlations among political skill dimensions are consistent with prior research validating the Political Skill Inventory, which conceptualizes PS facets as distinct yet interrelated components of a broader social effectiveness construct (Ferris et al., 2007).

The benevolent dimension was directly negatively correlated with task performance, meaning that the higher the level of PW on the benevolent dimension, the lower the task performance. The self-serving dimension of PW was positively associated with social astuteness and networking ability; higher levels of self-serving PW were linked to greater social astuteness and stronger networking ability. Networking ability, in turn, was positively correlated with both task and contextual performance; greater networking ability corresponded to higher levels of task and contextual performance. Overall, the structural model indicates that self-serving PW influences job performance exclusively through political skill, particularly networking ability, whereas benevolent PW exerts a direct negative effect on task performance without any indirect effects through PS dimensions. Networking ability was a statistically significant mediator of the relationship between the self-serving dimension of PW and task performance ($B = [0.02; 0.06]$, $p < 0.01$) as well as contextual performance ($B = [0.04; 0.10]$, $p < 0.01$). The self-serving dimension of PW was not directly correlated with task or contextual performance. The final model explained 4.4% of the variance in task performance and 11.1% of the variance in contextual performance.

4. Discussion

The primary objective of this study was to move beyond the traditional interactive perspective of political influence and examine the pattern of associations linking PW and JP through PS. Specifically, we tested the hypothesis that specific dimensions of PS mediate the relationship between benevolent and self-serving PW dimensions and task and contextual performance.

The results provided partial support for this general hypothesis, highlighting a differentiated pattern of relationships through which political motivation translates into organizational outcomes. Among the four dimensions of PS, only networking ability emerged as the statistically significant mediator, and exclusively for self-serving PW. Thus, hypotheses **H5** and **H6** were supported. The analysis showed that individuals driven by self-serving motives (e.g., the need for power, achievement, or status) report higher levels of effort invested in building and leveraging professional networks. This finding is consistent with the Theory of Planned Behavior (Ajzen, 2011), suggesting that specific motivation (ambition) triggers

specific behaviors (networking) necessary to achieve goals. In turn, this enhanced networking ability was positively associated with both task and contextual performance. This result is consistent with previous research findings, that suggest networking is a high-leverage competency that allows employees to access critical information, resources, and support systems required to perform tasks efficiently and support the broader organizational context (Bing et al., 2011; Pfeffer, 1993).

Contrary to expectations, social astuteness, interpersonal influence, and apparent sincerity did not mediate the relationship between PW and JP. Thus, hypotheses **H1-H4** and **H7-H16** were not supported. This pattern suggests that while self-serving motivation may be related to the deployment of skills such as social astuteness, interpersonal influence and apparent sincerity, this skills are not sufficient to account for performance differences in the specific context of the surveyed Polish enterprises unless it is accompanied by the action-oriented behavior of networking.

Taken together, the findings indicate that, in the studied sample, "who you know" and the ability to mobilize those connections (networking ability) play a more central role in performance-related associations than how you present yourself (apparent sincerity) or how influential you are (interpersonal influence). This results may reflect characteristics of Polish organizational culture, which relies heavily on informal networks and relational access to resources

A particularly interesting and counterintuitive finding was the direct negative relationship between benevolent PW and task performance. The path analysis revealed that high levels of benevolent motivation (the desire to act for the good of the organization) were associated with lower task performance. This phenomenon might be explained in such a way that employees high in benevolent PW may become more involved in organizational politics to "fix the system", advocate for others, or engage in voice behaviors. While well-intentioned, such activities consume time, energy, and emotional resources that – as a consequence – are diverted from their core duties (task performance). This may suggest that a potential cost of high political altruism is reduced individual efficiency.

Limitations and future research

Although the study offers valuable empirical insights, several limitations should be considered when interpreting the results. First, the purposive non-probability sampling strategy, while appropriate for targeting middle and senior managers, restricts statistical generalizability. Future research should expand to more diverse organizational levels and industries, thereby increasing the representativeness of the sample.

Second, the cross-sectional design prevents strong causal inferences about the direction of the observed relationships. Although the theoretical model assumes that political will is associated with job performance through political skill, reciprocal or dynamic effects cannot be

ruled out. Longitudinal or time-lagged designs would provide stronger evidence for temporal ordering and allow researchers to examine the dynamic development of workplace political behavior.

Third, the exclusive use of self-report questionnaires raises concerns about common method variance (CMV). While the measurement model showed good discriminant validity and the structural effects align with theory, CMV cannot be fully excluded because all data came from a single source at one time. Future work should integrate multi-source data, such as supervisor ratings of performance or peer assessments of political skill, to reduce potential inflation of associations.

Fourth, although reliability levels were generally satisfactory, several short-form subscales – particularly apparent sincerity and task performance – exhibited lower internal consistency. This is common in abbreviated instruments but may attenuate relationships and influence non-significant effects. Using full-length Polish scales could improve measurement precision.

Fifth, the study was conducted solely in the Polish organizational context, characterized by high power distance, relational dependence, and strong informal influence structures. These socio-cultural features may shape political behavior and managers' interpretations of political motives. Cross-cultural replications are therefore needed to assess whether the patterns of association identified in the present study generalize similarly in other environments.

Finally, the exclusive focus on middle and senior managers strengthens internal validity but limits generalization to non-managerial employees. Political will, political skill, and their links to performance may manifest differently among frontline staff or in collaborative, less hierarchical settings. Extending the model to diverse occupational groups would broaden theoretical generalizability.

These limitations point to several directions for future research. Probability-based sampling or larger, more heterogeneous samples would enhance generalizability across roles and industries. Longitudinal or time-lagged designs would clarify causal processes and better capture how political will and political skill evolve over time. Multi-source measurement strategies would reduce CMV and strengthen the validity of performance assessments. Psychometric refinement of political skill and performance measures would benefit future studies. Cross-cultural comparisons could identify boundary conditions related to power distance, informality, and leadership structures. Finally, expanding research to non-managerial roles and non-hierarchical environments may reveal alternative patterns of political motivation, political competencies, and performance outcomes, contributing to a more comprehensive understanding of political behavior at work.

Theoretical and Practical Implications

Theoretically, this study contributes to the literature by demonstrating that PW and PS do not merely interact but are linked through a structured pattern of associations. However, this pattern is not uniform; it is highly specific to the networking ability dimension. This finding strengthens emerging theoretical perspectives suggesting that political behavior should be conceptualized as a motivational–behavioral sequence at the conceptual level rather than a static interplay of traits (Ferris et al., 2019; Kapoutsis et al., 2017).

By showing that self-serving PW is associated with higher levels of a specific behavioral competency – networking ability – this study provides empirical support for process-oriented models of political behavior grounded in Social Cognitive Theory (Bandura, 2001) and the Theory of Planned Behavior (Ajzen, 2011). In this view, political action does not stem from motivation alone; instead, motivation must be linked to contextually relevant behavioral strategies.

Importantly, the results refine existing theory by revealing asymmetry among PS dimensions. Although prior research typically treats PS as a unified set of competencies (Ferris et al., 2005), our findings indicate that only networking ability emerges as the central dimension statistically accounting for the association between political motivation and job performance. This supports a dimensional rather than global conceptualization of PS and suggests that different political competencies may serve distinct functional purposes in organizational contexts.

Finally, the negative direct effect of benevolent PW on task performance contributes to theoretical debates about the potential "dark side" of prosocial motives (Bolino, Grant, 2016). This finding suggests that political benevolence – while normatively highly valued – may impose cognitive or emotional costs that detract from core performance, offering a novel theoretical insight into unintended consequences of prosocial political engagement.

The findings of this study also offer several practical implications for leadership development and human resource management. First, the results highlight the importance of networking ability as the only political skill dimension consistently associated with performance outcomes. This aligns with prior research demonstrating that networking represents the most behaviorally consequential facet of PS, enabling access to resources, information, and support that facilitate superior performance outcomes (Blickle et al., 2013; Wolff, Moser, 2009). Organizations seeking to enhance managerial effectiveness should therefore prioritize strengthening relational and networking competencies. Targeted training initiatives, cross-functional assignments, and structured opportunities for interdepartmental collaboration may support the development of these competencies (Ferris et al., 2007).

Second, the differentiated effects of benevolent and self-serving political will suggest that managers may require tailored developmental support. Individuals high in benevolent PW may benefit from interventions focused on task prioritization, role clarity, and boundary

management, as prosocial motives can sometimes diffuse attention away from core task responsibilities (Grant, 2007). Conversely, individuals high in self-serving PW may require development aimed at channeling their political motivation into prosocial and organizationally constructive behavior, consistent with evidence that political skill can buffer or redirect self-serving tendencies (Ferris et al., 2007).

Third, the study reinforces the view that PS is not an innate trait, instead it could be developed and strengthened through coaching, feedback, behavioral modelling, and experiential learning (Ferris et al., 2005; Semadar et al., 2006). This suggests that organizations can purposefully design developmental pathways that target specific political competencies –particularly those most strongly linked to performance.

Finally, by clarifying how political motivation and political competencies jointly contribute to task and contextual performance, the study provides HR practitioners and senior leaders with a more precise framework for identifying high-potential employees and shaping leadership pipelines. Political competence, especially its relational and networking components, may be considered an essential element of managerial readiness and leadership effectiveness in contemporary organizational environments (Ferris et al., 2019).

5. Conclusion

This study clarifies the pattern of relationships through which PW is associated with JP by examining the mediating role of PS dimensions. Moving beyond the traditional interactive perspective, the findings provide empirical support for a process-oriented model in which political motivation is systematically linked to behavioral competencies that are relevant for work outcomes. The results indicate that this mechanism is not the same across PS components. Rather, networking ability emerged as the exclusive mediator linking self-serving PW with both task and contextual performance. This highlights the unique role of networking in gaining access to resources, information, and support necessary for effective performance, which is consistent with previous research, emphasizing its key importance in political competence (Blickle et al., 2009; Ferris et al., 2007; Wolff, Moser, 2009).

At the same time, the study revealed no mediating effects for social astuteness, interpersonal influence, or apparent sincerity, suggesting that these competencies – while theoretically important – may not be directly associated with performance within the managerial and cultural context examined. Moreover, the unexpected negative direct relationship between benevolent political will and task performance provides a new insight: prosocial political motives, although well-intentioned, may redirect effort and attention away from core responsibilities. This finding enriches existing theory by illustrating the potential performance costs of politically motivated prosocial engagement (Grant, 2007).

Taken together, the results contribute to political influence research by demonstrating that PW and PS are related through a structured and domain-specific pattern of associations primarily centered on networking behavior, rather than a uniform causal chain. These findings refine conceptualizations of political behavior at work and offer a more differentiated understanding of how motivational and behavioral political resources jointly shape managerial effectiveness.

Despite its contributions, the study has the limitations, including the use of purposive sampling, a cross-sectional and single-source design, lower reliability of selected short subscales, and the specificity of the Polish organizational context. These limitations highlight the need for future research employing longitudinal designs, multi-source data, culturally diverse samples, and psychometrically enhanced instruments.

Overall, this study advances both theory and practice by identifying networking ability as the behavioral dimension most strongly associated with the link between political motivation and performance outcomes, and by demonstrating that different forms of PW have distinct implications for managerial effectiveness. These insights may guide leadership development efforts by helping organizations more effectively cultivate political competencies that support task and contextual performance.

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References

1. Ajzen, I. (2011). The theory of planned behaviour: Reactions and reflections. *Psychology & Health*, *26*(9), 1113-1127. https://doi.org/10.1080/08870446.2011.613995
2. Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology*, *52*, 1-26. https://doi.org/10.1146/annurev.psych.52.1.1
3. Bing, M.N., Davison, H.K., Minor, I., Novicevic, M.M., Frink, D.D. (2011). The prediction of task and contextual performance by political skill: A meta-analysis and moderator test. *Journal of Vocational Behavior*, *79*(2), 563-577. https://doi.org/10.1016/j.jvb.2011.02.006
4. Blass, F.R., Ferris, G.R. (2007). Leader reputation, the role of mentoring, political skill, contextual learning, and adaptation. *Human Resource Management*, *46*(1), 5-19. Scopus. https://doi.org/10.1002/hrm.20142

5. Blickle, G., Kane-Frieder, R.E., Oerder, K., Wihler, A., von Below, A., Schütte, N., Matanovic, A., Mudlagk, D., Kokudeva, T., Ferris, G.R. (2013). Leader Behaviors as Mediators of the Leader Characteristics—Follower Satisfaction Relationship. *Group & Organization Management*, *38*(5), 601-629. https://doi.org/10.1177/1059601113503183
6. Blickle, G., Witzki, A., Schneider, P.B. (2009). Self-initiated mentoring and career success: A predictive field study. *Journal of Vocational Behavior*, *74*(1), 94-101. https://doi.org/10.1016/j.jvb.2008.10.008
7. Bolino, M.C., Grant, A.M. (2016). The bright side of being prosocial at work, and the dark side, too: A review and agenda for research on other-oriented motives, behavior, and impact in organizations. *The Academy of Management Annals*, *10*(1), 599-670. https://doi.org/10.1080/19416520.2016.1153260
8. Borman, W., Motowidlo, S. (1993). Expanding the Criterion Domain to Include Elements of Contextual Performance. *Personnel Selection in Organizations*, 71-98.
9. Borman, W., Motowidlo, S. (1997). Task Performance and Contextual Performance: The Meaning for Personnel Selection Research. *Human Performance*, *10*(2), 99-109. https://doi.org/10.1207/s15327043hup1002_3
10. DeRUE, D.S., Ashford, S.J. (2010). Who Will Lead and Who Will Follow? A Social Process of Leadership Identity Construction in Organizations. *The Academy of Management Review*, *35*(4), 627-647.
11. Doldor, E., Anderson, D., Vinnicombe, S. (2013). Refining the Concept of Political Will: A Gender Perspective. *British Journal of Management*, *24*, 414-427.
12. Ferris, G.R., Ellen, B.P.I., McAllister, C.P., Maher, L.P. (2019). Reorganizing Organizational Politics Research: A Review of the Literature and Identification of Future Research Directions. *Annual Review of Organizational Psychology and Organizational Behavior*, *6*(1), 299-323. https://doi.org/10.1146/annurev-orgpsych-012218-015221
13. Ferris, G.R., Perrewé, P., Davidson, S.L. (2006). Social and political skill. *Personal Excellence*, *11*.
14. Ferris, G.R., Perrewé, P.L., Anthony, W.P., Gilmore, D.C. (2000). Political skill at work. *Organizational Dynamics*, *28*(4), 25-37. https://doi.org/10.1016/S0090-2616(00)00007-3
15. Ferris, G.R., Treadway, D.C., Kolodinsky, R.W., Hochwarter, W.A., Kacmar, C.J., Douglas, C., Frink, D.D. (2005). Development and Validation of the Political Skill Inventory. *Journal of Management*, *31*(1), 126-152. https://doi.org/10.1177/0149206304271386
16. Ferris, G.R., Treadway, D.C., Perrewé, P.L., Brouer, R.L., Douglas, C., Lux, S. (2007). Political Skill in Organizations. *Journal of Management*, *33*(3), 290-320. https://doi.org/10.1177/0149206307300813
17. Grant, A.M. (2007). Relational Job Design and the Motivation to Make a Prosocial Difference. *Academy of Management Review*, *32*(2), 393-417. https://doi.org/10.5465/amr.2007.24351328

18. Grant, A.M., Ashford, S.J. (2008). The dynamics of proactivity at work. *Research in Organizational Behavior*, *28*, 3-34. https://doi.org/10.1016/j.riob.2008.04.002
19. Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E. (2019). *Multivariate data analysis* (Eighth edition). Cengage.
20. Kanfer, R. (2012). Work motivation: Theory, practice, and future directions. In: *The Oxford handbook of organizational psychology, Vol. 1* (pp. 455-495). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199928309.001.0001
21. Kapoutsis, I., Papalexandris, A., Treadway, D.C., Bentley, J. (2017). Measuring Political Will in Organizations: Theoretical Construct Development and Empirical Validation. *Journal of Management*, *43*(7), 2252-2280. https://doi.org/10.1177/0149206314566460
22. Kline, R.B. (2016). *Principles and practice of structural equation modeling, 4th ed* (pp. xvii, 534). The Guilford Press.
23. Koopmans, L., Bernaards, C.M., Hildebrandt, V.H., de Vet, H.C.W., van der Beek, A.J. (2014). Construct Validity of the Individual Work Performance Questionnaire. *Journal of Occupational & Environmental Medicine*, *56*(3), 331-337. https://doi.org/10.1097/JOM.0000000000000113
24. Latham, G.P., Pinder, C.C. (2005). Work Motivation Theory and Research at the Dawn of the Twenty-First Century. *Annual Review of Psychology*, *56*, 485-516. https://doi.org/10.1146/annurev.psych.55.090902.142105
25. Luthfiyana, D.A., Widowati, R., Surwanti, A. (2024). Mapping Trends on Employee Performance and Work Environment: A Bibliometric Analysis. *Jurnal Syntax Transformation*, *5*(04), 1-13. https://doi.org/10.46799/jst.v5i04.950
26. Maher, L.P., Coleman Gallagher, V., Rossi, A.M., Ferris, G.R., Perrewé, P.L. (2018). Political skill and will as predictors of impression management frequency and style: A three-study investigation. *Journal of Vocational Behavior*, *107*, 276-294.
27. Mintzberg, H. (1983). *Power In and Around Organizations, Vol. 5*. Prentice-Hall. https://doi.org/10.1177/017084068400500419
28. Mintzberg, H. (1985). The Organization as Political Arena. *Journal of Management Studies*, *22*(2), 133-154. https://doi.org/10.1111/j.1467-6486.1985.tb00069.x
29. Mitchell, T.R., Daniels, D. (2003). Motivation. In: *Handbook of psychology: Industrial and organizational psychology, Vol. 12* (pp. 225-254). John Wiley & Sons, Inc. https://doi.org/10.1002/0471264385.wei1210
30. Motowidlo, S.J., Van Scotter, J.R. (1994). Evidence that task performance should be distinguished from contextual performance. *Journal of Applied Psychology*, *79*(4), 475-480. https://doi.org/10.1037/0021-9010.79.4.475
31. Pfeffer, J. (1993). *Managing With Power: Politics and Influence in Organizations* (Reprint edition). Harvard Business Review Press.

32. Semadar, A., Robins, C., Ferris, G.R. (2006). Comparing the validity of multiple social effectiveness constructs in the prediction of managerial job performance. *Journal of Organizational Behavior*, *27*(4), 443-461. Scopus. https://doi.org/10.1002/job.385
33. Tangen, S. (2005). Demystifying productivity and performance. *International Journal of Productivity and Performance Management*, *54*(1), 34-46. https://doi.org/10.1108/17410400510571437
34. Treadway, D.C. (2012). Political will in organizations. In: G.R. Ferris, D.C. Treadway (Eds.), *Politics in Organizations: Theory and Research Considerations* (pp. 529-554). Routledge/Taylor & Francis Group; Scopus. https://doi.org/10.4324/9780203197424
35. Treadway, D.C., Ferris, G.R., Duke, A.B., Adams, G.L., Thatcher, J.B. (2007). The moderating role of subordinate political skill on supervisors' impressions of subordinate ingratiation and ratings of subordinate interpersonal facilitation. *The Journal of Applied Psychology*, *92*(3), 848-855. https://doi.org/10.1037/0021-9010.92.3.848
36. Treadway, D.C., Hochwarter, W.A., Kacmar, C.J., Ferris, G.R. (2005). Political will, political skill, and political behavior. *Journal of Organizational Behavior*, *26*(3), 229-245. https://doi.org/10.1002/job.310
37. Viswesvaran, C., Ones, D.S. (2000). Perspectives on Models of Job Performance. *International Journal of Selection and Assessment*, *8*(4), 216-226. https://doi.org/10.1111/1468-2389.00151
38. Wolff, H.-G., Moser, K. (2009). Effects of networking on career success: A longitudinal study. *Journal of Applied Psychology*, *94*(1), 196-206. https://doi.org/10.1037/a0013350
39. Yukl, G. (2008). How leaders influence organizational effectiveness. *The Leadership Quarterly*, *19*(6), 708-722. https://doi.org/10.1016/j.leaqua.2008.09.008

Appendix

Table 4.
List of specific hypotheses (H1-H16) required to fully test a general hypothesis

Hypothesis No.	Relationship Tested (IV → Mediator → DV)	Description
H1	PW-S → PS-SA → JP-TP	Social astuteness mediates the relationship between self-serving political will (IV) and task performance (DV).
H2	PW-S → PS-SA → JP-CP	Social astuteness mediates the relationship between self-serving political will (IV) and contextual performance (DV).
H3	PW-S → PS-II → JP-TP	Interpersonal influence mediates the relationship between self-serving political will (IV) and task performance (DV).
H4	PW-S → PS-II → JP-CP	Interpersonal influence mediates the relationship between self-serving political will (IV) and contextual performance (DV).
H5	PW-S → PS-NA → JP-TP	Networking ability mediates the relationship between self-serving political will (IV) and task performance (DV).
H6	PW-S → PS-NA → JP-CP	Networking ability mediates the relationship between self-serving political will (IV) and contextual performance (DV).
H7	PW-S → PS-AS → JP-TP	Apparent sincerity mediates the relationship between self-serving political will (IV) and task performance (DV).
H8	PW-S → PS-AS → JP-CP	Apparent sincerity mediates the relationship between self-serving political will (IV) and contextual performance (DV).
H9	PW- B → PS-SA → JP-TP	Social astuteness mediates the relationship between benevolent political will (IV) and task performance (DV).
H10	PW-B → PS-SA → JP-CP	Social astuteness mediates the relationship between benevolent political will (IV) and contextual performance (DV).
H11	PW-B → PS-II → JP-TP	Interpersonal influence mediates the relationship between benevolent political will (IV) and task performance (DV).
H12	PW-B → PS-II → JP-CP	Interpersonal influence mediates the relationship between benevolent political will (IV) and contextual performance (DV).
H13	PW-B → PS-NA → JP-TP	Networking ability mediates the relationship between benevolent political will (IV) and task performance (DV).
H14	PW-B → PS-NA → JP-CP	Networking ability mediates the relationship between benevolent political will (IV) and contextual performance (DV).
H15	PW-B → PS-AS → JP-TP	Apparent sincerity mediates the relationship between benevolent political will (IV) and task performance (DV).
H16	PW-B → PS-AS → JP-CP	Apparent sincerity mediates the relationship between benevolent political will (IV) and contextual performance (DV).

Note. Independent Variable (IV) - Political Will (PW): Benevolent (PW-B) and Self-Serving (PW-S); Mediator - Political Skill (PS): Social Astuteness (PS-SA), Interpersonal Influence (PS-II), Networking Ability (PS-NA), Apparent Sincerity (PS-AS); Dependent Variable (DV) - Job Performance (JP): Task Performance (JP-TP) and Contextual Performance (JP-CP).

Source: own study.

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IN SEARCH OF A HIDDEN CLINICAL RESEARCH PROJECT MANAGER – AN EXAMPLE OF NON-COMMERCIAL ORGANIZATIONS IN POLAND

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Purpose: The objective of this study is to examine which roles are responsible for managing non-commercial clinical trials. A further objective is to assess the adequacy of the current recommendations concerning project management at the model Clinical Research Support Centre in Poland.
Design/methodology/approach: The theoretical scope of the study encompasses issues related to methodical project management and key roles in the management of non-commercial clinical trials. The research method employed is desktop research and in-depth analysis of scientific sources and current standards set by industry organisations in the healthcare sector.
Findings: The findings demonstrate the existence of numerous analogous terms that describe the roles of a non-commercial clinical trial manager, including but not limited to clinical trial coordinator, clinical trial associate, principal investigator, clinical trial manager and research project manager. It has been identified a very general overview of current recommendations and guidelines regarding the requirements for managers of non-commercial clinical trials, as well as imprecisely formulated job descriptions. Moreover, the result of the work is a conclusion that will act as a recommendation for implementing changes in the model Clinical Research Support Centre in Poland.
Research limitations/implications: The present study was grounded in extant literature on the subject, in addition to official documentation (legal regulations, guidelines, recommendations, good practices). Market information, in the form of job offers for management positions in clinical research projects, was not a factor in the study.
Practical implications: The present study offers a valuable resource for decision-makers and legislators by proposing a methodical approach to clinical trial management and enhancing work efficiency through the focus on qualified management staff.
Originality/value: This work addresses a significant gap in the literature by providing a systematic review of the roles of clinical trial managers. The paper presents a comparative analysis of the responsibilities of a non-commercial clinical trial manager in the context of methodological guidelines, including PMBOK, PRINCE2, AgilePM, and Scrum.
Keywords: project management, project manager, non-commercial, clinical research, clinical trials.
Category of the paper: research paper.

1. Introduction

The modern pharmaceutical market is developing dynamically due to the ageing population, its increasing wealth, and the emergence of new diseases (e.g. those caused by the SARS-CoV-2 virus). The most important factors in this development are the growth of innovative activities and the production, commercialisation and sale of increasingly new medicinal products whose effectiveness in achieving the desired therapeutic effects is confirmed by research, development and clinical trials. Recent publications highlight their role in generating high-quality evidence for health policy and medical practice (Ellis et al., 2025; Wen et al., 2025; Akinbolade et al., 2025).

A clinical trial is a prospective scientific study in which participants are assigned to one or more interventions (e.g. drugs, procedures, devices, diagnostic procedures or behavioural interventions) to assess their impact on health outcomes (WHO, 2025). Clinical trials can be small, preliminary studies or randomised controlled trials designed to evaluate safety and efficacy. They are carefully designed, reviewed and approved prior to commencement and involve the testing of new therapies, devices or preventive procedures.

The ICH-GCP guidelines (latest version E6(R3), 2025) and EU regulations (Regulation EU 536/2014) set out the requirements for conducting clinical trials, the priority of participant safety, and the mechanisms for approval and supervision.

A non-commercial clinical trial, otherwise referred to as an investigator-initiated trial (IIT), is a trial that has been designed and initiated by a researcher (university, research institute, scientific society, or public entity) in response to a scientific question of clinical or social importance, rather than primarily for commercial product development. Typically, these initiatives are sponsored by non-profit organisations or public entities, with funding frequently derived from public sources, grants, or non-profit organisations (Del Álamo et al., 2024).

In the context of EU legal and operational documents, this concept is recognised and distinguished from industry-led research; it does not automatically imply less rigour, with regulatory requirements proportionate to risk still applying (European Parliament, 2014).

The term "clinical trials" is characterised by specific features, including but not limited to the following: a clearly defined objective, a defined timeframe, a specified budget, a defined scope, a defined group of stakeholders, and a defined set of risks. In practice, project management methodologies and techniques, such as planning, scheduling, risk management, CPM/PERT, agile/hybrid, and digital tools, are increasingly being applied to clinical trials (Gumber et al., 2024; Peralta, Sánchez-Santiago, 2024).

The following observations have been made (Wang et al., 2025):

– Clinical trials are characterised as project-based, requiring meticulous planning encompassing a protocol, schedule, and budget. These trials are initiated with a defined objective, commonly referred to as a research question or a specific clinical outcome,

and are subject to various constraints in terms of resources, including staff, budget, and equipment. The temporal aspect of clinical trials, characterised by the initiation, progression, and conclusion of specific projects, is another salient feature. Consequently, clinical trials align with the conventional characteristics of a project, encompassing the necessity for thorough planning, the establishment of a defined objective, and the allocation of resources in accordance with the stipulated budget and equipment.

- Project management tools and techniques are utilised in the management of clinical research projects, encompassing domains such as process organisation, role allocation, administrative process optimisation, regulatory compliance oversight, and the coordination of multiple studies concurrently.

It is evident that clinical trials, encompassing both commercial and non-commercial domains, are characterised by the hallmarks of a project (Doganov, Yanev, 2006; Farrell, Kenyon, Shakur, 2010). Consequently, the effective implementation of these trials necessitates the integration of professional project management principles and tools. The hallmarks of such initiatives include a clearly delineated objective, a defined temporal framework, specified resources, a team with clearly defined roles, and the necessity for continuous coordination of activities and risk management. Consequently, a project-based approach is imperative to ensure structure, transparency, and predictability of activities. The role of the project manager becomes of particular significance in this context. The project manager is responsible for planning, scheduling, monitoring progress, managing an interdisciplinary team, and identifying and controlling risks that may affect the safety of participants and the quality of data. The extent to which the project manager is adequately prepared and demonstrates competence has been shown to have a significant impact on the success of a clinical trial, with the result that it is more likely to be conducted in an efficient, ethical, and regulatory-compliant manner.

Furthermore, recent studies highlight that the Research Project Manager plays a pivotal role in all phases of the collaborative research project, from the ideation stage through to transformation and execution, post-execution and project closure (Barbosa et al., 2025).

Other research findings at the intersection of health sciences and management sciences indicate that it is worthwhile to introduce managerial and strategic (management) roles into health-related projects (Carman, Pendergrass, 2025).

The objective of the present study is to make a comparison between the roles of a project manager as defined in a selection of project management methodologies (PRINCE2, AgilePM, PMBOK Guide) and the roles and positions found in non-commercial clinical research projects. The work is descriptive and comparative in nature and is based on an analysis of extant sources, including industry documents and publicly available materials.

A qualitative approach, underpinned by document analysis (desk research), was employed. This method facilitates the systematic collection and interpretation of information characterising both the formal requirements of selected methodologies and the practical roles

found in the clinical research environment. The paper discusses the case of a model Clinical Research Support Center developed by the Medical Research Agency in Poland.

2. Literature review

The following literature review is divided into two complementary areas. The first of these concerns managerial roles as defined in selected leading international project management standards and methodologies. The second area of focus in this text is on the analysis of the role of the project manager in clinical research projects, with particular emphasis on the specific nature of research and regulated projects.

2.1. Managerial roles in selected leading project management standards

Internationally recognised project management methodologies, including the PMBOK Guide, PRINCE2, and agile methodologies, establish consistent standards for project execution across diverse sectors. The definition of key processes, knowledge areas, and project artefacts is fundamental to ensuring transparency, control, and repeatability of activities (Liebert, 2017; Brzozowski, 2020).

Furthermore, they provide a robust foundation for precisely defining the role of a project manager. This is achieved by describing their responsibilities in terms of planning, communication, stakeholder management, risk management, quality management, budget management, and team management. Consequently, the role of the project manager is not only clearly delineated, but also comparable across organisations and industries, thereby promoting professionalisation and enhancing project effectiveness (Jamali, Oveisi, 2016; Zubon, Taher, 2022). This section of the study examines a selection of leading project management methodologies and their approach to the role of the project manager. The primary focus of this analysis is on competency requirements and responsibilities.

The project manager's competencies in planning, organising, allocating resources, using PM tools, and dealing with interpersonal and contextual factors are identified as "key elements" in determining the success of a project. This gives the project manager a pivotal role, connecting the project's objectives with its daily execution. The project manager is entrusted with the responsibility of establishing structure, maintaining order, facilitating communication, and adapting to evolving circumstances (Gasemagha, Kowang, 2021). The primary functions of a project manager are presented in Table 1.

Harold Kerzner (2022), a leading authority in the field of project management, defines a project manager as a person who is responsible for planning, organising, directing, and controlling project resources in order to achieve project objectives in accordance with the agreed scope, time, budget, and quality. In Kerzner's classic approach, a project manager is:

- the single point of responsibility for project implementation,
- the person coordinating the activities of an interdisciplinary team,
- the negotiator in contacts with stakeholders and management,
- the leader responsible for communication, motivation, and conflict resolution,
- a risk and change manager,
- a person supervising the integration of all project processes.

Table 1.
Primary functions of a project manager

Planning project activities The project manager bears responsibility for the planning of all project activities, including the schedule, task distribution, and resource allocation. In addition, the project manager assesses team members' competencies and assigns tasks appropriately.	**Project team management** The ability to manage people effectively is pivotal. The manager must assess the skills of team members, divide roles and tasks, motivate, coordinate activities, and monitor the team's work.
Application of project management tools and techniques It is imperative to emphasise that the adept utilisation of PM techniques and tools (e.g., methodologies, planning, control, and monitoring techniques) constitutes a pivotal competency that is instrumental in the success of a project.	**Managing the political and cultural context of a project** In projects – especially those of an organisationally complex or intercultural nature – the manager must demonstrate competence in dealing with issues of organisational politics, stakeholder relations, and cultural differences. This is also a crucial element of project management.

Source: Own elaboration based on Gasemagha, Kowang, 2021.

Kerzner (2022) emphasizes that a project manager must combine technical, organizational, and interpersonal skills, and that their role is to create an environment that enables the project's goals to be achieved — regardless of the organizational or technological complexity of the undertaking.

In accordance with the fundamental principles of management, during the implementation phase of a project, the project manager is required to (Karbownik, 2022):

- maintain intensive communication with the client, senior management, and resource providers,
- monitor and control project work,
- deepen team members' knowledge of the project,
- identify and solve problems,
- delegating tasks,
- involving the team in the decision-making process.

The nature of a project manager's tasks and role is contingent on the approach to project management. In the traditional approach to project management, the project manager's role is to build, motivate and lead the team to achieve goals. This includes planning, budgeting, resource allocation, supervising and managing conflicts. The agile approach uses self-disciplined and self-organising teams of highly competent members with certain personality

traits. Agile project management methods, such as Scrum, do not use a project manager (Karbownik, 2022; Romański, 2025).

The following Table 2. sets out a comparison of the definitions and key responsibilities of a project manager in a selection of project management methodologies, including both traditional approaches (PMBOK, PRINCE2, IPMA) and agile approaches (AgilePM, Scrum). This comparison facilitates an understanding of the differences in assigned roles, tasks and competencies in different project contexts.

Table 2.
A comparison of selected definitions of the role of a project manager

Source	Definition of a project manager	Key highlights/elements of the role
Harold Kerzner (2022)	A project manager is a person responsible for planning, organizing, directing, and controlling resources in order to achieve project objectives in accordance with the scope, schedule, budget, and quality.	– single point of responsibility, – integration of activities and processes, – team, communication, and stakeholder management, – risk and change management, – combining technical, organizational, and interpersonal skills.
PMBOK® Guide 7th ed. (PMI)	The project manager is a person appointed to lead the project team in order to achieve the project's objectives and generate value for stakeholders.	– responsibility for the project team, – ensuring the implementation of PM processes and practices, – leadership, communication, facilitation of cooperation, – supervision of scope, schedule, costs, risks, – focus on value and stakeholders.
PRINCE2®	The project manager is responsible for the day-to-day management of the project and for delivering project products within the tolerances set by the management (Project Board).	– product-based planning, – day-to-day project management, – reporting to the Project Board, – risk, quality, and configuration management, – maintaining documentation and stage control.
IPMA ICB 4.0	A project manager is a professional who applies technical, behavioral, and contextual competencies to achieve project goals in a specific organizational environment.	– broad competency model (29 elements), – emphasis on soft skills: leadership, communication, self-awareness, motivation, – context and stakeholder management, – adaptation of methods to the project environment.
AgilePM (DSDM)	The Project Manager is responsible for planning, monitoring, and coordinating the project, ensuring compliance with business objectives while maintaining Agile flexibility.	– iteration planning, – communication, – risk management, – collaboration with the Agile Team and Business Sponsor, – supervision of the delivery process.
Scrum	Scrum does not provide for the role of project manager; responsibilities are divided between the Scrum Master, Product Owner, and Development Team.	– Scrum Master: facilitation and removal of obstacles, – Product Owner: backlog management Team: product delivery

Source: Own elaboration based on: DSDM Consortium, 2014; International Project Management Association, 2015; AXELOS, 2017; Schwaber, Sutherland, 2020; Project Management Institute, 2021; Kerzner, 2023.

In summary, Kerzner emphasises integration, control, and the role of the manager as the "central point of responsibility". The PMBOK methodology is predicated on the principles of value creation and effective team leadership, with a focus on best practices and a flexible

approach. The PRINCE2 framework places significant emphasis on the role of the manager as the operational leader of the project, with responsibility to report to the Project Board and deliver products within prescribed tolerances. The IPMA model is distinguished by a broad competency framework encompassing both the hard and soft aspects of management.

2.2. The role of project manager in clinical research projects

The Core Competency Framework, published by the Joint Task Force for Clinical Trial Competency (which is responsible for updating the scientific and methodological basis for conducting clinical trials), clearly recommends the need to develop the project management skills of people working in this field (Sonstein et al., 2022). The planning and management of clinical trials, including non-commercial clinical trials (NCTs), is a complex process that typically demands a range of competencies. Recent studies have highlighted a significant shortage of adequately trained management staff at research centres conducting such trials (Mitchell et al., 2022).

It has been posited that clinical trials meet the requisite criteria to be classified as projects. The specific characteristics of clinical research projects include, above all: the establishment of objectives at the planning stage, the identification of the resources necessary to achieve the planned objectives, the proper planning of activities adequate to achieve these objectives, the continuous monitoring of work progress and results based on clear performance criteria, the ongoing evaluation, the project closure if the objectives are achieved or cannot be achieved, the implementation of activities in accordance with a pre-prepared clinical trial protocol, and the use of this document as a basis for monitoring project progress (Goodarzynejad, Babamahmoodi, 2015).

In accordance with the universal PMI methodology, the project life cycle is comprised of five phases (initiation, definition and planning, execution, performance monitoring, and closure). In the context of healthcare projects conducted within the pharmaceutical market and clinical trials, analogous stages can also be applied (Schwalbe, Furlong, 2017).

When discussing the organisation of a non-commercial clinical trial in terms of attributes, the following example can be used. Prior to the initiation of a clinical trial project, the principal investigator and the sponsor of the trial are obliged to establish a small working group. This working group should consist of investigators, a statistician, and an individual with experience in clinical trial methodology. The steering committee is responsible for all significant decisions pertaining to the initiation, management, and cessation of the trial. The sponsor is the entity that assumes responsibility for the trial, which may also be the funding organisation. The coordination centre and data centre are responsible for the day-to-day tasks of conducting the trial, including randomisation, data collection and circulation, review of ongoing documentation, and organisation of monitoring visits to trial sites. The endpoint validation committee is responsible for verifying the documentation prepared by the coordination centre regarding the study endpoints. The safety assessment committee is

responsible for liaising with the steering committee and medical agencies (e.g., EMA or FDA), providing information regarding any irregularities in the non-commercial clinical trial project (Boissel, 2004).

Recent studies (Barbosa et al., 2025) have highlighted a paucity of clarity and consensus with regard to the role of research project managers in collaborative research projects, as well as an absence of a widely accepted definition of what the position of research project manager should and should not entail.

As Ernø-Kjølhede (1999) has demonstrated, the function of research project manager is situated at the intersection of Research Management and Administration and Project Management.

Research Project Manager typically exerts minimal formal authority over project members/participants (Ernø-Kjølhede, 2000). In contradistinction to the prevailing paradigm of general project management, in which the Project Manager (PM) typically reports directly to the governing body or funder, the Research Project Manager (RPM) frequently collaborates with the Project Manager/Scientific Manager or Principal Investigator (PI). This PI is typically a visionary who, prior to the initiation of the project, establishes a project consortium comprising organisations collaborating on a designated joint research project and secures funding, often with the support of the Research Manager and Administrator. It should be noted that, although the same individual may sometimes fulfil both the roles of Principal Investigator and Research Project Manager, these roles are distinct and interrelated, thus forming a dynamic leadership duo. The RPM is concerned with management principles, regulations, and contract details, ensuring that the project fulfils its obligations to the funder, while the PI is responsible for scientific direction and decision-making. The success of the project is contingent on the effective fulfilment of both roles, with internal communication being of paramount importance. The RPM is charged with the facilitation of this process (Ernø-Kjølhede, 1999).

Research Project Managers constitute a discrete yet interconnected component of the research administration framework. The role of the aforementioned parties encompasses several fundamental elements, which are outlined below (Barbosa et al., 2025):

- The implementation and support of projects that span multiple phases of the life cycle is a responsibility that falls upon these individuals.
- They are assigned to specific projects on a permanent basis, playing a proactive role in them. They respond to the needs of the principal investigator (PI), but also initiate activities independently, using their knowledge.
- These individuals are not typically academic staff members. In instances where they assume dual roles, they undertake project activities in a manner that is distinct from their academic responsibilities.
- The role description of the project manager corresponds to the definitions of project management and is formally recognised (e.g., by the funding institution or central university units).

- It is imperative that the requirements of the grantors and institutions are reconciled with the needs of the PI, the consortium, and the project objectives, while adhering to the established rules, procedures, and regulations.
- Their approach is characterised by a holistic perspective, encompassing multiple areas of expertise and collaboration with diverse project partners.

During the implementation phase of a research (clinical trial) project, the research project manager is responsible for tasks such as: Project Phase Planning, Funding entity knowledge, Contract Management, Consortium Management, Budget Management, Risk Management, Progress Tracking, Reporting, Quality Management, Evaluation and Assessment, Change Management, Impact Assessment, Management Communication within the Project. In addition, the research project manager may also have additional responsibilities: Data Management, Compliance and Ethics, IP Management and Exploitation, Communications and Dissemination, Stakeholder Management, Procurement Management, Resource Management, Gender dimension (Barbosa et al., 2025). The authors cited here claim that the successful coordination of a collaborative research project necessitates a proficient Research Project Manager, a dedicated and enthusiastic Principal Investigator, along with a group of collaborating partners, and constant dialogue among the professionals involved in the project life cycle support.

The sponsor of a non-commercial clinical trial may delegate its project management responsibilities to third-party organizations. Clinical Trial Units (CTUs; also called academic Clinical Research Organizations) are non-profit organisations that support academic investigators and sponsors. They raise awareness of national challenges and create a more favourable environment for clinical research. CTUs are usually linked to university medical schools, health care units or university hospitals. Their main function is to support research-active clinicians in planning and executing patient-oriented research projects and advancing the quality of clinical research (Batuca, Maia, 2024).

Trial management procedures/responsibilities that are common across all trials are usually defined in the standard operating procedures (SOPs). For example, the Standard Operating Procedure (SOP) developed by the Cambridge Clinical Trials Unit (2024) concerning the organisation and launch of Clinical Trial of Investigational Medicinal Product describes the step-by-step process of starting up/setting up a CTIMP trial, i.e., all activities from the moment funding is granted to the activation of the first (lead) centre. This SOP delineates the composition of the clinical trial project team as follows: The Chief Investigator, Principal Investigator, Clinical Trials Coordinator, Data Manager and Research Nurse at the coordinating site are to be identified and delegated by the CI and/or Sponsor. The sponsor is defined as a person, company, institution or organisation that assumes responsibility for the initiation, management and/or financing of a clinical trial. This example demonstrates that clinical trial projects (including non-commercial ones) do not explicitly provide for the role of a project manager, but often only for a trial coordinator.

The management of diverse multidisciplinary teams to run clinical trials is challenging. An organisational structure must be defined, with three committees typically overseeing trials: Trial Management Board, Trial Steering Committee and Data and Safety Monitoring Board (DSMB). The Trial Management Board's role is to lead and oversee clinical trials, focusing on practical execution, resource allocation, problem-solving and handling administrative components. Responsibilities include (Batuca, Maia, 2024):

- liaising between sponsors and research teams,
- hiring and training staff,
- ensuring awareness of roles and responsibilities,
- coordinating research teams,
- tracking finances,
- ensuring regulatory compliance, subject safety and data quality,
- tracking subject recruitment and retention,
- Adverse Event (AE) documentation and reporting,
- oversight of drug storage and use,
- data management – data collection, Electronic Data Capture (EDC),
- renewing financial and regulatory approvals.

The group includes the Chief Investigator, the Trial Manager, the Statistician, the Database Manager, the Database Programmer, Pharmacist, Health Economist and one or two site Principal Investigators.

The list of tasks of a clinical research project manager may also include (Nagy, 2024):

- plan creation for tasks, including deliverables, measures, timescales, strategy and tactics,
- establishment of responsibilities, objectives, accountabilities and measures by agreement and delegation,
- setting of standards, quality, time and reporting parameters,
- controlling and maintenance of activities against parameters,
- maintenance of overall performance against the plan,
- reporting on progress towards the group's aims,
- reviewing, re-assessing and adjusting plans, methods and targets as necessary,
- liaising with stakeholders, including team members, project specialists, the project coordinator and the project leader.

In addition, the (non-commercial clinical trial) project manager's duties are (Batuca, Maia, 2024):

- define all activities required to produce project deliverables,
- define the activities' order or sequence and relationship,
- establish the required resources,
- estimate the duration of activities.

In practice, there are often two roles: project manager and project coordinator (research). A project manager is responsible for the success of a project. A project coordinator supports the project manager and ensures the project runs smoothly. This includes scheduling meetings, maintaining documentation and coordinating activities. The project coordinator ensures everyone is on the same page and communication flows smoothly (Nagy, 2024). Therefore, the coordinator's role is less significant than that of the project manager, as they are not responsible for making decisions about the course of the project. The tasks and responsibilities of the project leader, manager and coordinator complement each other. Ideally, these roles should be taken on by different stakeholders, as assuming all of them can lead to confusion, communication difficulties, overload and burnout. However, these roles can be centralised in the hands of one person (Nagy, 2024).

In the pharmaceutical industry, the role of a project manager is defined more broadly, but still in line with the general definition in management science. As indicated by Ahmed (2022) the project manager plays an important role in the pharmaceutical industry, not only by strategising the organisation's marketing strategy for products, but also by implementing it. From pre-launch and launch campaigning to post-launch marketing, every aspect is handled thoroughly by the project manager. Every product in the pharmaceutical industry goes through the typical four phases of the life cycle: introduction, growth, saturation and decline, or the stable phase. Project management and sales are responsible for an organization's revenue targets. In the pharmaceutical industry, a project manager's responsibilities typically encompass (Ahmed, 2022):

- defining the project,
- selecting the team and overseeing organization,
- planning, scheduling and monitoring progress,
- handling problems and making decisions using prototypes,
- obtaining senior management approval and overseeing operations,
- managing proactive changes in real time.

Regulation (EU) No 536/2014 and ICH E6(R3) establish the fundamental legal and quality framework for conducting clinical trials in the European Union and internationally, but both acts differ significantly from typical project management documents. EU Regulation No 536/2014 (Official Journal of the European Union, 2014) is a legal act that regulates the formal aspects of clinical trials on medicinal products. In particular, it establishes the rules for notification, defines the key terms ('sponsor', 'protocol', 'clinical trial'), and outlines the obligations of state authorities, the procedures for authorisation, and the requirements for the protection of trial participants. Throughout the text of the Regulation, there are no references to the concept of 'project' in the management sense, and the term 'management' appears only in the context of the obligations of the clinical trial sponsor and its responsibility for initiating, financing, organising and supervising the trial. This corresponds to the practice of supervising

the research process, rather than the general principles of conducting scientific research or investment projects.

The ICH E6(R3) GCP guideline (European Medicines Agency, 2025), a document prepared by the International Conference on Harmonisation, provides detailed quality principles for the design, conduct, monitoring, analysis and reporting of clinical trials. The purpose of this guideline is to ensure the protection of the rights, safety and well-being of participants, as well as the reliability of data. While the document organises processes and assigns responsibilities (in particular to the sponsor and investigators), it does not utilise the term 'project' as a conceptual category specific to project management, nor does it define project structures or phases. In the context of GCP, management explicitly refers to the implementation of a quality management system, the oversight of risk, and the assignment of responsibilities within a clinical trial. These functions are necessary for the compliant conduct of a trial; however, they do not constitute a described project management methodology.

Consequently, although clinical trials meet many of the criteria for a project in practice (unique objective, limited duration, complex stakeholder structure and high risk), in the regulatory documents analysed, they are conceptualised primarily as a process regulated and controlled in terms of compliance, safety and data quality, rather than as a project in the management sense. The existence of this conceptual gap serves to underscore the necessity for the utilisation of project management expertise in the design of organisational structures, coordination mechanisms and controls for the conduct of clinical trials, without compromising legal requirements and GCP guidelines.

Despite the growing importance of non-commercial clinical trials in Poland, a significant research gap remains in scientific literature and system documents regarding the precise definition of the position, role, and function of the project manager in clinical trial projects. This issue is further complicated by the inconsistency of the terminology used. Terminology related to clinical project management is used ambiguously and interpreted in different ways, both in organisational practice and in scientific studies. This paper aims to contribute to the existing body of knowledge by addressing the research gap identified in the field. It also seeks to stimulate discussion on the validity of current legal regulations and public guidelines of organisations supporting non-commercial clinical research projects in Poland.

3. Method

The objective of the present study is to make a comparison between the roles of a project manager as defined in a selection of project management methodologies (PRINCE2, AgilePM, PMBOK Guide) and the roles and positions found in non-commercial clinical research projects.

The work is descriptive and comparative in nature and is based on an analysis of extant sources – industry documents and publicly available materials.

A qualitative approach, underpinned by document analysis (desk research), was employed. Desk research, as one of the non-reactive research methods, inherits all the textbook advantages of non-reactive research. According to Babbie (2003) there are three non-reactive methods of data analysis. These are content analysis, analysis of existing statistical data and historical-comparative analyses. Desk research may be considered as a combination, or even the essence, of these methods. A comprehensive desk research analysis is conducted, incorporating content analysis from the initial stage of source identification, alongside extensive utilisation of existing statistical data. Cross-sectional analyses and comparisons of historical data are also performed (Bednarowska, 2015).

This method facilitates the systematic collection and interpretation of information characterising both the formal requirements of selected methodologies and the practical roles found in the clinical research environment.

The present study is of a secondary nature and is based on sources that have already been developed, thus enabling the compilation of dispersed information and the creation of a synthetic comparative model.

The analysis took into account official and publicly available publications: PRINCE2 – Managing Successful Projects with PRINCE2 and AXELOS materials on roles and responsibilities; AgilePM – AgilePM Handbook and DSDM Consortium guides defining roles in agile projects; PMBOK Guide – selected chapters of the PMBOK Guide (e.g. versions 6 and 7), in particular the section on roles, project manager competencies and areas of responsibility. For each methodology, the following were identified: role titles, duties, decision-making responsibilities, required and key competencies, the role's place in the project structure.

The following categories of sources were used to collect data:

- The present corpus of scientific publications focuses on the roles of project managers (and associated positions) in research projects, with a particular emphasis on clinical research projects and projects in the pharmaceutical industry.
- A comprehensive compendium of job descriptions and regulations for entities can be found on the websites of universities, clinical research centres and research institutes.
- The documentation encompassed within this category includes industry and regulatory documents, such as those from the ECRIN and EUPATI repositories, along with guidelines stipulated by the GCP. Additionally, the subject matter encompasses charts that delineate the respective responsibilities of sponsors and research teams.
- Industry reports are documents that concern the organisation of processes in non-commercial research. Such reports are published by international clinical research networks, for example reports on the role of Trial Manager and Project Manager in NCTN, NCRI and ECRIN.

The analysis focused on determining: role nomenclature, scope of responsibility, decision-making areas, relationships with other team members (PI, Sponsor, Monitor, CRA, Data Manager), degree of compliance or differences with project methodologies.

Document analysis is a suitable method for several reasons. The normality of project methodologies is evident in the formalised and publicly described roles, responsibilities and areas of competence presented by PRINCE2, AgilePM and PMBOK. This data can be obtained without the need for field research. The public nature of clinical trial data is a key consideration in the realm of academic research and commercial clinical trials. Academic institutions, research centres and entities conducting non-commercial clinical trials are required to publish a range of materials, including job descriptions (e.g. Project Manager, Clinical Project Manager, Trial Coordinator, Sponsor Representative), recruitment materials and regulatory documents. The potential for cross-sector comparisons is evident. Document analysis is an efficient method for building a comparative matrix of roles between the 'classic' project sector and clinical projects. In clinical projects, role structures often do not correspond to methodologies in terms of nomenclature.

Research based on document analysis is subject to certain limitations. The diversity of nomenclature employed by clinical trial units has the potential to impede the process of achieving comprehensive standardisation of roles. It has been observed that certain job descriptions are not entirely transparent, with some institutions imposing limitations on the extent to which duties are delineated. Systemic differences between countries may have implications for the scope of responsibility of the Project Manager in clinical trials. Document analysis does not permit an evaluation of the actual performance of roles; it examines declarations, not operational practice. These limitations do not nullify the value of the study, but rather highlight the necessity for caution in interpretation.

The adopted methodology enables a systematic and reliable comparison of the roles of a project manager in three key project management methodologies with roles occurring in non-commercial clinical trials. The analysis of documentation facilitates not only the identification of similarities and differences, but also addresses a research gap concerning the application of formal project methodologies in the specific context of clinical trials.

4. Results – The case of non-commercial clinical trial projects in Poland

Non-commercial clinical research projects in Poland are carried out by a variety of entities, including universities or other scientific institutions authorised to award academic degrees, healthcare entities, researchers (doctors), patient organisations, organisations of researchers or other natural or legal persons, or organisational units without legal personality. The activities

carried out are not aimed at making a profit related to the conduct and organisation of clinical trials, as well as the manufacture or marketing of medicinal products.

In addition, non-commercial clinical trials (NCTs) are conducted without the involvement of the pharmaceutical industry. The fundamental principle of NCTs is that the data collected cannot be utilised to obtain marketing authorisation for designated medicinal products or to effect modifications to extant authorisations (Wąsik, Kuczur, 2016).

The Medical Research Agency (2024) in Poland (*Agencja Badań Medycznych*, ABM) has developed guidelines for entities that have or plan to establish a Clinical Research Support Centre (*Centrum Wsparcia Badań Klinicznych*, CWBK) within their structures. Operating as a shared services model, CWBK provides comprehensive and systematic support for the implementation of both commercial and non-commercial clinical trials. Its main area of activity is conducting clinical trials, including contracting and budgeting, as well as managing processes in accordance with established procedures. In order to achieve these objectives, it is necessary to employ qualified staff and establish the appropriate infrastructure.

The model CWBK includes the following basic, mandatory positions: two management staff positions, three clinical trial coordination positions and one project management position. The CWBK management team oversees three main areas of activity, each responsible for specific processes: contracting; budgeting; administrative management of research; and supervision of the research coordination process. Clinical trial coordinators should be responsible for the ongoing verification of quality indicators in trials, such as the number of outstanding queries, the number of incomplete CRF pages, issues relating to the quality of medical documentation and discrepancies in the accounting of investigational medicinal products. Their other responsibilities include planning, organising and supervising the various stages of clinical trials, as well as managing time and resources.

CWBK provides dedicated project management staff who are responsible for preparing grant applications and acquiring new research projects for the centre, as well as assisting researchers with their applications. The competences and expected results of the project manager are as follows (Medical Research Agency, 2024):

- Preparing documentation related to the implementation of the project, including drawing up funding applications for non-commercial research together with the required attachments.
- Developing, supervising and updating documents necessary to initiate and conduct a clinical trial, including the trial protocol, laboratory instructions, risk management plan, trial monitoring plan, safety management plan, forms and SOPs.
- Taking responsibility for communication with external service providers (e.g. pharmaceutical manufacturers and other clinical centres).
- Resolving ongoing issues during the trial.
- Directly cooperating with institutions to obtain the necessary data to prepare a funding application.

- Processing applications at the formal and substantive assessment stages.
- Preparing information, reports and summaries on the progress and implementation of projects.
- Preparing a package of documentation for submission to the Bioethics Committee and Office for Registration of Medicinal Products, Medical Devices and Biocidal Products / Clinical Trials Information System.
- The ability to think analytically and draw conclusions.

The minimum requirements for the position of clinical research project manager include only: higher education; one year of experience working in an R&D department or participation in the preparation of five applications for funding for projects financed from national or European funds in the field of R&D; intermediate level of English.

Furthermore, according to the model Clinical Research Support Centre, the project team for a non-commercial clinical trial should primarily comprise (Medical Research Agency, 2024):

- investigators and co-investigators,
- nurses,
- pharmacists,
- laboratory diagnostician,
- clinical trial monitor, and
- a medical writer.

The CWBK Model Standard, promoted by ABM, stipulates that centres must meet organisational and procedural requirements that are appropriate to the complexity of the research. Since clinical trials, especially multi-centre non-commercial or commercial ones, are complex undertakings requiring planning, resources, schedules, supervision, communication and coordination, it is logical that effectively implementing these requires someone to perform the analogous function of a 'project manager'. In practice, the CWBK model creates structures in which individuals are responsible for designing and managing trials.

Examples from other research organisations in Poland show that it is possible and worthwhile to plan the management of non-commercial clinical trials in such a way as to separate the roles of project manager and principal investigator. For example, in one of its main competitions for funding innovative projects, the National Centre for Research and Development recommends (by preparing an appropriate grant application form) separating the roles of R&D manager and R&D module manager (Narodowe Centrum Badań i Rozwoju, 2025). The R&D manager can be compared to the principal investigator in clinical trials, while the R&D module manager can be compared to the project manager.

The most significant stakeholders in non-commercial clinical trials are as follows (elements of the organisational structure of the environment) (Grzeszczyk, Zawada, 2024):

- Trial Sponsor – the entity providing financial backing for the initiation of a trial. In the context of commercial trials, this role is typically assumed by a pharmaceutical company. Conversely, in the case of non-commercial trials, scientific institutions or other research institutions frequently serve as the sponsor. Furthermore, a researcher may also act as a clinical trial sponsor.
- A Contract Research Organisation (CRO) – the entity that conducts a given clinical trial on behalf of the sponsor. The CRO often employs a clinical trial coordinator, clinical trial associate, data manager, biostatistician and other specialists.
- Research centres – the facilities designated for the conduct of clinical trials. Such centres may be located within hospitals or medical clinics.
- Medical staff/researchers – doctors engaged in research activities, with the principal investigator being a salient example. Additionally, the term encompasses nurses and pharmacists involved in research endeavours.
- Study participants – individuals who engage in the study in the capacity of either patients (i.e. persons afflicted by a specified illness) or healthy volunteers.
- Bioethics Committee – the independent institution that provides an opinion on a given clinical trial, with particular emphasis on its legitimacy, feasibility, and the safety of its participants. Similarly, the term "Ethics Committee" denotes an independent institution that performs a similar function in the context of clinical trials.
- Public administration bodies – the institutions that have been charged with the responsibility of overseeing, providing opinions on and approving (i.e. enabling the commencement of) clinical trials. In addition to this, they are also tasked with ensuring that the research project is conducted in accordance with the prevailing legislation.

A comprehensive delineation of the pivotal roles within non-commercial clinical research projects, accompanied by a delineation of task equivalents according to project management methodologies (classical and agile), is presented in the following Table 3.

Table 3.
Clinical roles translated into project roles according to PRINCE2, PMBOK and AgilePM

Role in a clinical trial (non-commercial)	Typical tasks in a clinical trial	Equivalent project role – PRINCE2	Equivalent project role – PMBOK	Equivalent project role – AgilePM
Principal Investigator (PI)	Scientific responsibility, protocol compliance, substantive supervision	Executive (if acting as benefit owner) or Senior User (recipient of scientific value)	Sponsor or Key Stakeholder	Business Sponsor / Business Visionary

Cont. table 3.

Sub-Investigator (Sub-I)	PI support, medical responsibility	Senior User (joint responsibility for requirements)	Stakeholder (Subject Matter Expert)	Business Advisor
Study Coordinator / Clinical Trial Coordinator	Operational coordination of the study, documentation, visit schedule	Team Manager (manages the work area)	Project Coordinator / Project Team Member	Team Member
Project Manager (Clinical PM – if present in the trial structure)	Scope, schedule, risk and communication management	Project Manager	Project Manager (PMBOK roles are process-based, but the PM is responsible for integration)	Project Manager / AgilePM
Data Manager	EDC support, data quality, validation, cleaning	Team Manager or Specialist Role	Specialist / SME (Quality, Data)	Technical Coordinator or Solution Developer
Clinical Research Associate (CRA)	Data monitoring, compliance verification, follow-up visits	Team Manager / Quality Reviewer	Quality Assurance / Control Specialist	Technical Advisor
Regulatory Specialist	Bioethics committee approvals, regulatory documentation	Project Assurance (quality and compliance perspective)	Compliance Specialist / Stakeholder	Business/Technical Advisor
Study Nurse / Research Nurse	Implementation of research procedures, patient support	Team Member	Project Team Member	Team Member
Biostatistician	Randomisation, statistical analysis	Senior Supplier (expert responsibility)	SME (Subject Matter Expert)	Technical Advisor / Solution Developer
Pharmacist / IMP Manager	Medicinal product management, IMP preparation	Supplier / Team Manager	Procurement / SME	Technical Coordinator
Ethics Committee (as stakeholder unit)	Ethical supervision, protocol approval	Project Board – Project Assurance (external)	External Stakeholder	Business Sponsor (advisory role, non-operational)
Academic sponsor (university, institute)	Funding, formal responsibility	Executive	Sponsor	Business Sponsor

Source: Own elaboration based on: DSDM Consortium, 2014; International Project Management Association, 2015; AXELOS, 2017; Schwaber, Sutherland, 2020; Project Management Institute, 2021; Kerzner, 2023; Grzeszczyk, Zawada, 2024.

With reference to the functions of the project manager in non-commercial clinical trials, illustrative role summaries can be found in Table 4.

Table 4.
Main roles of the project manager: comparison of methodologies and clinical trials

Area / Role element	PRINCE2 (Project Manager)	PMBOK (Project Manager)	AgilePM (Project Manager / Team Leader)	Clinical trials (NC) – project manager / trial manager / study coordinator
Project planning	full responsibility for the plan	full responsibility for the plan and management of the project triangle	shared with the team, iterative planning	preparation of the study plan, schedule, tasks for the PI and team
Scope management	scope control, deliverables	key area (Scope Management)	iterative scope, determined jointly	defining the operational scope of the study in accordance with the protocol
Schedule management	preparation and control	full responsibility	short-term, iterative plan	preparing the timeline, visits, recruitment, monitoring
Budget management	monitoring and reporting (decisions made by the Executive)	PM responsible for costs and budget	depends on the organisation	most often: budget preparation, grant settlements, but financial decisions formally made by the sponsor/institution
Risk management	formal risk management process	Risk Management central element	adaptive approach to risks	identification of compliance, delay and recruitment risks; GCP compliance
Communication management	full responsibility	Communication Management Plan	strong emphasis on team communication	coordination of PI, clinical team, CRO/monitors, sponsors
Quality Management	in accordance with the Quality Management Approach	Quality Management Plan	team responsibility	Very high responsibility for data quality, compliance with GCP and protocol
Team management	team work control	PM responsible for team leadership	team leader → joint responsibility	often coordinates research, but is not the formal supervisor of the team
Relationship with stakeholders	stakeholder analysis, communication	Stakeholder Engagement	key element of Agile	Cooperation with PI, sponsors, monitors, bioethics committee, hospital pharmacy, laboratory
Decision-making	within the limits of assigned powers	PM makes operational decisions	short-term decisions	operational decisions; clinical and ethical decisions → PI and Sponsor
Documentation	complete project documentation management	full project documentation	minimal, iterative documentation	key role: TMF, protocol, consents, reports, GCP documents

Source: Own elaboration based on: DSDM Consortium, 2014; International Project Management Association, 2015; AXELOS, 2017; Schwaber, Sutherland, 2020; Project Management Institute, 2021; Kerzner, 2023; Grzeszczyk, Zawada, 2024.

A comparative analysis revealed significant similarities between the role of a project manager as defined in the PRINCE2, PMBOK and AgilePM methodologies and the roles performed in non-commercial clinical trials. In both areas, schedule, communication and risk management, as well as team coordination and integration of the activities of multiple stakeholders, are of central importance. The project manager plays a pivotal role in orchestrating the implementation process of the project, ensuring the coherence of operational activities, the seamless flow of information, and the delivery of tasks that meet the requisite standards. This convergence lends further credence to the hypothesis that the fundamental project competencies – planning, progress monitoring, resource management and communication – are universal and retain their relevance in the clinical research environment.

Concurrently, substantial discrepancies have been identified, attributable to the distinct nature of the clinical sector. It is imperative to recognise that clinical research projects are subject to stringent regulatory oversight. Consequently, the project manager is obligated to possess a comprehensive understanding of Good Clinical Practice (GCP) principles, ethical procedures, personal data protection protocols, the reporting of adverse events, and the management of research documentation. In contradistinction to conventional projects, the project manager in clinical trials frequently lacks formal hierarchical authority over the team, assuming instead a coordination and negotiation role. Furthermore, the Principal Investigator retains responsibility for the substantive outcome of the trial, while the project manager's remit is to ensure the organisational, qualitative and regulatory correctness of the trial's implementation. In addition, clinical project structures include specialised roles – such as monitor (CRA), data manager or pharmacovigilance specialist – which have no direct equivalents in traditional project management methodologies. Consequently, there is a requirement for the adaptation of project role models to the realities of medical research.

In summary, the following elements can be identified as the key findings from the analysis:

- Non-commercial clinical research projects conducted in Polish scientific and research units meet the definition of projects.
- Poland has a public organization whose task is to support the conduct of clinical research projects in public healthcare institutions.
- Medical Research Agency (*Agencja Badań Medycznych*, ABM) finances Clinical Research Support Centres (*Centrum Wsparcia Badań Klinicznych*, CWBK), which supports the conduct (management) of clinical research projects (including non-commercial ones) within public healthcare institutions.
- Model CWBK assumes the existence of the following positions: clinical trial coordinator and project manager, indicating the basic responsibilities for these roles.
- It is possible to compare the roles of a clinical trial coordinator and a clinical trial project manager with the recommendations for project management roles formulated by project management methodologies (e.g. PRINCE2, PMBOK, AgilePM).

– In clinical trial management practice (including non-commercial trials), there are many managerial roles (Project Manager, Principal Investigator, Clinical Trial Coordinator) that differ significantly from one another.

5. Discussion

Clinical research represents a significant interdisciplinary domain within the realm of scientific endeavours, underscoring the complexity and multifaceted nature of contemporary scientific pursuits. The implementation of clinical trials, including non-commercial in nature, is characterised by a series of project attributes (including specific objectives, temporal constraints, resource allocation, scope, and stakeholders, as well as risk considerations). It is evident that Project Management (PM) methodologies and techniques, which include planning, scheduling, risk management, CPM/PERT, agile/hybrid methodologies, and the utilisation of digital tools, are being adopted in increasing measure for their application in this domain (Goodarzynejad, Babamahmoodi, 2015; Barbosa et al., 2025).

This study's findings, based on analytical processes, demonstrate that a combination of effective preparation and competent project management can substantially enhance the likelihood that a clinical trial will be executed in a manner that is efficient, ethical and compliant with regulatory standards. New insights are presented below, alongside references to earlier scientific works. The majority of the results (relating to the approach to project management) are consistent with the principles of management science and the findings of other authors. Nevertheless, there remains a lack of scientific research concerning the management of non-commercial clinical trials within Polish organisational units.

Documents from the Medical Research Agency (ABM) in Poland and descriptions from the Clinical Research Support Centre (CWBK) indicate that the model CWBK provides for structures and functions that correspond to the role of project manager, which is undoubtedly of great value. This is in line with the findings of other studies cited in this paper (Ernø-Kjølhede, 1999; Sonstein et al., 2022; Batuca, Maia, 2024; Barbosa et al., 2025), which emphasise the importance of appointing a Project Manager / Research Project Manager. Despite the fact that the model standard for Clinical Research Support Centres provides for a project management position, the scope of formal competency requirements for this role remains relatively general and limited mainly to professional experience and knowledge of GCP principles. It is also indicated by other studies (Mitchell et al., 2022) that there is a necessity to improve the competencies of those who manage research projects. In light of the intricacies inherent in non-commercial clinical trials, which are distinguished by a considerable regulatory risk, multi-stakeholder participation, interdisciplinary nature and substantial time and budgetary constraints, it is rational to advocate for a substantial augmentation in competency requirements

in the domain of professional project management. This augmentation should encompass expertise in recognised methodologies, planning tools, risk management, communication and stakeholders.

In consideration of the extant data, it can be deduced that the model CWBK supported by ABM provide for a function that can be interpreted as the role of a project manager – only the function responsible for ‘project management’ is envisaged as a basic position (1 full-time position). However, there is a clear absence of specifics regarding the required competences (knowledge, skills, familiarity with project management methodologies and techniques).

It is important to note that neither the Medical Research Agency documents nor the CWBK Model Standard, in their publicly available definition of 'project manager' as a formal, unified role, contain a publicly available document that states: The necessity for a designated Project Manager within CWBK is essential for the effective management of projects.

A further significant limitation of the current model CWBK is its overly general approach to the competency requirements for individuals performing management functions in clinical projects, which focuses primarily on general experience and knowledge of Good Clinical Practice principles. Meanwhile, the effective management of a complex research project requires advanced, specialist knowledge of project management. This includes the development of work breakdown structures and schedules, cost estimation and control using earned value methods, systematic project risk management, stakeholder and communication management, change control and quality assurance of project processes.

The limitations of the study (i.e. those aspects excluded from the scope) are also recommendations and further research plans. Further in-depth research is recommended, in the form of individual interviews and focus groups, in order to provide a more robust confirmation of the conclusions of this study. It appears imperative to undertake empirical research in the form of observations of the work of teams (individuals) managing non-commercial clinical trials in Poland. In the field of research, the subsequent study could focus on the analysis of the competencies of clinical trial managers, clinical trial coordinators and principal investigators in the domain of project management. When undertaking further research on this topic, it should be noted that the structures and job titles vary, with individuals being referred to as 'research coordinator' or 'project specialist', suggesting that the role may not always be designated 'Project Manager' and that its scope and title may vary.

6. Summary

Non-commercial clinical research projects are of significant importance in the advancement of medical knowledge, the improvement of healthcare quality, and the filling of research gaps. Due to their high organisational complexity, stringent regulatory requirements, multiple

stakeholders, and significant scientific and operational risks, a professional approach is required for the execution of these projects, utilising structured methodologies, tools, and project management techniques. A series of lessons were identified through the course of the analyses.

It is recommended that entities conducting non-commercial clinical trials establish a separate, formally recognised position of research project manager (clinical trial project manager), distinctly separate from both scientific and administrative roles. It is recommended that such a position should be systematically financed by grants from the Medical Research Agency. This approach would ensure employment stability, continuity of organisational competence and professionalisation of clinical trial portfolio management. Consequently, it would increase the effectiveness of project implementation, the quality of supervision and the likelihood of achieving the intended scientific and implementation results.

Despite the fact that the model standard for Clinical Research Support Centres provides for a project management position, awareness of the importance of this role in the research community remains limited. The prevailing approach continues to place the burden of organisational responsibility primarily on the principal investigator or study coordinator. This has resulted in a dispersion of responsibility for the schedule, budget, risks and communication with stakeholders. It is therefore reasonable to formally define the role of clinical trial project manager as a separate function, responsible for the overall integration of project activities, planning, monitoring progress and ensuring that the project is implemented in accordance with strategic and operational objectives.

The results of this research have the potential to be applied in the domain of public management practice. A fundamental condition for the effective implementation of professional project management is the recognition of the position of clinical trial project manager as a reimbursable cost in projects financed by the Medical Research Agency in Poland. This solution will enable project implementing entities to flexibly hire highly qualified experts, including on a contract or interim management basis, without the need for long-term organisational commitments. This will facilitate the transfer of expertise from the commercial market to the non-commercial clinical research sector, increase the stability of project implementation and improve the efficiency of public funds utilisation. The financing management competences of organisations can be directly influenced by grants, thereby reducing the risk of underestimating the organisational costs of projects and enhancing their predictability.

Concurrently, it is imperative that organisational and systemic changes are implemented at the institutional and regulatory level. It is recommended that the Medical Research Agency provide clarification on the CWBK model standard by means of the following measures: firstly, by clearly defining the role of the project manager; secondly, by specifying minimum competence requirements and recommended certifications; and thirdly, by introducing the obligation to use formal project management plans in funded research. The Ministry of Health has the capacity to facilitate the enhancement of project competencies through the

implementation of training programmes, the establishment of career pathways for research project managers, and the integration of project management within clinical research development strategies. Consequently, the legislator should establish a legal framework that facilitates the flexible employment of project experts in public entities and the recognition of management competence costs as an integral component of research project funding. It is asserted that consistent action on these three levels has the potential to significantly increase the organisational maturity of the Polish non-commercial clinical research system, thereby enhancing its competitiveness and efficiency.

In summary, the professionalisation of the role of project manager in non-commercial clinical trials is identified as a key condition for increasing the efficiency, predictability and quality of publicly funded projects. Consequently, there is a compelling rationale for conducting additional empirical research on the impact of project management maturity on clinical trial outcomes, the effective utilisation of funding, and the development of organisational competencies of research centres in Poland.

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References

1. Ahmed, S. (2022). Role of Project Manager in Pharmaceutical Industry. *International Journal of Scientific Research in Science and Technology*, 118-125, doi:10.32628/IJSRST1254122
2. Akinbolade, S., Fairbairn, R., Inskip, A., Potter, R., Oliver, A., Craig, D. (2025). Repurposed Medicines: A Scan of the Non- commercial Clinical Research Landscape. *Pharmacology Research & Perspectives*, 13(1), e70049, https://doi.org/10.1002/prp2.70049
3. AXELOS. (2017). *Managing successful projects with PRINCE2 (6th ed.)*. Stationery Office.

4. Babbie, E. (2003). *Badania społeczne w praktyce [The Practice of Social Research]*. Warszawa: PWN.
5. Barbosa, C., Cebolla Sanahuja, L., Collini, M., Moser, R.R.C.A. Santos, J. M., Twohig, R., Vare, D. (2025). Research Project Management: Defining Roles and Responsibilities from Practice/Experience. *Journal of Research Management and Administration*, *4(1),* 2025082701, doi:10.18552/jorma.v4i1.1196
6. Batuca, J., Maia, S. (2024). *Trial management* (Chapter 3). CONSCIOUS II Consortium. Erasmus+ Programme, Key Action 2: Cooperation for innovation and the exchange of good practices, Strategic Partnerships in higher education (Project No. 2021-1-CZ01-KA220-HED-000023177). Retrieved from: https://www.conscious2.eu/, 05.12.2025.
7. Bednarowska, Z. (2015). Desk research–wykorzystanie potencjału danych zastanych w prowadzeniu badań marketingowych i społecznych. *Marketing i rynek*, *7*, 18-26.
8. Boissel, J.-P. (2004). Planning of clinical trials. *Journal of Internal Medicine*, *255(4),* 427-438, doi:10.1111/j.1365-2796.2004.01311.x
9. Brzozowski, M. (2021). The use of project management methodologies and project risk management in the light of empirical research. *Zeszyty Naukowe Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach. Seria: Administracja i Zarządzanie [Scientific Journals of the University of Natural Sciences and Humanities in Siedlce. Series: Administration and Management], 54(127),* 13-21, doi:10.34739/zn.2020.54.02
10. Cambridge Clinical Trials Unit (2024). *CCTU SOP047 CTIMP set up procedure for trial teams*. Retrieved from: https://cctu.org.uk/sites/default/files/2024-11/CCTU_SOP047%20CTIMP%20Set%20up%20Procedure%20For%20Trial%20Teams.pdf, 09.09.2025.
11. Carman, A.L., Pendergrass, M.E. (2025). The role of the Chief Health Strategist in community health improvement: A MAPP 2.0 counterproposal. *Frontiers in Public Health*, *13*, 1601406, doi:10.3389/fpubh.2025.1601406
12. Del Álamo, M., Lémeret, S., Nieto, C., Pandya, L., Hagen, H., Walker, S., Demotes, J. (2024). Funding multinational investigator-initiated clinical studies in Europe: Why and how? *Trials*, *25(1),* 689, doi:10.1186/s13063-024-08548-1
13. Doganov, B.K., Yanev S. (2006). *Implementation of project management principles in clinical trial process*. Paper presented at PMI® Global Congress 2006 – EMEA, Madrid, Spain. Newtown Square, PA: Project Management Institute.
14. DSDM Consortium (2014). *Agile Project Management Handbook (v2)*. DSDM Consortium.
15. Ellis, P.M., Long, L., Coschi, C.H., Sathiyapalan, A. (2025). A Narrative Review of the Strengths and Limitations of Real-World Evidence in Comparison to Randomized Clinical Trials: What Are the Opportunities in Thoracic Oncology for Real-World Evidence to Shine? *Current Oncology*, *32(11),* 629, doi:10.3390/curroncol32110629
16. Ernø-Kjølhede, E. (1999). The Coming of Age of the Danish Research Manager. Department of Management, Politics and Philosophy, CBS. *MPP Working Paper*, *No. 5.*

17. Ernø-Kjølhede, E. (2000). Project Management Theory and the Management of Research Projects. Department of Management, Politics and Philosophy, CBS. *MPP Working Paper*, *No. 3.*
18. European Medicines Agency (2025). *ICH E6(R3) Guideline for good clinical practice (GCP) — Step 5* (EMA/CHMP/ICH/135/1995). Retrieved from: https://www.ema.europa.eu/en/documents/scientific-guideline/ich-e6-r3-guideline-good-clinical-practice-gcp-step-5_en.pdf, 05.12.2025.
19. European Parliament (2014). Council of the European Union. Regulation (EU) 536/2014 of the European Parliament and of the Council of 16 April 2014 on clinical trials on medicinal products for human use, and repealing Directive 2001/20/EC. *Official Journal of the European Union*, 27 May 2014; L158, 1-76.
20. Farrell, B., Kenyon, S., Shakur, H. (2010). Managing clinical trials. *Trials*, *11(1),* 78, doi:10.1186/1745-6215-11-78
21. Gasemagha, A.A., Kowang, T.O. (2021). Project Manager Role in Project Management Success. *International Journal of Academic Research in Business and Social Sciences*, *11(3),* pp. 1345-1355, doi:10.6007/IJARBSS/v11-i3/9230
22. Goodarzynejad, H., Babamahmoodi, A. (2015). Project Management of Randomized Clinical Trials: A Narrative Review. *Iranian Red Crescent Medical Journal*, *17(8),* doi:10.5812/ircmj.11602
23. Grzeszczyk, T.A., Zawada, M. (2024). *Adaptacyjne planowanie przebiegu projektów niekomercyjnych badań klinicznych [Adaptive planning of non-commercial clinical trials]*. Warsaw: CeDeWu.
24. Gumber, L., Agbeleye, O., Inskip, A., Fairbairn, R., Still, M., Ouma, L., Lozano-Kuehne, J., Bardgett, M., Isaacs, J.D., Wason, J.M., Craig, D., Pratt, A.G. (2024). Operational complexities in international clinical trials: A systematic review of challenges and proposed solutions. *BMJ Open*, *14(4),* e077132, doi:10.1136/bmjopen-2023-077132
25. *International Clinical Trials Registry Platform (ICTRP).* Retrieved from: https://www.who.int/tools/clinical-trials-registry-platform, 15.11.2025.
26. International Project Management Association (2015). *IPMA Individual Competence Baseline for Project, Programme & Portfolio Management. Version 4.0.* IPMA.
27. Jamali, G., Oveisi, M. (2016). A Study on Project Management Based on PMBOK and PRINCE2. *Modern Applied Science*, *10(6),* 142, doi:10.5539/mas.v10n6p142
28. Karbownik, A. (2022). *Kierownik projektu – zadania i kompetencje [Project manager – tasks and competences]*. Gliwice: Wydawnictwo Politechniki Śląskiej.
29. Kerzner, H. (2022). *Project management: A systems approach to planning, scheduling, and controlling (13th Edition)*. Wiley.
30. Liebert, F. (2017). Zarządzanie projektami w przedsiębiorstwach branży IT – Studium Literaturowe [Project management in IT companies – Literature review]. *Zeszyty Naukowe*

Politechniki Śląskiej, Organizacja i Zarządzanie [Scientific Journals of the Silesian University of Technology, Organization and Management], *101*, 271-284.

31. Medical Research Agency (2024). *Standard of the model clinical trials support centre* (Version 3.0) *[Standard modelowego centrum wsparcia badań klinicznych]*. Warsaw, Poland.
32. Mitchell, E.J., Goodman, K., Wakefield, N., Cochran, C., Cockayne, S., Connolly, S., Desai, R., Hartley, S., Lawton, S.A., Oatey, K., Rhodes, S., Savage, J.S., Taylor, J., Youssouf, N.F.J., on behalf of the UK Trial Managers' Network, Mitchell, E., Goodman, K., Wakefield, N., Cochran, C., … Youssouf, N. (2022). Clinical trial management: A profession in crisis? *Trials*, *23(1),* 357, doi:10.1186/s13063-022-06315-8
33. Nagy, V. (2024). *Leadership for 21st century trialists* (Chapter 10). CONSCIOUS II Consortium. Erasmus+ Programme, Key Action 2: Cooperation for innovation and the exchange of good practices (Project No. 2021-1-CZ01-KA220-HED-000023177).
34. Narodowe Centrum Badań i Rozwoju (2025). *Wzór wniosku o dofinansowanie – FENG.01.01-IP.01-002/25 Projekty realizowane w konsorcjach [Application for funding template – FENG.01.01-IP.01-002/25 Projects implemented in consortia, version 2/2025]*. Retrieved from: https://www.gov.pl/web/ncbr/feng0101-ip01-00225---projekty-realizowane-w-konsorcjach, 05.12.2025.
35. Official Journal of the European Union (2014). *Regulation (EU) No 536/2014 of the European Parliament and of the Council of 16 April 2014 on clinical trials on medicinal products for human use, and repealing Directive 2001/20/EC* (Consolidated version: 05.12.2022). EUR-Lex. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02014R0536-20221205, 05.12.2025.
36. Peralta, G., Sánchez-Santiago, B. (2024). Navigating the challenges of clinical trial professionals in the healthcare sector. *Frontiers in Medicine, 11*, 1400585, doi:10.3389/fmed.2024.1400585
37. Project Management Institute (2021). *A guide to the project management body of knowledge (PMBOK® Guide) (7th ed.)*. Project Management Institute.
38. Romański, P. (2025). Kompetencje kierownika projektu jako czynnik sukcesu w zarządzaniu projektami [Project Manager's Competencies as a Success Factor in Project Management]. *Studia i Prace Kolegium Zarządzania i Finansów [Studies and Works of the Collegium of Management and Finance]*, *200*, pp. 73-96, doi:10.33119/SIP.2025.200.5
39. Schwaber, K., Sutherland, J. (2020). *The Scrum Guide: The Definitive Guide to Scrum*. Scrum.org.
40. Schwalbe, K., Furlong, D. (2017). *Healthcare Project Management*. Minneapolis, Minnesota: Schwalbe Publishing.
41. Sonstein, S.A., Kim, L.P., Ichhpurani, N., Padbidri, R., White, S.A., Aldinger, C.E., Bierer, B.E. (2022). Incorporating Competencies Related to Project Management into the Joint

Taskforce Core Competency Framework for Clinical Research Professionals. *Therapeutic Innovation & Regulatory Science*, *56(2),* 206-211, doi:10.1007/s43441-021-00369-7

42. Wang, F., Wang, X., Liu, E., Song, F., Chen, Y. (2025). Impacts of clinical research units on clinical research—A systematic review of empirical studies. *Systematic Reviews*, *14(1),* 94, doi:10.1186/s13643-025-02813-3
43. Wąsik, D., Kuczur, T. (2016). *Badania kliniczne produktów leczniczych i wyrobów medycznych: Zagadnienia prawne [Clinical trials of medicinal products and medical devices: Legal issues]*. Warsaw: Wolters Kluwer.
44. Wen, S.W., Zeng, N., Krewski, D., Walker, M.C. (2025). When results from clinical trials are different from observational studies. *Journal of Clinical Epidemiology*, *178*, 111573, doi:10.1016/j.jclinepi.2024.111573
45. Zubon, S., Taher, M. (2022). A Comparison Between the International Standards PRINCE2 and PMBOK in Project Management. Proceedings of 2nd International Multi-Disciplinary Conference Theme: Integrated Sciences and Technologies, IMDC-IST 2021, 7-9 September 2021, Sakarya, Turkey. *Proceedings of 2nd International Multi-Disciplinary Conference Theme: Integrated Sciences and Technologies*, IMDC-IST 2021, 7-9 September 2021, Sakarya, Turkey, Sakarya, Turkey, doi:10.4108/eai.7-9-2021.2315307

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SPATIAL ANALYSIS OF THE PHENOMENON OF WOMEN'S UNEMPLOYMENT IN COUNTRIES OF THE EUROPEAN UNION

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Purpose: The main objective of this study is to analyze the spatial and temporal variation in female unemployment rates in the European Union between 2010 and 2024. The study will identify key factors influencing regional differences, assess the degree of spatial dependence, and examine whether female unemployment clusters at high or low levels in the EU labor market. Furthermore, it will examine whether spatial autocorrelation strengthens or weakens over time and what implications this has for labor market convergence.
Design/methodology/approach: Global Moran's I and Global Geary's C statistics were used to examine spatial autocorrelation. Panel data models (Pooled OLS, Fixed Effects, Random Effects) were then estimated, and the Hausman test was applied. Next, spatial panel models were used to account for spatial dependencies between neighboring EU countries. The data used in the study come from Eurostat databases and cover the period 2010–2024.
Findings: The study confirmed both spatial and temporal variation in female unemployment across EU countries. Moran's global coefficient values were positive and statistically significant throughout the study period, indicating persistent clusters of similar unemployment levels. However, a decline in these values over time suggests a gradual weakening of the spatial relationship. In turn, Geary's global coefficient values were increasing, indicating increasing local heterogeneity. The selected panel model, i.e., random effects, identified significant determinants of female unemployment, highlighting that labor market participation, educational attainment, and economic activity strongly influence cross-country variation.
Research limitations/implications: The study's limitations include data availability, which may not fully reflect individual countries' labor market policies. Future research should incorporate more detailed regional data to further examine, for example, the impact of policies in EU countries on women's employment. Additional research could uncover post-pandemic labor market changes and the impact of the armed conflict in Ukraine.
Practical implications: The results obtained may be helpful in guiding labor market policies in countries with high female unemployment, and may be used by policymakers to develop more effective interventions in education, childcare availability, and gender-sensitive employment programs.
Originality/value: This study is one of the few spatially oriented analyses of female unemployment in the EU in the post-pandemic period. It applies spatial econometrics to gender-sensitive labor market analysis, offering new insights into the dynamics of unemployment clusters and their evolution over time.

Keywords: female unemployment; European Union; panel model; Moran's I; labour market disparities.
Category of the paper: Research paper.

1. Introduction

For many years, changes in the European Union labor market, including the position of women in it, have been a major topic of economic, social, and demographic research. The observed developments in gender equality and the steadily increasing participation of women in the labor market have not translated into a reduction in the gaps between EU countries in terms of employment and unemployment rates. Publications on unemployment and the general situation of women in the EU reveal the numerous problems women face, such as occupational segregation, lower wages, difficulties reconciling work and family life, and limited access to childcare services (European Commission, 2023).

Research shows that women's unemployment rates vary significantly across countries and are more sensitive to macroeconomic shocks than men's. In many European countries, institutional factors such as labor market flexibility, tax systems, and access to professional activation programs play a significant role. Furthermore, publications include analyses of differences between Southern and Eastern European countries and Northern and Western European countries, which are shaped by, among other factors, different social policy models and historically rooted gender norms (Plantenga, Remery, 2010).

The COVID-19 pandemic has had a significant impact on women's situation in the labor market. The literature contains studies demonstrating how the restrictions introduced during this period affected women working in retail, hospitality, education, and care (Alon et al., 2020). Additionally, Hupkau and Petrongolo (2020) present the gender division of labor in the labor market and households during the pandemic and the potential consequences for inequality.

A growing body of research in spatial econometrics (Anselin, 1988; Elhorst, 2014; LeSage, Pace, 2009) provides analyses demonstrating that labor markets in EU countries are strongly interconnected. Unemployment is often characterized by spatial dependence, i.e., neighboring countries face similar structural, cyclical, and demographic challenges, as confirmed by positive values of the global Moran statistic. This implies that the analysis of female unemployment requires considering both temporal and spatial dimensions to accurately capture the underlying mechanisms and interdependencies.

The main objective of this study is to conduct a comprehensive analysis of female unemployment in the European Union between 2010 and 2024, using panel econometric models and spatial autocorrelation tools. The study examines key macroeconomic and structural factors, such as the percentage of women with higher education, the gender pay gap, the percentage of women working part-time, public spending on childcare, and the level of

economic development. Additionally, spatial autocorrelation analysis allows for an assessment of the extent to which female unemployment is subject to spatial effects across EU countries and whether these trends are decreasing, increasing, or stabilizing over time.

2. Literature Review

The situation of women in the European Union's labor market is a central focus of contemporary socio-economic policy. It is directly linked to the achievement of the UN Sustainable Development Goals (SDGs), particularly those related to gender equality and decent work and economic growth. As the European Commission's (2024) report indicates, despite legislative progress, such as the Pay Transparency Directive, systemic gender employment gaps still require coordinated action at the regional level.

Research on female unemployment in the EU (Figure 1) reveals persistent differences between countries, which can be classified according to welfare state models (Rubery, 2015; Mandel, Shalev, 2009).

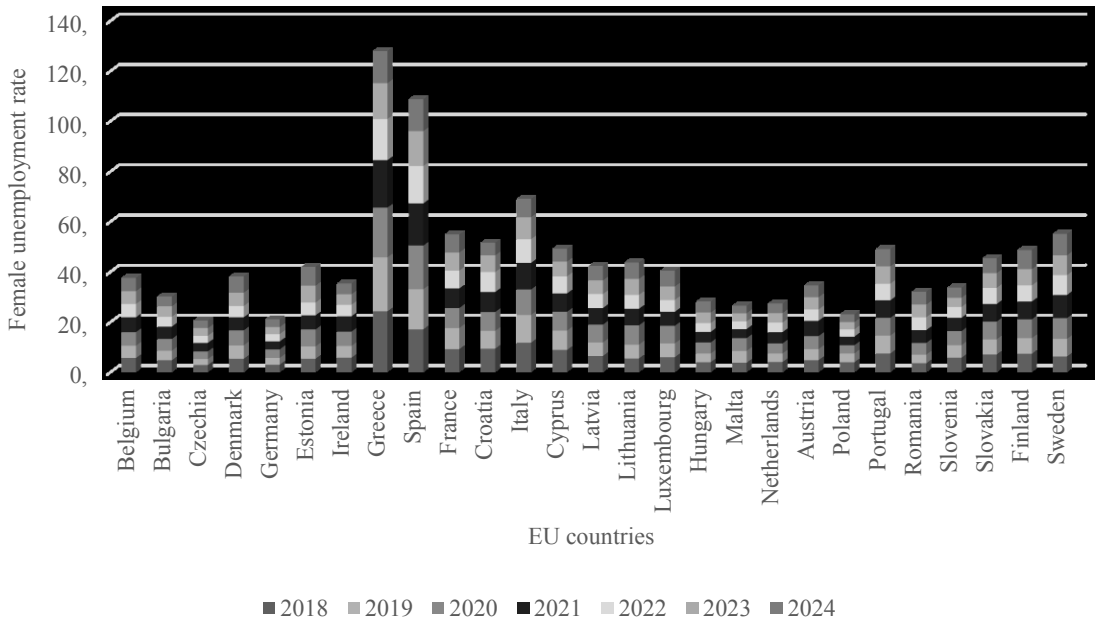


Figure 1. Female unemployment rate in EU countries in 2018-2024.

Source: own study based on Eurostat.

As Figure 1 indicates, Southern European countries such as Greece, Spain, and Italy consistently have the highest unemployment rates among women, while Nordic countries maintain relatively low rates.

The differences visible in Figure 1 can be attributed to specific institutional frameworks. The information presented in Table 1 illustrates how different welfare state models influence these rates.

Table 1.
Regional and Structural Differences in Female Unemployment Across EU Countries

Welfare State Model	Example Countries	Average Female Unemployment Rate (2024)	Key Characteristics
Nordic	Sweden, Denmark, Finland	4-5%	High female labour force participation, flexible labour markets, extensive childcare provision
Continental	Germany, Austria, Netherlands, Belgium	5-6%	Strong family support policies, widespread part-time employment among women
Southern	Italy, Spain, Greece, Portugal	9-13%	Low female labour participation, limited institutional childcare, persistent traditional gender norms
Post-socialist	Poland, Czechia, Hungary, Romania	4-7%	High educational attainment among women, but persistent labour market inequalities and uneven access to public services

Source: own study based on Eurostat.

Nordic countries have the lowest unemployment rates, which is attributed to strong support for work-life balance. Conversely, southern countries face the highest unemployment rates, reflecting structural barriers and traditional gender norms (Table 1). In Germany, Austria, the Netherlands, and Belgium, moderate levels of female unemployment are observed. This situation is influenced by well-developed family policies and the prevalence of part-time employment, which may limit full integration into the labor market. The situation in post-socialist countries is more diverse. Although women in these countries often achieve high levels of education, structural differences in employment opportunities and unequal access to public services contribute to higher unemployment compared to Nordic countries.

In summary, the results indicate that female unemployment in the EU is strongly influenced not only by economic conditions but also by the institutional framework, cultural norms, and the structure of social policy.

Other factors that differentiate women's situation include caregiving responsibilities, occupational segregation, and technological change. Regional analyses conducted by UNECE and UN Women (2021) show that women in Europe and Central Asia spend an average of five hours per day on household chores, while men only spend two, leading to a "double burden" phenomenon and often forcing women to take part-time work or leave the workforce altogether (Gornick, Meyers, 2003). The literature also points to the negative impact of motherhood on earnings and career advancement, which persists across various social welfare systems (Aisenbrey et al., 2009; Kleven et al., 2019).

Research demonstrates that the development of a knowledge-based economy and high-skilled science and technology (HRST) are contributing to the improvement of women's professional status in the EU (Bal-Domańska, 2022). In turn, women with lower education are more vulnerable to the effects of automation and AI (Autor, Dorn, 2013; Elson, 2017; Cortés, Pan, 2019).

Scientific literature highlights generational and sectoral differences as key factors influencing employment stability. Women aged 15–24 are significantly more likely to experience uncertainty and labor market segmentation (OECD, 2020; Scarpetta et al., 2010).

Research on youth unemployment demonstrates that the growth of the manufacturing sector is a key factor in reducing the unemployment rate among young women (Bal-Domańska, 2022). Conversely, the increased number of women employed in the service and care sectors increases their vulnerability to unemployment during periods of economic downturn (Blau, Kahn, 2017; Rubery, Rafferty, 2013). Statistical data confirm that it is the youngest cohort of women who are most vulnerable (Figure 2).

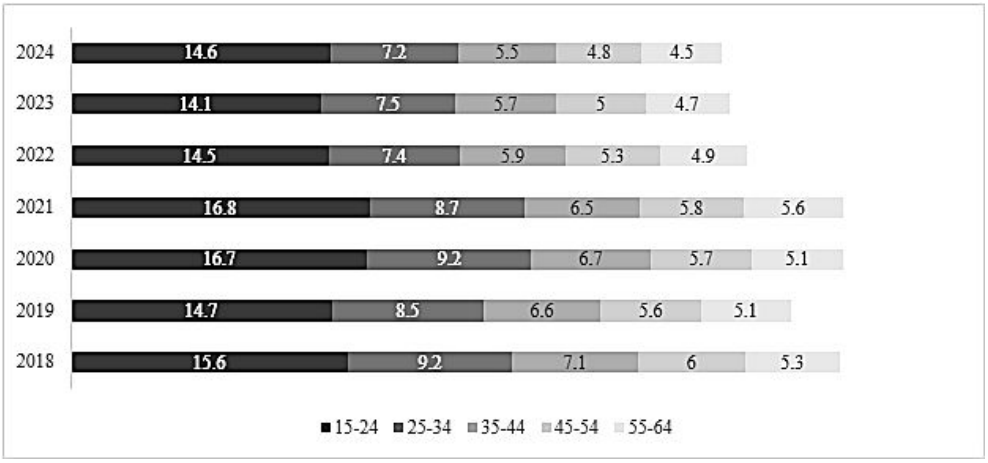


Figure 2. Unemployment rate of women in different age groups in the EU in 2018-2024.
Source: own study based on database of Eurostat.

As shown in Figure 2, the group of women aged 15-24 had the highest unemployment rate during the analyzed period. This situation is exacerbated by the fact that young women often work under fixed-term contracts, which is associated with lower employment security and the risk of long-term unemployment (Kalleberg, 2011; OECD, 2020).

Analysis cannot ignore groups that accumulate disadvantages in the labor market. Migrant backgrounds often mean that women face systemic barriers, such as lack of recognition of qualifications, language barriers, and discrimination (Kogan, 2017). Kogan (2017) also demonstrated how migrant women, women with disabilities, and older women face increasing disadvantages in the labor market, requiring targeted social policy interventions.

A key element of recent research is the shift from analyzing unemployment as a geographically isolated phenomenon to a spatial analysis. Studies at the level of NUTS 2 regions demonstrate that the gender employment gap (GEG) exhibits strong spatial

autocorrelation (Matuszewska-Janica, Fernández-Avilés, 2025). Of particular importance is the spillover effect associated with education – higher levels of education among women in one region contribute to reducing the GEG in neighboring regions as well (Matuszewska-Janica, Fernández-Avilés, 2025).

In terms of wages, analyses at the macroregional level (NUTS 1) indicate the existence of local spatial clusters, especially in Western Europe, where geographic proximity determines similar wage gap levels (Matuszewska-Janica, 2025).

The dynamics of spatial phenomena in the labor market were put to the test during the COVID-19 pandemic. Research confirms that although strong spatial interdependencies are persistent, they temporarily weakened during periods of the most severe pandemic restrictions (Wleklińska, 2024). The pandemic also intensified the burden of unpaid work on women, deepening pre-existing inequalities (European Commission, 2024).

It is also worth mentioning that the 2008 financial crisis and the COVID-19 pandemic caused a significant decline in women's employment due to sectoral concentration and increased caregiving burdens (Del Boca et al., 2020). In the face of these challenges, the literature suggests specific mechanisms for addressing them.

Research shows that in countries with equal access to parental leave, it improves job quality and significantly reduces gender inequalities (Thévenon, 2011; Kleven et al., 2019). EU countries are using various strategies to mitigate gender inequalities in the labor market (European Commission, 2021). Research indicates that combining childcare development with skills development and labor force activation policies is most effective (OECD, 2020).

The literature indicates the need for a multidimensional approach to female unemployment, combining the analysis of structural barriers (unpaid work), macroeconomic barriers (sectoral structure) and spatial regional interactions.

3. Research methodology

3.1. Panel Data Models

Econometric panel data models constitute a sophisticated group of tools that enable the simultaneous analysis of variability across units, such as countries, and changes over time. The structure of panel data, combining cross-sectional and time-series data, allows analysts to capture individual heterogeneity as well as the dynamics of socioeconomic processes (Baltagi, 2021; Wooldridge, 2010, 2019). Using a cross-sectional or time-series approach alone increases the risk of omitted variable error and reduces estimation efficiency.

The general form of a panel data model can be expressed as:

$$y_{it} = \alpha_i + \lambda_t + \beta X_{it} + \mu_{it}, \quad (1)$$

where:

y_{it}– the value of the dependent variable for unit *i* in period *t*,

X_{it}– the vector of explanatory variables,

α_i – unobserved individual heterogeneity (a fixed or random effect),

λ_t – the time effect representing shocks common to all units (such as business cycles or institutional changes),

μ_{it}– the random error term.

Introducing both components into the model (Hsiao, 2014; Arellano, 2003) allows for controlling for persistent structural differences between individuals as well as time-varying trends. This approach is particularly important in the analysis of EU countries differing in their institutional settings, labor market structures, and socio-demographic patterns.

The most commonly used panel models are fixed-effects (FE) and random-effects (RE) models. In the FE model, it is assumed (Greene, 2018) that unobserved individual characteristics remain constant over time and can be correlated with explanatory variables. Estimation is based on an "in-neighborhood" transformation, which eliminates time-invariant heterogeneity and mitigates the omitted variable problem.

In the RE model, it is assumed (Baltagi, 2021) that unobserved individual-specific effects are random and uncorrelated with the regressors, which allows for more efficient GLS estimation.

The selection of the appropriate model is made based on the Hausman test (Hausman, 1978), which assesses the consistency of the RE estimator with respect to the FE.

The use of panel data models in the analysis of female unemployment in EU countries allows for the isolation of the impact of different economic conditions or social, while taking into account persistent differences between countries and changes over time.

3.2. Spatial statistics

The Moran statistics (Moran, 1950) is one of the most widely used measures in the study of spatial autocorrelation. The global Moran's *I* is defined as follows:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\cdot\sum_{i=1}^{n}(x_i-\bar{x})^2} = \frac{n}{S_o}\cdot\frac{z^T W z}{z^T z}, \quad (2)$$

where:

x_i, x_j are the values of variables in the spatial unit *i* and *j*,

$\bar{x}$ is the mean of the variable for all units,

n is the total number of spatial units that are included in the study,

S_0 is the sum of all elements of a spatial weight matrix,

z is a column vector of elements $z_i = x_i - \bar{x}$,

W is the spatial weight matrix degree n, defining the structure of the neighbourhood,
w_{ij} is an element of weights matrix W (Kopczewska, 2020).

This statistic takes values ranging from [–1, 1]: positive, when tested objects are similar, negative, when there is no similarity between them, and approximately equal to 0 for a random distribution of objects.

If the Moran statistic has a value $I \approx -(n-1)^{-1}$, it indicates a random spatial pattern. However, when $I > -(n-1)^{-1}$, the spatial autocorrelation is positive, and if $I < -(n-1)^{-1}$, the spatial autocorrelation is negative.

Another global measure of spatial autocorrelation is global Geary's C (Geary, 1954). This statistic, is given by

$$C = \frac{(n-1)\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\cdot(x_i - x_j)^2}{2\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\cdot\sum_{i=1}^{n}(x_i-\bar{x})^2} = \frac{n}{n-1}\left[\frac{n}{S_0}\cdot\frac{z^{\mathrm{T}}\mathrm{diag}(w_i)z}{z^{\mathrm{T}}z} - I\right], \quad (3)$$

where all elements of the formula are defined as in statistic I.

The above formula shows that the Geary measure can be expressed by the Moran statistic (2). Although Moran and Geary measures give similar results, the Moran statistic is more effective. This is due to greater sensitivity of the variance of the Geary statistic to the distribution of a sample. Values of this statistic can be impaired when the matrix of weights is asymmetrical.

The value of Global Geary's C is always positive and takes values ranging from $[0, 2]$. In the case of: $1 < C < 2$, the spatial autocorrelation is negative; when $0 < C < 1$, the spatial autocorrelation is positive; finally, when $C \approx 1$, there is no spatial autocorrelation.

4. Empirical analysis

This study examines the determinants of female unemployment in European Union countries, taking into account temporal and spatial variation within individual countries. Data used in the study came from Eurostat databases and covered the period 2010-2024. Analyzing the situation of women in the labor market has long been a key socioeconomic challenge in EU countries (European Commission, 2023a). The literature review in Chapter 2 indicates that women's employment is sensitive to institutional, structural, demographic, and cultural factors, as well as various types of crises (Klasen, Pieters, 2015; Blau, Kahn, 2017).

Additionally, spatial analyses show that female unemployment can form regional clusters, resulting from similar economies or the spread of the phenomenon to neighboring areas, for example, as a result of warfare. Therefore, combining panel models and spatial correlation in the study provides a more comprehensive analysis of the topic.

To further explore this topic, the following research questions were posed:

1. What economic and social factors influence the female unemployment rate in EU countries?
2. Is it possible to observe a stable level of female unemployment over the selected period?
3. When analyzing the phenomenon of female unemployment, can spatial autocorrelation be observed, creating clusters of countries within the EU?

The empirical research covered the 27 EU Member States. The female unemployment rate was selected as the dependent variable Y, while the selection of explanatory variables (X1, X2, X3, and X4) was based on the labor market literature:

- X1 – percentage of women with higher education (Becker, 1993),
- X2 – gender pay gap (Olivetti, Petrongolo, 2016),
- X3 – percentage of women employed part-time,
- X4 – logarithm of GDP per capita,
- time effects (dt) – reflecting typical macroeconomic shocks and time trends in all EU countries.

The study used econometric models based on panel data (Table 2). Standard diagnostic tests were performed to determine the appropriate model specification:

- the Breusch–Pagan LM test, which confirmed that the pooled least squares (OLS) method was inappropriate and that a panel model should be used,
- the Hausman test, which showed no significant difference between the FE and RE estimators ($p > 0.238$), allowing the selection of a random effects (RE) model,
- the Wooldridge test, which revealed first-order autocorrelation in the panel residuals, consistent with unemployment dynamics.

Table 2.
Panel model estimation results (Two-way Random Effects, GLS)

Variable	*β*	Std. Err	t-stat	*p-value*
const	11.54	2.28	5.06	<0.0001
X1	0.084	0.022	3.75	0.0002
X2	−0.067	0.027	−2.45	0.014
X3	0.059	0.02	3.02	0.0026
X4	−2.706	0.439	−6.16	<0.0001
dt	0.45–3.21	different	all statistically significant	<0.05

Source: own study.

Table 2 presents the results of estimating the coefficients of the random effects model using GLS with a quasi-degrading effect, which improves efficiency while preserving information between countries. The obtained results indicate that economic development, measured by the logarithm of GDP per capita ($\beta = -2.706$, $p < 0.001$), has the greatest impact on the female unemployment rate in the EU. A negative value of this variable confirms that countries with

a higher GDP per capita are characterized by lower female unemployment. This may be due to greater diversity in female employment, better access to care services, or higher productivity.

Another variable, the percentage of women with higher education, shows a positive impact on the female unemployment rate ($\beta = 0.084$, $p = 0.0002$). This variable indicates that increasing women's education level does not necessarily translate into better employment prospects. This may be related, for example, to difficulties in returning to the labor market after maternity leave, or to women with higher qualifications taking jobs below their qualifications or being unable to find work.

Another explanatory variable, X3—part-time work among women—also influences the increase in unemployment among women ($\beta = 0.059$, $p = 0.0026$). Part-time work may represent a flexible form of employment that facilitates the balance of work and family responsibilities, but it may also imply partial participation in the labor market and may limit career mobility.

Variable X2—the gender pay gap—shows a slight negative impact ($\beta = -0.067$, $p = 0.0143$). The negative effect of this variable suggests that in countries with a lower pay gap, women are more economically active.

Time effects (dt_1–dt_11) represent changes in female unemployment from 2010 to 2024. The significance of time effects confirms that female unemployment has changed over time.

To verify spatial dependencies in female unemployment in selected EU countries, global spatial autocorrelation measures were used (Table 3).

Table 3.
Global statistics estimation results

Global Statistics	2018	2021	2024
Moran	0.6269	0.5703	0.5419
Geary	0.3106	0.3395	0.4383

Source: own study.

Table 3 presents the results of estimating the global Moran and Geary statistics for 2018, 2021, and 2024. The results show a decline in the global Moran coefficient, indicating that the female unemployment rate is becoming less homogeneous across EU countries. At the same time, the observed increase in the global Geary coefficient indicates increasing local differences between neighboring countries, which may indicate that some countries are becoming more diverse in terms of female unemployment.

5. Discussion

The results of the panel study conducted for 27 European Union countries in the years 2010-2024 allow for a multidimensional interpretation of the situation of women in the labor market, combining hard economic data with the institutional and spatial context.

The random-effects model estimation showed that the strongest factor reducing female unemployment in the EU is the level of economic development, measured by the logarithm of GDP per capita, which is consistent with the general economic literature. As Bal-Domańska (2022) points out, economic development, and in particular the dynamics of the industrial processing sector, is a key factor stimulating demand for women's labor and reducing their unemployment, which is particularly visible in the 15-24 age group.

A surprising result of research, however, is the positive correlation between the percentage of women with higher education and the unemployment rate. Although theoretically, the development of a knowledge-based economy should foster an improvement in women's professional position (Bal-Domańska, 2022), the obtained parameter suggests the occurrence of a structural mismatch or difficulties in professional reintegration after interruptions related to motherhood. This may support the thesis that women's higher education generates positive effects and reduces the employment gap primarily when combined with an appropriate demand structure and positive spillover effects in neighboring regions (Matuszewska-Janica, Fernández-Avilés, 2025).

Institutional conditions remain a significant barrier, as reflected in the model by the variable for part-time work. The positive impact of this variable suggests that flexible employment arrangements, although facilitating role reconciliation, may contribute to market segmentation and increase the risk of long-term unemployment. The literature emphasizes that this form of work often results from the "double burden" of unpaid care and domestic work for women, to which they devote an average of five hours per day in Europe, compared to only two hours for men (UNECE & UN Women, 2021; Gornick, Meyers, 2003). At the same time, the coefficient for the pay gap indicates that reduced pay discrimination promotes the stabilization of women's professional activity, which is consistent with the EU's gender equality strategy and the UN Sustainable Development Goals, which view reducing the pay gap as the foundation for decent work and economic growth (European Commission, 2024).

Analysis of spatial dependence over time using Moran and Geary statistics provides evidence of the evolution of unemployment patterns in Europe. The observed decline in the global Moran coefficient, coupled with an increase in the Geary statistic, suggests that the EU labor market is becoming less homogeneous across the continent, with deepening local differences between neighboring countries. Studies at the NUTS 2 and NUTS 1 regional levels confirm that while strong spatial autocorrelation is a persistent feature of the European labor market (Matuszewska-Janica, Fernández-Avilés, 2025), local regimes and specific national

policies are becoming increasingly important determinants (Matuszewska-Janica, 2025). These processes are strongly influenced by temporal factors and crisis situations. Crises such as the COVID-19 pandemic can temporarily weaken spatial dependencies by "freezing" local markets and restricting mobility (Wleklińska, 2024), while also hitting the service and care sectors where women are overrepresented, increasing their vulnerability to unemployment during periods of slowdown (Blau, Kahn, 2017; Del Boca et al., 2020).

In summary, the obtained results indicate the need for a multidimensional approach to labor market policy, combining the analysis of structural, macroeconomic, and spatial barriers within regional interactions. Simply improving women's qualifications is insufficient without accompanying changes to the social welfare system. The most effective solution remains combining the development of institutional childcare with professional activation policies and equal access to parental leave, which allows for a lasting reduction in gender inequalities (OECD, 2020; Kleven et al., 2019; Thévenon, 2011). In future research, we plan to consider the impact of digitalization and automation, which pose new challenges for women with lower professional qualifications.

6. Summary

The analysis conducted provides a critical assessment of the determinants of female unemployment in the European Union, highlighting the complexity of this phenomenon between 2010 and 2024. Evaluation of previous research and the results of the panel model reveal certain limitations of the traditional view of education as the primary factor protecting against unemployment. A weakness of the current market system is the paradoxical, positive correlation between higher education and the unemployment rate, suggesting the existence of structural barriers, such as skill mismatches and difficulties in professional reintegration after career interruptions due to family reasons. This finding highlights the significant limitations of policies focused solely on improving qualifications, which, without concomitant institutional support (e.g., in the area of childcare), fail to guarantee women's professional stability.

The new insights provided by this study focus on the dynamic evolution of spatial dependencies. It shows that the EU labor market is becoming increasingly differentiated locally, as evidenced by a decline in homogeneity measured by Moran's statistic and a simultaneous increase in neighborhood differentiation measured by Geary's statistic. A key finding from this dynamic is that local national specificities and national social policies are becoming more important determinants than geographic location alone. The study also provides evidence that crises such as the COVID-19 pandemic act as catalysts for inequality, temporarily weakening spatial dependencies and increasing the vulnerability of women employed in the service and care sectors to unemployment.

The significance of this study for the discipline of economics and social policy lies in demonstrating that female unemployment is the result of a combination of macroeconomic and non-economic factors. The demonstrated strong impact of GDP per capita and the negative effects of part-time work shed new light on the problem of the "double burden". This information is crucial for achieving the UN Sustainable Development Goals, indicating to policymakers that combating unemployment must be integrated with reducing the wage gap and addressing barriers related to unpaid domestic work, which in Europe is still predominantly performed by women.

The obtained results can provide guidance for developing intervention projects in regions with low female labor force participation, particularly by combining the development of institutional care with professional activation policies. These findings provide a solid foundation for further research, which should focus on the impact of digitization and automation on particularly vulnerable groups, such as older women, migrants, and people with disabilities, who face additional systemic and discriminatory barriers in the modern labor market.

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References

1. Aisenbrey, S., Evertsson, M., Grunow, D. (2009). Is There a Career Penalty for Mothers' Time Out? A Comparison of Germany, Sweden and the United States. *Social Forces*, *88(2),* 843-874. https://doi.org/10.1353/sof.0.0252
2. Alon, T., Doepke, M., Olmstead-Rumsey, J., Tertilt, M. (2020). The impact of COVID-19 on gender equality. *NBER Working Paper, No. 26947*. National Bureau of Economic Research. https://doi.org/10.3386/w26947
3. Anselin, L. (1988). *Spatial econometrics: Methods and models*. Springer.
4. Arellano, M. (2003). *Panel data econometrics*. Oxford University Press.

5. Autor, D., Dorn, D. (2013). The growth of low-skill service jobs and the polarization of the US labor market. *American Economic Review*, *103(5),* 1553-1597. https://doi.org/10.1257/aer.103.5.1553
6. Bal-Domańska, B. (2022). The impact of macroeconomic and structural factors on the unemployment of young women and men. *Economic Change and Restructuring*, *55*, 1141-1172. https://doi:10.1007/s10644-021-09341-9
7. Baltagi, B.H. (2021). *Econometric analysis of panel data* (6th ed.). Springer.
8. Becker, G.S. (1993). *Human capital: A theoretical and empirical analysis, with special reference to education* (3rd ed.). University of Chicago Press.
9. Blau, F., Kahn, L. (2017). The gender wage gap: Extent, trends, and explanations. *Journal of Economic Literature*, *55(3),* 789-865. https://doi.org/10.1257/jel.20160995
10. Cortés, G., Pan, J. (2019). *Gender, occupational segregation, and automation*. The Brookings Economic Studies.
11. Del Boca, D., Oggero, N., Profeta, P., Rossi, M. (2020). Women's work, housework, and childcare before and during COVID-19. *IZA Discussion Paper*, 13409. https://doi.org/10.2139/ssrn.3636638
12. Elhorst, J.P. (2014). *Spatial econometrics: From cross-sectional data to spatial panels*. Springer.
13. Elson, D. (2017). Recognizing, reducing and redistributing unpaid care work: A gender equality approach. *New Labor Forum*, *26(2),* 52-61.
14. European Commission (2024). *2024 report on gender equality in the EU*. Luxembourg: Publications Office of the European Union. https://doi:10.2838/401813
15. European Commission (2021). *Report on gender equality in the EU 2021*. Publications Office.
16. European Commission (2023). *Employment and social developments in Europe 2023*. Publications Office of the European Union.
17. European Commission (2023a). *Report on gender equality in the EU 2023*. Publications Office of the European Union.
18. Geary, R. (1954). The Contiguity Ratio and Statistical Mapping. *The Incorporated Statistician, 5*, 115-145. https://doi.org/10.2307/2986645
19. Gornick, J., Meyers, M. (2003). *Families that work: Policies for reconciling parenthood and employment*. Russell Sage Foundation.
20. Greene, W.H. (2018). *Econometric analysis* (8th ed.). Pearson.
21. Hausman, J. (1978). Specification tests in econometrics. *Econometrica*, *46(6),* 1251-1271.
22. Hsiao, C. (2014). *Analysis of panel data* (3rd ed.). Cambridge University Press.
23. Hupkau, C., Petrongolo, B. (2020). Work, care, and gender inequality during the COVID-19 crisis. *Oxford Review of Economic Policy, 36*(Supplement 1), S169-S186. https://doi.org/10.1111/1475-5890.12245

24. Kalleberg, A.L. (2011). *Good Jobs, Bad Jobs: The Rise of Polarized and Precarious Employment Systems in the United States, 1970s-2000s*. Russell Sage Foundation.
25. Klasen, S., Pieters, J. (2015). What explains the stagnation of female labor force participation in urban India? *World Bank Economic Review, 29*(3), 449-478. https://doi.org/10.1093/wber/lhv026
26. Kleven, H., Landais, C., Søgaard, J. (2019). Children and gender inequality: Evidence from Denmark. *American Economic Journal: Applied Economics*, *11(4),* 181-209. https://doi.org/10.1257/app.20180010
27. Kogan, I. (2016). Integration Policies and Immigrants' Labor Market Outcomes in Europe. *Sociological Science, 3,* 335-358. https://doi.org/10.15195/v3.a16
28. Kopczewska, K. (ed.) (2020). *Przestrzenne metody ilościowe w R: Statystyka, Ekonometria, Uczenie maszynowe, Analiza danych*. Warszawa: CeDeWu.
29. LeSage, J.P., Pace, R.K. (2009). *Introduction to spatial econometrics*. CRC Press.
30. Mandel, H., Shalev, M. (2009). Gender, class, and varieties of capitalism. *Social Politics*, *16(2),* 161-181. https://doi.org/10.1093/sp/jxp006
31. Matuszewska-Janica, A., Fernández-Avilés, G. (2025). Towards sustainable labour market: Spatial analysis of the differences in the employment of women and men across the EU regions. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, *20(2),* pp. 509-548. https://doi:10.24136/eq.3634
32. Matuszewska-Janica, A. (2025). Spatial autocorrelation of the Gender Pay Gap indicator across the macroregions of the European Union. *Folia Oeconomica Stetinensia*, *25(1),* pp. 180-200. https://doi:10.2478/foli-2025-0009
33. Moran, P.A.P. (1950). Notes on Continuous Stochastic Phenomena. *Biometrika, 37(1),* 17-23. https://doi.org/10.2307/2332142
34. OECD (2020). *Employment Outlook 2020: Worker Security and the COVID-19 Crisis*. OECD Publishing. https://doi.org/10.1787/19991266
35. Olivetti, C., Petrongolo, B. (2016). The evolution of gender gaps in industrialized countries. *Annual Review of Economics, 8*(1), 405-434. https://doi.org/10.1146/annurev-economics-080614-115329
36. Plantenga, J., Remery, C. (2010). *Flexible working time arrangements and gender equality: A comparative review of 30 European countries*. European Commission.
37. Rubery, J. (2015). Austerity and the future for gender equality in Europe. *ILR Review*, *68(1),* 715-741. http://www.jstor.org/stable/24812005
38. Rubery, J., Rafferty**,** A. (2013). Women and recession revisited. *Work, Employment and Society*, *27(3),* 414-432. https://doi.org/10.1177/0950017012460314
39. Scarpetta, S., Sonnet, A., Manfredi, T. (2010). Rising youth unemployment during the crisis. *OECD Social, Employment and Migration Working Papers*, *106*. https://doi.org/10.1787/5kmh79zb2mmv-en

40. Thévenon, O. (2011). Family policies in OECD countries. *Population and Development Review*, *37(1),* 57-87. https://doi.org/10.1111/j.1728-4457.2011.00390.x
41. UNECE & UN Women (2021). *Empowering women through reducing unpaid work: A regional analysis of Europe and Central Asia*. Geneva: United Nations.
42. Wleklińska, D. (2024). The analysis of spatial-temporal differences in unemployment rates in Poland by counties in the years 2019-2023. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, *201*, 379-394. https://10.29119/1641-3466.2024.201.29
43. Wooldridge, J.M. (2010). *Econometric analysis of cross section and panel data* (2nd ed.). MIT Press.
44. Wooldridge, J.M. (2019). *Introductory econometrics: A modern approach* (7th ed.). Cengage.

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TEAM EFFECTIVENESS IN TECHNOLOGY-BASED ORGANIZATIONS. REFLEXIVE INVESTIGATION AMONG IT EXPERTS

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Purpose: The study aims to provide a deeper understanding of team effectiveness in technology-based organizations. Considering the technologically driven environment, the exploration focuses on team effectiveness and its essential aspects.
Design/methodology/approach: Team reflexivity is discussed as a theoretical context for team functioning in dynamic environments. Using a qualitative approach and thematic analysis, participants of the investigation provided definitions and engaged in discussions to refine key aspects of team effectiveness. An in-person investigation involved fifty-two information technology experts from diverse specializations, including cybersecurity, project management, UX design, software development, IT Architecture, DevOps, and Leadership.
Findings: The study's findings highlight primary aspects of team effectiveness (1) fulfillment of business requirements, (2) delivery of high-quality products, and (3) teamwork. Holistically, twelve aspects of team effectiveness emerged, including best practices for development, proper technology selection, user experience, managing technical debt, skills development, risk management, cybersecurity, and work environment.
Originality/value: The study contributes to the theory exploring team effectiveness and its aspects. It offers practical insights for managers, emphasizing the importance of aligning team goals with business needs, maintaining high-quality standards, and fostering teamwork. Future research directions include longitudinal studies to identify changes in team effectiveness over time and comparative analyses across industries. Findings underscore the necessity for a nuanced understanding of team effectiveness tailored to the challenges faced by technology-based organizations.
Keywords: Technology-based organizations, Team effectiveness, Team reflexivity.
Category of the paper: Research paper.

1. Introduction

Technology-based organizations are focused on adopting new technologies to improve operational efficiency and expand market opportunities (Cascio, Montealegre, 2016). They act in the technology-organization-environment (Li, 2020) using research and development (R&D) activities to maintain competitiveness and provide high-quality service most effectively.

Digital transformation has become a key factor in the evolution of technology-based organizations, involving adopting digital technologies to improve processes and create value (Reis, Amorim, Melão, Matos, 2018).

Findings provided by Gimpel, Hosseini, Huber, Probst, Röglinger, and Faisstet (2018) indicate that managers should adapt their business strategy to a new digital reality. This mainly results in the adaptation of processes and operations management. Therefore, as Urbach & Röglinger (2019) underline, digitalization causes processes of rethinking business in contemporary organizations. Because of dynamic changes, many technology-based organizations make decisions to conduct projects in agile teams, that can quickly adapt to needs or requirements and work effectively. Business managers and researchers underline a strong desire to understand how agile teams reach effectiveness (Steegh, Van De Voorde, Paauwe, 2025) and explore what helps agile teams be successful (Adzgauskaite, Tam, Martins, 2025). Therefore, this study aims to investigate two following research questions:

RQ 1: How do team members in technology-based organizations define team effectiveness?

RQ 2: What are the main aspects of team effectiveness that are essential for team members in technology-based organizations?

To answer these RQs, it is necessary to explain the technology-organization-environment, and specificity of working in teams, then identify definitions of team effectiveness, that can be understood differently.

The theoretical goal of this study is to revisit the findings on team effectiveness presented in former studies. The empirical goal of this study is to provide evidence from team members who work in teams in technology-based organizations referring to team effectiveness. Based on the participants` contribution it is expected to provide insights on how nowadays team members define team effectiveness and then what main technological, organizational, or environmental aspects of team effectiveness, are crucial for them.

Many years ago, Kozlowski and Ilgen (2006), desired to identify what we know, what we think we know, and what we need to know to improve the effectiveness of work groups and teams. Referring to their statement, *today we need to reflect on how we understand and define team effectiveness and its aspects, considering the dynamic technology-based world*. Then, we will be able to go deeper to improve effectiveness and facilitate the organizational environment. Therefore, the study contributes to the literature by re-examining the understanding of team effectiveness, which might be more complex and dynamic than its

former definitions. Additionally, using a qualitative approach, crucial aspects of team effectiveness are discovered.

2. Theoretical background

2.1. Teams in technology-based organizations

The digital age has changed the nature of work in ways that were unimaginable in the past (Barley, Bechky, Milliken, 2017). In technology-based organizations, teams often operate in virtual or hybrid environments, utilizing digital tools to facilitate communication and collaboration across geographical boundaries. Therefore, teams in technology-based organizations can be defined as groups of individuals with complementary skills collaborating to achieve common objectives, particularly in developing, implementing, and managing technological solutions (Garro-Abarca, Palos-Sanchez, Rus-Arias, 2020).

Effective leadership in these teams is often agile, characterized by flexibility, adaptability, and a focus on empowering team members to respond swiftly to changing technological demands (Larson, DeChurch, 2020). Additionally, they have a cross-functional composition comprising members from diverse functional backgrounds, enabling a holistic approach to problem-solving and innovation (Leite, Pinto, Kon, Meirelles, 2020) and given the rapid pace of technological advancement, team members are expected to engage in continuous learning to keep abreast of new tools, methodologies, and industry trends (López-Fernández, Díaz, García, Pérez, González-Prieto, 2021; Shvindina, Piven, 2024). Teams in technology-based organizations face challenges such as communication barriers (Garro-Abarca et al., 2020), technology-organization-environment context (Ng, Lit, Cheung, 2022), coordination tasks complexity, and lack of motivators that can influence effectiveness (Trzeciak, Banasik, 2022).

2.2. Defining team effectiveness

For decades researchers and managers have desired to enhance team effectiveness (Kozłowski, Illgen, 2006). However, different studies proposed a variety of factors for team effectiveness such as performances in work quality, changes, interpersonal interactions, values, and overall performance (Tran, Vu, 2021). For example, team effectiveness was defined as performance, satisfaction, and longevity of the team (Dennis, Fuller, Valacich, 2008), team performance, quality of team experience, and team viability (Aubé, Rousseau, 2005), the capacity a team has to accomplish the goals or objectives administered by an authorized organization or individual (Kozłowski, Ilgen, 2006) quality of problem-solving methods, and team members' solutions that increase work efficiency (Hambley, O'Neill, Kline, 2007) or the degree to which a team achieves its objectives, works well together and maintains or

enhances its ability to perform as a unit in the future (Mathieu, Maynard, Rapp, Gilson, 2008). Next, researchers proposed to define and measure team effectiveness based on on-time performance, product quality, and customer satisfaction (Maynard, Mathieu, Rapp, Gilson, 2012).

Researchers underline that team effectiveness evolves as more than the sum of individual efforts, but involves multiple paths of social influence (DeOrtentiis, Summers, Ammeter, Douglas, Ferris, 2013), therefore they define team effectiveness as the collective belief amongst team members in each other's skills and ability to achieve success, which is a social perception influenced by both individuals and the group as a whole. The perception of team effectiveness results in team members who are motivated and engaged in team activities, as they feel invested in the team's goals and perceive their work as meaningful (Muresan, Mititelu, Andres, Schraefel, 2024). Referring to the call to redefine team effectiveness taking into account contemporary circumstances, Junker, Bakker, and Derks, (2025) proposed sustained team effectiveness, defined based on two criteria. Firstly, teams must be able to meet their goals across multiple performance episodes, which is the performance criterion. Second, it should not go at the expense of team members' psychological and physical health, which is the well-being criterion.

It would be valuable to examine this model of sustained team effectiveness with empirical evidence, because as researchers emphasize, there are various aspects of team effectiveness (Tran, Vu, 2021) and an evaluation of specific aspects of team effectiveness is required, therefore a deeper exploration could help in finding insights into team effectiveness.

2.3. Team reflexivity in technology-based teamwork: conceptual background

Team reflexivity refers to the extent to which team members collectively reflect on and adapt their functioning to improve team processes and outcomes (Schippers, Edmondson, West, 2014). This concept draws on theories of team information-processing, which emphasize that team effectiveness depends on the capacity of members to engage in activities such as acquiring, sharing, elaborating, and revising information (Wilson, Goodman, Cronin, 2007). Teams despite having access to a broad pool of information, often rely disproportionately on shared knowledge, neglecting unique perspectives held by individual members (Edmondson, Harvey, 2018). Therefore, a key benefit of team reflexivity lies in mitigating failures and enhancing effectiveness.

Moreover, team members may hesitate to introduce novel ideas due to conformity pressures or low motivation to engage in discussions (Schippers, Rus, 2021). Reflexive teams prioritize open dialogue and critical evaluation of information, fostering an environment in which unshared knowledge is actively solicited and valued (Postmes, Spears, Cihangiret, 2001). Consequently, reflexivity broadens the team's focus, enhancing the diversity of information considered during decision-making.

Research shows that teams often fail to derive meaningful insights from new information due to a tendency to cling to initial preferences (Edmondson, Harvey, 2017) so building psychological safety in the team is crucial to building open discussion and space for reflections (Edmondson, Lei, 2014). Without adequate reflection, diverse perspectives may remain unintegrated, leading to incomplete task representations and diminished team effectiveness (Homan, Van Knippenberg, Van Kleef, De Dreu, 2007). Reflexivity addresses this issue by highlighting discrepancies in task understanding and encouraging members to reconcile different viewpoints. Reflexive teams are better at integrating unique knowledge, ultimately leading to more comprehensive and innovative solutions (Van Ginkel, Tindale, Van Knippenberg, 2009).

Teams in technology-based organizations exist in dynamic and innovative environments, where assumptions quickly become obsolete, and failure to update strategies, reflect and redefine requirements can strongly undermine effectiveness (Schippers, Rus, 2021). Teams often develop habitual routines that persist even when circumstances change, a phenomenon known as inertial behaviour (Gersick, Hackman, 1990). Reflexivity helps teams break free from these patterns by fostering a mindset of continuous improvement. Moreover, holding teams accountable for their decision-making processes, rather than merely their outcomes, encourages ongoing reflection and reassessment (Schippers et al., 2014) consequently, team reflexivity can enhance the team's ability to learn from experience and adjust accordingly to provide better effectiveness. Therefore, considering dynamic changes, complexity, the necessity of continuous learning, and the requirement to adapt to changing circumstances, it is worth exploring how currently team effectiveness is defined and understood in teams that work in technology-based organizations.

3. Methodology

This study undertakes explorative research based on a qualitative method. The group investigation aimed to discover the current understanding of team effectiveness and team effectiveness aspects in teams that work in technology-based organizations. The group of participants consisted of fifty-two IT Experts` who agreed to participate voluntarily in the session.

At the study's design stage, the sample was comprehensively considered referring to commendations proposed by Bekele and Ago (2022), as the sample size and characteristics can significantly affect results. To provide a relevant sample composition for this investigation, only people who work in teams in technology-based organizations were invited. Secondly, the quality of the data is significant, so all participants took part in the investigation (1) voluntarily; (2) in person; (3) and in advance they were aware of the objective of the session.

Thirdly, the wideness or narrowness of the scope of the study affects the size of the sample. In the case of this study, the scope refers to one specified concept: team effectiveness with its aspects.

Referring to particular numbers for sample size, Bernard (2013) suggested that 10-20 key research participants are enough to uncover and understand the major issues in any study of lived experience (after Bekele, Ago, 2022). At least 6 participants for phenomenological studies and approximately 30-50 participants for ethnographies and grounded theory studies were proposed by Bernard (2013). Former, Creswell (2007) recommended between 5 and 25 interviews for a phenomenological study and 20-30 for a grounded theory study. The biggest sample size suggested for the qualitative research was estimated at 30-60 participants (Guest, Bunce, Johnsonet, 2006). To provide as relevant a sample as possible, this suggestion was implemented in this study.

In this study, participants were IT Experts who worked in teams and were responsible for the following specializations: Cybersecurity, Product Management, Project Management, UX design, Software Development, IT Architecture, AI Solutions, DevOps, and IT Leadership. The group of participants consists of nine women and forty-three men. The anonymity of participation was assured to them.

The session took place in November 2024. It was conducted physically, discussions were recorded and transcribed. Additionally, written notes from every participant were collected. Based on them team effectiveness and aspects of team effectiveness were discussed. Group investigation with IT experts provided insights that were examined via text mining and content analysis. More precisely, to conduct an investigation the reflexive thematic analysis was used as the method of identifying, analyzing, and reporting patterns or themes (Braun, Clarke, 2019, 2022),

The protocol of the investigation was the following: (1) presenting the topic of the session which is team effectiveness; (2) ensuring that participation is anonymous and voluntary and that anyone can end the session at any time; (3) agreeing on the objectives of the session which are formulating a team effectiveness definition and identification of team effectiveness aspects crucial for IT Experts who work in teams in technology-based organizations; (4) asking participants to write how they understand team effectiveness – they provided their definitions using keywords working individually in silence; (5) participants were asked to write on a piece of paper keywords that they used; (6) when everyone was ready the discussion was opened starting with keywords they used; (7) when the particular keyword was said aloud other participants were asked to collect papers with the same keyword to see how many included this keyword in the definition and based on this part of the discussion aspects of team effectiveness were identified; (8) participants were asked to read definitions that were prepared at the beginning of the session and every definition was discussed with additional questions to be precise about how definitions are understood including the semantic dimension of the language; (9) during the session in the discussion, categories of team effectiveness aspects and the

definition of team effectiveness were formulated. It is worth to take into account the semantic aspects of the process. Intentionally definitions were not described at the beginning of the action. As some keywords might have several meanings for different people (e.g. cybersecurity or teamwork), the core part of the discussion was the process of reaching the shared definitions.

It is worth underlining that although team reflexivity is discussed in the theoretical background, the present study did not operationalize team reflexivity as an analytic construct. Reflexive thematic analysis (Braun, Clarke, 2019, 2022) was used as a methodological approach to identify themes in how participants defined team effectiveness and which aspects they associated with it.

4. Results

During the investigation, participants mentioned various team effectiveness aspects, that emerged from used keywords. They are presented in Table 1 in the order of how often the aspects appeared in the materials provided by the participants. The twelve aspects identified in this study represent constitutive elements of how IT experts conceptualize team effectiveness in technology-based organizations. Given the exploratory qualitative design, these aspects are not presented as causal antecedents or outcomes, but rather as interconnected components that practitioners associate with effective team functioning.

Table 1.
Team effectiveness aspects emerged from the investigation

Number	Aspects of team effectiveness in technology-based organizations
1	Fulfillment of business requirements
2	High-quality product (including DoD* and DoR**)
3	Teamwork
4	Best practices for development
5	Proper selection of technology
6	Including User Experience (UX) & User Interface (UI)
7	Managing technical debt
8	Skills development
9	Risk management
10	Documentation
11	Cybersecurity
12	Work environment

DoD*: Definition of Done, DoR**: Definition of Ready

Source: own elaboration.

1. Fulfillment of Business Requirements was identified as essential for IT Experts. A successful team consistently delivers solutions that meet the needs and objectives of stakeholders. This involves clear communication with business representatives, comprehensive requirements gathering, and the ability to translate these requirements into technical deliverables. By maintaining a focus on business value, the team can

prioritize work that directly impacts organizational goals, ensuring that efforts align with strategic initiatives and customer expectations.

2. High-quality product was revealed at the second position in conducted investigation. for maintaining user satisfaction and long-term product success. Participants underlined that teams can achieve this by adhering to well-defined standards such as the Definition of Done (DoD) and Definition of Ready (DoR), which ensure that tasks are fully complete and meet all acceptance criteria before moving forward. High-quality products are characterized by robustness, reliability, and maintainability, which are achieved through rigorous testing, regular code reviews, and continuous integration practices.
3. Teamwork fosters a collaborative and supportive work environment, which is fundamental to achieving team goals. Effective teams communicate openly, share responsibilities, and leverage diverse skill sets to solve complex problems. By fostering trust and mutual respect, members can collaborate efficiently, resolve conflicts constructively, and continuously improve both individual and team performance. High levels of teamwork contribute to better decision-making, higher morale, and more innovative solutions. During the discussion participants underlined also awareness of talents in team and reasonable sharing task and duties among team members.
4. Best Practices for Development - In this aspect participants emphasized practices like regular refactoring, thorough testing (unit, integration, and end-to-end), and conducting systematic code reviews. Best practices help prevent technical debt, improve maintainability, and enhance the overall efficiency of the development process. Teams that consistently apply these practices can reduce errors, accelerate delivery, and adapt more easily to changing requirements. Participants provided examples of rules and tools that support the best practices, e.g. DRY (do not repeat yourself, do not do the same job twice) or KISS (principle advises keeping designs simple and avoiding unnecessary complexity, making them user-friendly).
5. Proper Selection of Technology cannot be surprising while experts who work in teams in technology-based organizations participated in the investigation. Selecting the appropriate technology stack is crucial for long-term project success. The choice should align with business requirements, team expertise, scalability needs, and the anticipated lifespan of the product. Proper selection involves evaluating available tools and frameworks, considering both current and future needs, and balancing innovation with stability. Participants underlined that by choosing the right technology, teams can minimize risks, optimize performance, and ensure easier maintenance.
6. Including User Experience (UX) & User Interface (UI). Based on the investigation effective teams prioritize UX and UI as integral components of product development. A well-designed user interface enhances usability, while a positive user experience ensures that the product meets user expectations in terms of functionality, accessibility,

and aesthetics. Teams achieve this by involving UX/UI experts throughout the development process, conducting usability testing, and incorporating user feedback to iteratively improve the product.

7. Managing Technical Debt involves identifying, documenting, and addressing areas of the codebase that require improvement. Unchecked technical debt can lead to increased maintenance costs, slower development, and reduced product quality over time. Participants stressed that effective teams balance the delivery of new features with refactoring efforts and code clean-up to keep technical debt manageable. Regular code reviews, automated testing, and adherence to coding standards help mitigate technical debt.
8. Skills Development was also indicated by participants in this session. C continuous skills development is vital for maintaining a competitive edge in technology-driven environments. Teams that invest in upskilling their members can better adapt to evolving technologies, methodologies, and market demands. Participants have discussed also how it can be achieved and they provide examples such as formal training, mentorship programs, knowledge sharing, and participation in industry events.
9. Risk Management was especially stressed by cybersecurity experts during the session. Effective risk management helps teams anticipate and mitigate potential issues before they become critical. This involves identifying technical, operational, and business risks early, assessing their impact, and developing mitigation strategies. Regular risk assessments, proactive planning, and communication with stakeholders are essential for minimizing project disruptions and ensuring successful outcomes.
10. Documentation can be a bit surprising aspect of team effectiveness. It was a hot discussion about to what extent documentation is essential for team effectiveness. However, especially participants with leading positions and those who have already changed organisation or team underlined this aspect of team effectiveness. Documentation includes requirements, design decisions, API references, user guides, and operational procedures. Therefore, well-maintained documentation ensures knowledge transfer, facilitates onboarding of new team members, and supports ongoing maintenance. Teams should prioritize clear, concise, and accessible documentation as a part of their workflow.
11. Cybersecurity is a critical concern in technology-based organizations. Teams must implement robust security measures throughout the development lifecycle, including secure coding practices, regular vulnerability assessments, and adherence to industry standards and regulations. By proactively addressing security, teams can protect sensitive data, prevent breaches, and ensure compliance with legal requirements, safeguarding both users and the organization. During the discussion, participants underlined that this aspect will be even more essential in the future.

12. Work Environment can significantly contribute to team effectiveness. In this point of the discussion, participants included both the physical and psychological aspects, such as a well-equipped workspace, a culture of respect and inclusion, and support for work-life balance. They agreed that a healthy work environment promotes creativity, reduces stress, and enhances effectiveness.

Above, are presented aspects of team effectiveness discussed by participants of the investigation, using their statements and reflections. The final part of the session was focused on the formulation the definition of team effectiveness clear, understand and accepted by participants. Considering all discussed aspects and frequency of keywords essential to describe team effectiveness the final, formulated definition was the following:

Team effectiveness in technology-based organizations is the ability to deliver high-quality products that meet business requirements through teamwork. Effective teams understand business needs, maintain rigorous quality standards, and foster collaboration.

Additionally, effective teams adopt best development practices, select appropriate technologies, prioritize user experience, manage technical debt, and continually develop skills, taking care of risk management, clear documentation, robust cybersecurity, and a positive work environment.

5. Discussion

5.1. Findings

The findings presented based on the investigation revealed several critical aspects of team effectiveness in technology-based organizations, highlighting the multifaceted nature of effective teamwork. The definition consists of three dimensions such us (1) fulfillment of business requirements, (2) high-quality products, and (3) teamwork. It can be quite surprising that participants did not mention aspects that are included in widely used definitions, such us delivering the product till the deadline (Sarin, O`Connor, 2009), and providing the product within the established budget (Graham, Daniel, Doore, 2016), or viability as the team's capacity to sustain its functioning over time (Mathieu et al., 2008). Instead, participants propose fulfilling business requirements, which is a more comprehensive statement. It can suggest the necessity of wider flexibility, openness, listening, understanding and ability to adapt to dynamic business expectations.

The findings of this study resonate with recent advances in team effectiveness literature, particularly in the context of technology-based environments. The emphasis on aligning team output with business requirements and fostering high-quality deliverables is consistent with studies highlighting the critical role of goal clarity and outcome alignment in team success

(Kozlowski, Ilgen, 2006; Tran, Vu, 2021; Edmondson, Lei, 2014). Aligning team objectives with organizational strategy has become increasingly crucial in modern, rapidly digitizing industries. This alignment ensures that resources are effectively allocated and organizational goals are met efficiently.

The critical role of teamwork, a recurrent theme in prior research, is extensively validated in this study. Larson and DeChurch (2020) identified agile and cross-functional teams as essential in navigating technological complexities, a notion further corroborated by recent empirical studies (Steegh et al., 2025; Muresan et al., 2024). Reflexive practices, which Schippers et al. (2014) identified as pivotal in fostering innovation, were also underscored in our findings, reflecting the ongoing need for teams to regularly evaluate and improve their collaborative processes.

Additionally, the integration of best practices in development, proper technology selection, and a strong focus on user experience mirrors current trends in digital transformation. López-Fernández et al. (2021) pointed out that teams adept at integrating user-centered design and technical best practices tend to outperform their counterparts. Moreover, the growing recognition of managing technical debt as a strategic activity aligns with insights from Trzeciak and Banasik (2022), who emphasized its importance in long-term product sustainability.

Risk management emerged as another key theme in this study, particularly in the context of cybersecurity. Ng et al., (2022) highlighted that proactive risk management practices, including regular threat assessments and the implementation of robust security protocols, are essential in safeguarding critical digital assets. Additionally, the newest research suggests that currently, businesses must have a cybersecurity policy and supporting tools, and cybersecurity management including cybersecurity audit plays a crucial role in enhancing the self-efficacy of the workforce (Chaudhuri, Behera, Balaet, 2025). A supportive work environment was also mentioned by participants as a crucial aspect of team effectiveness. This finding aligns with Edmondson & Lei (2014), who demonstrated that psychological safety within teams fosters open communication and innovation, which cannot be overstated.

5.2. Theoretical Implications

This study contributes to the theoretical understanding of team effectiveness by providing a definition and aspects, particularly within technology-based organizations. First, the study enriches the conceptualization of team effectiveness by integrating business requirements, high-quality product delivery, and teamwork as core dimensions. This redefinition challenges traditional models that emphasize deadlines, budget adherence, and long-term viability (Mathieu et al., 2008; Sarin, O'Connor, 2009). By prioritizing the fulfillment of dynamic business needs, the study underscores the evolving nature of team goals in fast-paced technological environments.

Second, the study supports the understanding of sustained team effectiveness by aligning it with the notion of adaptive capability. As Junker et al. (2025) argue, the sustainability of team effectiveness depends on the ability to meet performance goals while maintaining the well-being of team members. The emphasis on reflexivity, continuous learning, and best practices in development illustrates how teams can remain effective in the face of changing technological landscapes. This reinforces the relevance of reflexive practices (Schippers et al., 2014) and positions team reflexivity as a critical mechanism for fostering adaptability and innovation.

Third, by identifying specific technological, organizational, and environmental aspects of team effectiveness—such as proper technology selection, technical debt management, and cybersecurity—the study broadens the scope of factors traditionally considered in team effectiveness research. The explicit inclusion of these elements suggests that the effectiveness of teams in technology-driven contexts cannot be fully understood without accounting for the complex interplay of these aspects, echoing insights from the Technology-Organization-Environment (TOE) framework (Ng et al., 2022; Tornatzky, Fleischer, 1990).

Lastly, this research highlights the role of psychological and physical work environments in fostering team effectiveness. This finding aligns with Edmondson and Lei's (2014) work on psychological safety and suggests that creating a supportive work environment is not merely a peripheral concern but a central factor influencing team performance and innovation.

Summarizing, the study contributes to theory by proposing a view on team effectiveness tailored to the specificities of technology-based organizations. It calls for future theoretical models to integrate adaptability, reflexivity, and context-specific factors, thereby offering a nuanced understanding of how contemporary teams can thrive in complex, rapidly evolving environments. Additionally, researchers underline that team effectiveness can be improved by supporting the development of social processes such as potency and learning (Puente-Palacios, Barouh, 2021), while one of the best ways to do it, can be team learning focused on a deep understanding of essential definitions.

5.3. Practical Implications

From a practical standpoint, this study offers several actionable insights for managers and team leaders in technology-based organizations. First, ensuring alignment with business requirements should be a primary focus. Clear communication channels between business stakeholders and technical teams can enhance mutual understanding and ensure that delivered solutions meet expectations. Second, maintaining high-quality standards through practices such as adherence to Definition of Done (DoD) and Definition of Ready (DoR) can significantly improve product reliability and user satisfaction. Managers should invest in robust quality assurance processes, including comprehensive testing and regular code reviews. Third, fostering a collaborative team culture is essential. Teams that promote trust, respect, and open communication are more likely to achieve higher levels of innovation and productivity.

Agile leadership practices that empower team members and encourage participation can further enhance collaboration. Additionally, the study highlights the importance of ongoing skills development. Organizations should establish formal training programs, mentorship opportunities, and avenues for knowledge sharing to ensure that team members stay current with technological trends. Risk management emerged as another critical aspect. Managers should implement proactive risk identification and mitigation strategies, particularly in areas such as cybersecurity, where potential threats can have significant consequences.

Lastly, the study underscores the value of a supportive work environment. Providing a well-equipped workspace, promoting work-life balance, and fostering a culture of respect and inclusion can enhance team morale and reduce turnover.

5.4. Limitations

While this study was conducted with attention to methodological rigor, sample composition, and size to provide valuable insights, the research is not without limitations. First, the investigation was conducted in person, with the participation of IT experts from different domains, however, the physical form of the session caused that participants were not a very diverse group in terms of region of origin or cultural background. Moreover, technological organizations are characterized by a high degree of masculinization, resulting in an uneven gender distribution, with a disproportionate ratio of men to women. Future studies could benefit from a more geographically diverse sample to enhance generalizability. Additionally, the particular composition of the group for this session could affect results. Participants shared their reflections strongly based on their specializations, so the group consisted of other specialists or in different proportions, e.g. less Product Managers and more IT architects might change the findings.

Second, the study relied on self-reported statements, which may be subject to biases such as social desirability bias. Participants could share their reflections with diversified levels of openness and honesty. Some of them were a bit shy. Moreover, the investigation was conducted in the form of group session conducted by facilitators and their presents might affected the discussion.

Third, the qualitative nature of the research means that the findings are context-specific and may not be universally applicable. This study was embedded in technology-based organizations and precisely the IT sector. Implementation of findings in another sector might require an investigation relevant to the sector. Additionally, considering the nature of qualitative studies, the quantitative studies could complement these findings by providing statistical validation of the identified aspects.

5.5. Directions for Future Research

Building on the findings of this study, future research could explore several avenues. First, longitudinal studies could examine how team effectiveness evolves over time in response to changes in organizational strategy, technology, and market dynamics. Such studies could provide deeper insights into the sustainability of team effectiveness.

Second, comparative studies across different industries could reveal whether the identified aspects of team effectiveness are unique to technology-based organizations or have broader applicability. This would help refine the proposed model and enhance its generalizability.

Third, further research could investigate the interplay between different aspects of team effectiveness. For example, examining how skills development influences technical debt management or how risk management practices impact product quality could yield valuable insights.

Moreover, an important finding is not only what participants emphasized, but also what was largely absent from their conceptualizations of team effectiveness. Classic criteria frequently discussed in the literature, such as adherence to deadlines, budget performance, or long-term team viability (Mathieu et al., 2008; Sarin, O'Connor, 2009) were not spontaneously mentioned by participants. One plausible explanation is the contextual specificity of technology-based and agile work environments, where effectiveness is often framed less in terms of fixed project constraints and more in terms of continuous value delivery, product quality, and adaptive collaboration. Additionally, as the participants were primarily technical experts rather than managerial decision-makers, budgetary or schedule considerations may have been perceived as organizational constraints external to the team's immediate sphere of influence. Finally, the open-ended structure of the session prompt may have encouraged a focus on shared meaning and operational practices rather than formal performance metrics. Therefore, future research could examine how different organizational roles or alternative framing of effectiveness prompts might elicit more traditional outcome criteria.

Lastly, exploring the role of emerging technologies, such as artificial intelligence and machine learning, in shaping team effectiveness could be a fruitful area of inquiry. As these technologies become more prevalent, exploring their impact on team dynamics, decision-making, and performance will be crucial. Therefore, further studies in these directions should be conducted to provide a deeper and comprehensive understanding.

Conclusion

Reality is complex, ambiguous, and multifaceted, which means that the approach to defining key concepts may vary significantly across different teams and organizations. Consequently, the way certain terms or ideas are understood and framed can differ depending on the unique context, culture, and operational environment of each organization. This is precisely why we should cultivate reflexivity and engage in critical questioning of existing concepts, ensuring that their interpretation and definition remain aligned with an ever-evolving reality. The proposed definition aligns with multidimensional views of team effectiveness emphasizing goal accomplishment and collaborative functioning (Kozlowski, Ilgen, 2006; Mathieu et al., 2008). At the same time, it highlights the particular importance of business requirement fulfillment and product quality in contemporary technology-based teams. By embracing a reflective mindset, we can continuously adapt our understanding to better address the complexities and dynamics of the contemporary environment. Therefore, this study explored the understanding of team effectiveness in technology-based organizations by identifying key aspects that contribute to it.

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References

1. Adzgauskaite, M., Tam, C., Martins, R. (2025). What helps Agile remote teams to be successful in developing software? Empirical evidence. *Information and Software Technology, 177*, 107593. https://doi.org/10.1016/j.infsof.2024.107593
2. Aubé, C., Rousseau, V. (2005). Team goal commitment and team effectiveness: The role of task interdependence and supportive behaviors. *Group Dynamics: Theory, Research, and Practice, 9(3),* 189-204. https://doi.org/10.1037/1089-2699.9.3.189
3. Barley, S.R., Bechky, B.A., Milliken, F.J. (2017). The changing nature of work: Careers, identities, and work lives in the 21st century. *Academy of Management Discoveries*, *3(2),* 111-115. https://doi.org/10.5465/amd.2017.0034

4. Bekele, W.B., Ago, F.Y. (2022). Sample Size for Interview in Qualitative Research in Social Sciences: A Guide to Novice Researchers. *Research in Educational Policy and Management, 4(1),* 42-50. https://doi.org/10.46303/repam.2022.3
5. Bernard, H.R. (2013). *Social Research Methods: Qualitative and Quantitative Approaches* (2nd ed). Los Angeles, CA: SAGE Publications.
6. Braun, V., Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health, 11(4),* 589-597. https://doi.org/10.1080/2159676X.2019.1628806
7. Braun, V., Clarke, V. (2022). Conceptual and design thinking for thematic analysis. *Qualitative Psychology, 9(1),* 3-26. https://doi.org/10.1037/qup0000196
8. Cascio, W.F., Montealegre, R. (2016). How technology is changing work and organizations. *Annual Review of Organizational Psychology and Organizational Behavior*, *3(1),* 349-375. https://doi.org/10.1146/annurev-orgpsych-041015-062352
9. Chaudhuri, A., Behera, R.K., Bala, P.K. 2025. Factors impacting cybersecurity transformation: An Industry 5.0 perspective. *Computers & Security*, *150*, 104267. https://doi.org/10.1016/j.cose.2024.104267
10. Creswell, J. (2007). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches* (2nd ed.). California, United States of America: SAGE Publications, Inc.
11. Dennis, A.R., Fuller, R.M., Valacich, J.S. (2008). Media, tasks, and communication processes: A theory of media synchronicity. *MIS Quarterly, 32(3),* 575-600. https://doi.org/10.2307/25148857
12. DeOrtentiis, S.P., Summers, K.J., Ammeter, P.A., Douglas, C., Ferris, R.G. (2013). Cohesion and satisfaction as mediators of the team trust – team effectiveness relationship: An Interdependence theory perspective. *Career Development International*, *18*, 521-543. http://dx.doi.org/10.1108/CDI-03-2013-0035, Emerald Group Publishing Limited.
13. Edmondson, A.C., Harvey, J.F. (2018). Cross-boundary teaming for innovation: Integrating research on teams and knowledge in organizations. *Human Resource Management Review, 28(4),* 347-360. https://doi.org/10.1016/j.hrmr.2017.03.002
14. Edmondson, A.C., Harvey, J.-F. (2017). *Extreme teaming: Lessons in complex, cross-sector leadership.* Emerald Group Publishing.
15. Edmondson, A.C., Lei, Z. (2014). Psychological safety: The history, renaissance, and future of an interpersonal construct. *Annual Review of Organizational Psychology and Organizational Behavior, 1*, 23-43. https://doi.org/10.1146/annurev-orgpsych-031413-091305
16. Garro-Abarca, V.M., Palos-Sanchez, P.R., Rus-Arias, E. (2020). Working in virtual teams: A systematic literature review and a bibliometric analysis. *IEEE Access*, *8*, 168923-168940. https://doi.org/10.1109/access.2020.3023546

17. Gersick, C.J.G., Hackman, J.R. (1990). Habitual routines in task-performing groups. *Organizational Behavior and Human Decision Processes, 47(1),* 65-97. https://doi.org/10.1016/0749-5978(90)90047-D
18. Gimpel, H., Hosseini, S., Huber, R., Probst, L., Röglinger, M., Faisst, U. (2018). Introduction to digitalization cases: How organizations rethink their business for the digital age. *Digitalization Cases: How Organizations Rethink Their Business for the Digital Age,* 1-12. https://doi.org/10.1007/978-3-319-95273-4_1
19. Graham, C.M., Daniel, H., Doore, B. (2016). Millennial teamwork and technical proficiency's impact on virtual team effectiveness: implications for business educators and leaders. *International Journal of E-Collaboration, 12(3),* 34-50. doi:10.4018/IJeC.2016070103
20. Guest, G., Bunce, A., Johnson, J. (2006). *How Many Interviews Are Enough? An Experiment with Data Saturation and Variability*. SAGE Journals, 59-82.
21. Hambley, L.A., O'Neill, T.A., Kline, T.J.B. (2007). Virtual team leadership: the effects of leadership style and communication medium on team interaction styles and outcomes. *Organizational Behavior and Human Decision Processes, 103(1),* 1-20. doi:10.1016/j.obhdp.2006.09.004
22. Homan, A.C., Van Knippenberg, D., Van Kleef, G.A., De Dreu, C.K. 2007. Bridging faultlines by valuing diversity: Diversity beliefs, information elaboration, and performance in diverse work groups. *Journal of Applied Psychology*, *92(5),* 1189-1199. https://doi.org/10.1037/0021-9010.92.5.1189
23. Junker, T.L., Bakker, A.B., Derks, D. (2025). Toward a theory of team resource mobilization: A systematic review and model of sustained agile team effectiveness. *Human Resource Management Review, 35(1),* 101043. https://doi.org/10.1016/j.hrmr.2024.101043
24. Kozlowski, S.W.J., Ilgen, D.R. (2006). Enhancing the Effectiveness of Work Groups and Teams. *Psychological Science in the Public Interest, 7(3),* 77-124. https://doi.org/10.1111/j.1529-1006.2006.00030.x
25. Larson, L., DeChurch, L.A. (2020). Leading teams in the digital age: Four perspectives on technology and what they mean for leading teams. *The Leadership Quarterly, 31(1),* 101377. https://doi.org/10.1016/j.leaqua.2019.101377
26. Leite, L., Pinto, G., Kon, F., Meirelles, P. (2020). The organization of software teams in the quest for continuous delivery: A grounded theory approach. *Information and Software Technology, 123*, 106294. https://doi.org/10.48550/2008.08652
27. Li, J.C.-F. (2020). Roles of individual perception in technology adoption at organization level: Behavioral model versus TOE framework. *Journal of System and Management* Sciences, *10(3),* 99.97-118. https://doi.org/10.33168/jsms.2020.0308
28. López-fernández, D., Dı´az, J., Garcı´a, J., Pérez, J.E., González-Prieto, Á. (2021). DevOps Team Structures: Characterization and Implications. *IEEE Transactions on Software Engineering, 48*, 3716-3736. doi:10.1109/TSE.2021.3102982

29. Mathieu, J.E., Maynard, M.T., Rapp, T., Gilson, L. (2008). Team effectiveness 1997-2007: A review of recent advancements and a glimpse into the future. *Journal of Management, 34(3),* 410-476. https://doi.org/10.1177/0149206308316061
30. Maynard, M.T., Mathieu, J.E., Rapp, T.L., Gilson, L.L. (2012). Something(s) old and something(s) new: Modeling drivers of global virtual team effectiveness. *Journal of Organizational Behavior, 33(3),* 342-365. https://doi.org/10.1002/job.1772
31. Muresan, G.C., Mititelu, S., Andres, J., Schraefel, M.C. (2024). Should I introduce myself?: Asynchronous semi-guided professional introductions for enhanced perceived team effectiveness in new virtual dyadic teams. *International Journal of Human–Computer Studies, 188*, 103279. https://doi.org/10.1016/j.ijhcs.2024.103279
32. Ng, P.M.L., Lit, K.K., Cheung, C.T.Y. (2022). Remote work as a new normal? The technology-organization-environment (TOE) context. *Technology in Society, 70*, 102022. https://doi.org/10.1016/j.techsoc.2022.102022
33. Postmes, T., Spears, R., Cihangir, S. (2001). Quality of decision making and group norms. *Journal of Personality and Social Psychology, 80(6),* 918-930. https://doi.org/10.1037/0022-3514.80.6.918
34. Puente-Palacios, K.E., Barouh, R.T.d.J. (2021). Relationship between team learning and team effectiveness. *Journal of Workplace Learning, Vol. 33, No. 7*, pp. 534-546. https://doi.org/10.1108/JWL-11-2020-0180
35. Reis, J., Amorim, M., Melão, N., Matos, P. (2018). Digital transformation: A literature review and guidelines for future research. *Advances in Intelligent Systems and Computing, 745*, 411-421. https://doi.org/10.1007/978-3-319-77703-0_41
36. Sarin, S., O'Connor, G.C. (2009). First among equals: The effect of team leader characteristics on the internal dynamics of cross- functional product development teams. *Journal of Product Innovation Management, 26(2),* 188-205. https://doi.org/10.1111/j.1540-5885.2009.00344.x
37. Schippers, M.C., Rus, D.C. (2021). Team reflexivity and innovation: The moderating role of team context. *Journal of Business Research, 127*, 548-559. https://doi.org/10.1016/j.jbusres.2021.01.065
38. Schippers, M.C., Edmondson, A.C., West, M.A. (2014). Team reflexivity as an antidote to team information-processing failures. *Small Group Research, 45(6),* 731-769. https://doi.org/10.1177/1046496414553473
39. Shvindina, H., Piven, D. (2024). The Evolution of Project-Based Organizations: A Bibliometric Analysis and Literature Review. *Journal of Technology Management & Innovation, 19*(2), 112-132. https://doi.org/10.4067/S0718-27242024000200112
40. Steegh, R., Van De Voorde, K., Paauwe, J. (2025). Understanding how agile teams reach effectiveness: A systematic literature review to take stock and look forward. *Human Resource Management Review, 35(1),* 101056. https://doi.org/10.1016/j.hrmr.2024.101056

41. Tran, T.B.H., Vu, A.D. (2021). Transformational leadership versus shared leadership for team effectiveness. *Asian Academy of Management Journal, 26(2),* 143-171. https://doi.org/10.21315/aamj2021.26.2.7
42. Trzeciak, M., Banasik, P. (2022). Motivators influencing the efficiency and commitment of employees of agile teams. *Journal of Open Innovation: Technology, Market, and Complexity, 8(4),* 176. https://doi.org/10.3390/joitmc8040176
43. Urbach, N., Röglinger, M. (2019). *Digitalization Cases - How Organizations Rethink Their Business for the Digital Age.* Cham: Springer International Publishing, https://link.springer.com/book/10.1007/978-3-319-95273-4
44. Van Ginkel, W.P., Tindale, R.S., Van Knippenberg, D. (2009). Team reflexivity, development of shared task representations, and performance improvement. *Organizational Behavior and Human Decision Processes, 109(1),* 61-71. https://doi.org/10.1016/j.obhdp.2009.12.002
45. Wilson, J.M., Goodman, P.S., Cronin, M.A. (2007. Group learning. *Academy of Management Review, 32(4),* 1041-1059. https://doi.org/10.5465/amr.2007.26585724

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THE IMPACT OF EMPLOYEES' EDUCATION LEVEL ON ACQUIRING DIRECT INVESTMENTS IN THE VISEGRAD GROUP COUNTRIES

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Purpose: Following the transition to a market economy in the 1990s, the Visegrad Group countries (V4: Czechia, Hungary, Poland, and Slovakia) began to narrow the economic gap with developed nations. After their accession to the European Union, this convergence accelerated. This article examines the impact of employees' education levels on changes in human capital efficiency and the attraction of foreign investments in the V4 countries.
Design/methodology/approach: The study draws on data from Eurostat, UNCTAD (2025), and Stooq.com (2025) for the period 2004-2024. It investigates the relationship between employees' education levels, human capital efficiency, and foreign investment inflows in the V4 countries using descriptive statistics, as well as correlation and determination analyses.
Findings: The results indicate that VAIC, as a measure of human capital efficiency in long-term, macroeconomic analyses, has limited applicability. Based on the ratio of real GDP growth to employment, the study finds that an increase in human capital (employees' educational attainment) and its efficiency is positively associated with the attraction of foreign investments.
Research limitations/implications: The generalizability of the findings is constrained by the specific characteristics of the V4 economies. The measures recommended in this study may have weaker effects in less developed countries due to their lower technological sophistication.
Practical implications: Since education, particularly higher education, enhances human capital efficiency and increases the scale of foreign investment inflows, governments should promote high participation in tertiary education. Fiscal interventions that reduce the wage share in GDP should be limited, as they discourage employees from investing in their own human capital.
Social implications: Citizens should be encouraged to improve their educational attainment, as it benefits both them and the entire economy, making it easier to attract foreign investments.
Originality/value: The article challenges the suitability of VAIC for long-term international comparisons. It underscores the significance of employees' education in driving economic development and advocates for restrained fiscal intervention by the state.
Keywords: Visegrad Group countries; VAIC; real GDP-to-employment ratio; employees' education level; human capital efficiency; foreign direct investment.
Category of the paper: Research paper.

1. Introduction

The interest in the concept of intellectual capital management and its element in the form of human capital, is related to the formation of a new civilization, the main attribute of which is knowledge and its effective use, resulting in the achievement of competitive advantage. Success and competitive advantage of an enterprise and country is not created by knowledge itself, but by its skillful use, transformation and exploitation (Mačerinskienė, Aleknavičiūtė, 2017).

The efficiency of human capital determines the competitiveness of human resources available to individual economies (Dakhli, De Clercq, 2004; Huggins et al., 2017). The aim of the article is to assess the relationship between the level of education of employees, changes in human capital efficiency (understood as average employee productivity) and the acquisition of foreign direct investment. It was assumed that an increase in employees' educational attainment facilitates the attraction of foreign investments, which in turn contributes to long-term growth in labor productivity. The article employs two indicators of human capital efficiency: the ratio of real GDP to employment, and Pulic's VAIC index (Pulic, 2000, 2004). A comparative analysis of these indicators, from the perspective of their usefulness in illustrating long-term macroeconomic changes, served as the basis for selecting one of them as a reference point for further research. The article contributes to the existing literature in several ways. First, we verify the usefulness of the Pulic' method in determining the value and efficiency of human capital in international comparisons over a long period. The subject of the study are the Visegrad Group (V4) countries, which are similar to each other in terms of development level, institutional conditions, economic structure and employment. Therefore, most of the limitations (wage gap, structural, institutional differences) for using VAIC as a measure of the value and efficiency of human capital in international comparisons are absent. Second, we complement theoretical work on the importance of the employees' education level on economic outcomes, including attracting foreign investment. Third, we complement empirical work using macroeconomic data to examine the relationship between the structure of employment by educational level (distinguishing between higher and secondary education) and the rate of economic growth and attracting foreign investment. Finally, our article contributes to the extensive and intensified policy and academic literature on the profitability of investing public funds in higher education and its economic effects.

The article consists of a theoretical introduction based on a literature review, a presentation of the method used and the sources of data acquisition, an empirical section, a discussion and conclusions.

2. Literature review

Investment in human capital by increasing resources for education is crucial for economic development, especially in the long term (Kraay, 2018; Lenkei, 2020; Andrijauskiene, 2021). Education increases people's productivity and preparing them for the challenges of advanced economies (Becker, 1993; Goldin, 2016; Habib et al., 2019), facilitating innovation and absorption of new technologies (Mulliqi, 2018; Castell´o-Climent, 2019; Diebolt, Hippe, 2019; Rossi, 2019; Sasso, Ritzen, 2019).

Outside the education system, employees can improve their human capital through: independent education, on-the-job training, public training in labor market policy, work experience in various types of organizations, social environment, peers, intergenerational transmission of human capital within the family, etc. (Hanushek, Woessmann, 2008; Antonelli et al., 2010; Flabbi, Gatti, 2018).

All the above-mentioned factors only create opportunities for human capital building, it is the workers themselves who decide how much they want to use them. Like the state and businesses, households devote time and resources to human capital development taking into account current benefits (consumption, acquisition of skills required in the labor market), but also about future monetary returns and non-monetary benefits. When it comes to deciding on university enrollment, individual returns are not fully known to students until they enter the labor market, making entering and completing studies a risky investment (Lee et al., 2015). Such a decision depends, among other things, on the magnitude of the income gap between university graduates and those with a high school education.

Higher education is seen as a prerequisite for access to higher segments of the occupational structure, requiring knowledge and greater skills. From the employee's perspective, higher education enables performing more complex tasks, allowing for higher incomes. From a macroeconomic perspective, higher productivity and development potential of employees with higher education support the development of the economy (Bal-Domańska, 2022; Schultheiss et al., 2023; Manuel, 2024). Based on studies covering both the OECD and developing countries, it was found that in countries that double the average number of years of secondary education, output per worker increases by a third.

Automation and digitalization increase the demands on employees, which entails the expansion of higher education in developed countries, contributing to increased productivity and innovation (Schultheiss et al., 2023). The level of actual earnings is influenced by the match between graduates' human capital and employers' requirements. University graduates working in positions related to their field of study earn more than those working in fields unrelated to their completed field of study (Somers et al., 2019; Manuel, 2024).

Potentially, the return on investment in human capital should be higher in developing countries, as it enables faster economic growth by attracting foreign investment. These contribute to increased labor productivity and raising funds for investment in human capital (Lim et al., 2018). According to neoclassical growth theory, when similar technologies are used, capital returns in richer regions (countries) are reduced, which attracts it to poorer locations. This leads to convergence in the long term within and between countries (Vatsa, Pino, 2023).

Technology transfers (direct investment) will not occur if the level of skills available in a country is not sufficient to assimilate and appropriately use the technology (Ali et al., 2018; Diebolt, Hippe, 2019; Mei, 2023). This is supported by studies showing that greater benefits from globalization accrue to those developing countries that have high secondary and higher education enrollment rates and high levels of health capital (Olagunju et al., 2019). A country receiving foreign direct investment (FDI) usually gains benefits in the form of further improving the level of human capital and applied technology (Mei, 2023), increasing its share in foreign trade, reducing unemployment, increasing prosperity and reallocating the labour force to more productive sectors (Carrère et al., 2020).

From the perspective of the article's focus, it is important to select an appropriate measure to assess changes in the value and efficiency of human capital. The most frequently proposed methods in the literature are cost or income methods of valuing human capital and its efficiency. In the cost approach, the human capital of an individual employee is defined as the outlay on acquiring: knowledge, experience and skills acquired at school, at work and in other forms of further education (Østergaard, Marinova, 2018; Naval et al., 2020), supplemented by costs incurred by the state and family (for education, health care), companies that employed the employee (expenditures on training and development at work) and the employee's own expenses. The income approach identifies human capital with the employee's productivity, which is manifested by their wage rate (Buesselmann, 2009; Škare, Lacmanović, 2015).

The GDP to employment ratio can be used to assess the efficiency of human capital on a macroeconomic scale in the long term (Klinger, Weber, 2019; Vladušić et al., 2020). An alternative measure of human capital efficiency is the Value Added Intellectual Coefficient (VAIC), proposed by Pulic (Pulic, 2000, 2004). Critics of Pulic's model point out that VAIC is not a good tool for international comparisons, under conditions of strong wage diversification (Ståhle et al., 2011, Iazzolino, Laise, 2013; Marzo, 2022). Proponents of the VAIC model, on the other hand, point out that estimates are based on market data (Ulum et al., 2014; Singla, 2020).

The V4 countries compared in the article are linked by geographical, historical and cultural proximity, a similar level of development, institutional similarities and a similar structure of the economy and employment (Dmytrów, Bieszk-Stolorz, 2019). In addition, at the same time (in 2004) the V4 countries joined the EU, which accelerated the acquisition of foreign direct investment (FDI), which created new jobs and contributed to wage growth (Kónya, 2018;

Antohi et al., 2019). The Visegrad Group countries rarely coordinate their positions on issues decided at the European Union level because their political and economic priorities differ (Dangerfield, 2008).

Despite relatively rapid economic growth in the 1990s and early 21st century, initiated by the transition from a socialist to a market economy, the V4 countries were characterized by a low level of GDP per capita, especially compared to the EU15 countries (Schmidt, 2016). Accession to the EU accelerated V4 economies' growth through access to the EU Common Market, EU structural funds, and foreign investments driven by relatively low labor costs (Prohorovs, Bistrova, 2022; Schwabe, 2021).

3. Research methods

The literature study allowed the following research hypotheses:

H1: The Real GDP to Employment and VAIC are reliable measures of changes in human capital efficiency in international comparisons.

H2: The growth in education of employees in the economies of the V4 countries facilitates the acquisition of foreign investments.

Verification of the first hypothesis was based on Eurostat data (Eurostat, 2025), i.e.:

- employment by sex, age and educational attainment level – sex: Total; age: 15-64; educational attainment level: Upper secondary and post-secondary non-tertiary education (levels 3-4), Tertiary education (levels 5-8); all in thousand persons.
- Gross Domestic Product (GDP) and main components: output (including Gross Value Added), expenditure and income (including Compensation of employees, Gross Operating Surplus and Mixed Income, Taxes on Production and Imports Less Subsidies) – current prices, chain linked volumes (2010); all in million euro.
- UN data (UNCTAD, 2025) and EURUSD quotes from Stooq.com (Stooq.com, 2025) were used to verify the second hypothesis:
- foreign direct investment: inward and outward flows and stock – Stock; annual; current prices, million US dollars.

For the verification of the first hypothesis, the initial assumption was made that the depiction of the efficiency of human capital (understood as the ratio of outputs to inputs), is the efficiency (productivity) of labor, which can be expressed using an indicator based on the size of employment (1), as well as, analogous to the VAIC model, on employee compensation (2) and (3):

$$Real\ GDP\ to\ Employment = \frac{GDP\ in\ Market\ Prices\ (Constant\ Prices\ from\ 2010)}{Employment} \quad (1)$$

$$Nominal\ Gross\ Value\ Added\ to\ Compensation\ of\ Employees = \\ = \frac{Nominal\ Gross\ Value\ Added}{Nominal\ Compensation\ of\ Employees} = \frac{Gross\ Value\ Added\ (Current\ Prices)}{Compensation\ of\ Employees\ (Current\ Prices)} \quad (2)$$

$$Nominal\ GDP\ to\ Compensation\ of\ Employees = \\ = \frac{Nominal\ GDP\ in\ Market\ Prices}{Nominal\ Compensation\ of\ Employees} = \frac{GDP\ in\ Market\ Prices\ (Current\ Prices)}{Compensation\ of\ Employees\ (Current\ Prices)} \quad (3)$$

A comparison of these indicators was made in order to decide which one to use later in the study. To determine the reasons for the variation in the analyzed indicators, changes in the structure of GDP in terms of income over the analyzed period were presented (Compensation of Employees, Gross Operating Surplus and Mixed Income, Taxes on Production and Imports Less Subsidies). Then the correlation between Real GDP and different measures of human capital efficiency (1-3) were calculated, what allowed for the verification of the hypothesis concerning the reliability of VAIC as a long-term measure of human capital efficiency in international comparisons.

For the purpose of verifying hypothesis 2 data on education levels for the 15-64 age group (Eurostat, 2025) as well as data on foreign direct investments (UNCTAD, 2025) were used. The groups of "upper secondary and post-secondary non-tertiary education" (3-4 education level) were used as secondary education, and "tertiary education" (5-8 education level) was used as tertiary education. The scale of direct investment sourced was related to the indicators used earlier, including the share in employment of people with higher education. Shares among employees with tertiary education and persons with at least secondary education (sum of persons with secondary and tertiary education) were next contrasted with data on Foreign Direct Investments.

Relationships between the considered quantities (indicators) were examined using Pearson's linear correlation coefficient ($p < 0.05$ was used as the level of significance), at the same time providing the coefficient of determination R^2, as a measure of the fit of the regression function to the empirical data.

4. Results

The research began by testing the hypothesis of whether the Real GDP-to-Employment ratio and VAIC-based measures accurately reflect changes in human capital efficiency in international comparisons for the V4 countries (Figure 1). As can be seen, in the analyzed economies between 2004 and 2024 (excluding Hungary) there was a significant difference in trend depending on the indicator adopted. In the first case, *Real GDP to Employment* (1),

one can see in all the economies under consideration a systematic increase throughout the study period. In contrast, measures based on VAIC, *Nominal Gross Value Added to Compensation of Employees* (2) as well as *Nominal GDP to Compensation of Employees* (3), show an increase over the entire period only for Hungary.

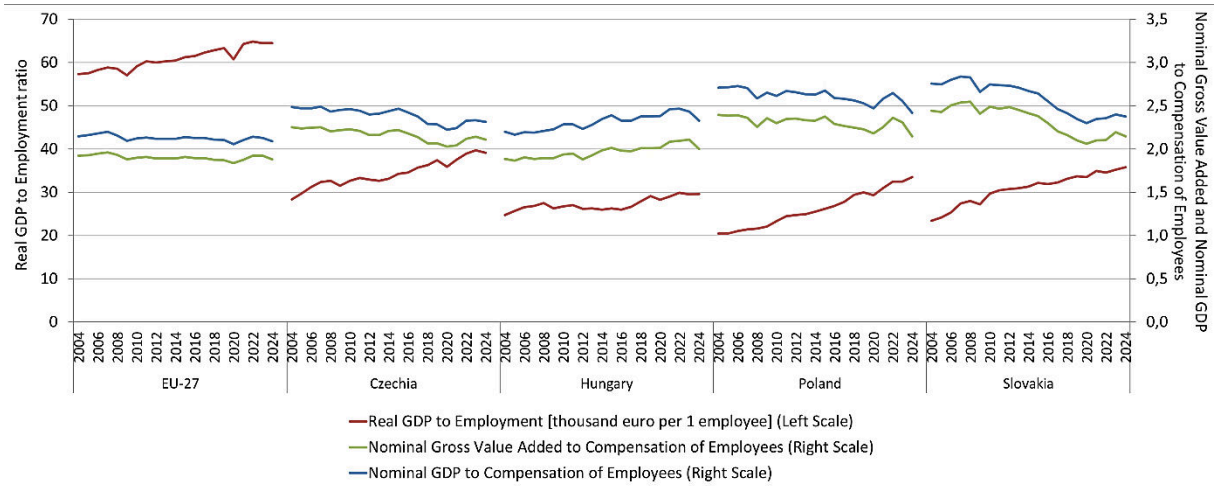


Figure 1. Labor productivity from various perspectives in the EU-27 and Visegrad Countries, 2004-2024.

Source: own compilation based on Eurostat data: Population and social conditions, Labor market, Employment and unemployment, GDP and main components (output, expenditure and income).

To explain the reasons for these discrepancies, it is necessary to look at the structure of GDP in terms of income (Figure 2). The data in Figure 2 (the structure of GDP in income terms by employee compensation, corporate operating surplus and indirect taxes) indicate that, unlike in the other analyzed economies, the dynamics of employee compensation in Hungary was systematically lower than the dynamics of GDP, which was positively reflected in the values of the corresponding indicators of labor efficiency (productivity) in relation to employee compensation.

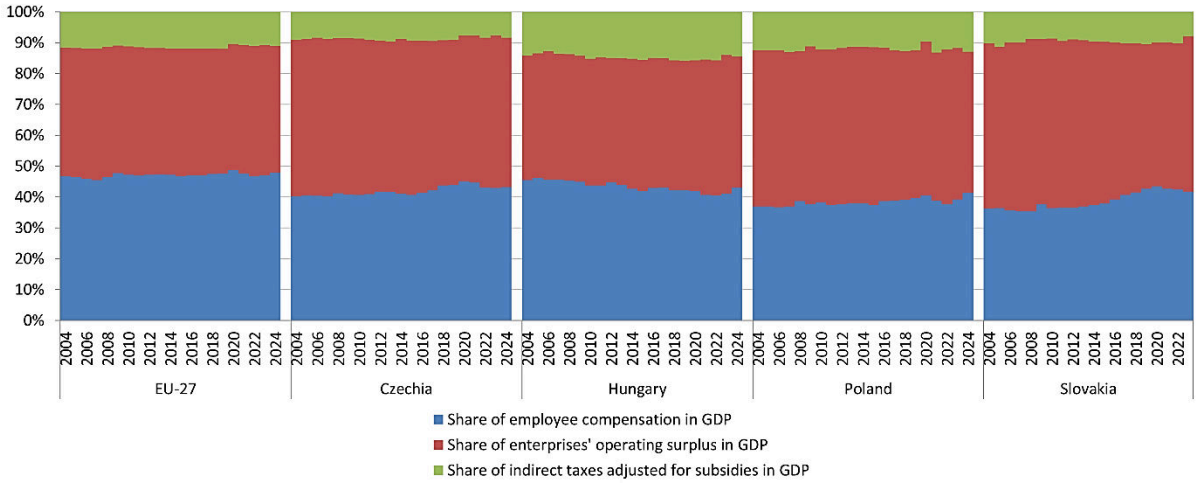


Figure 2. Income Structure of GDP in the EU-27 and Visegrad Countries, 2004-2024.

Source: own compilation based on Eurostat data: GDP and main components (output, expenditure and income).

Due to faster growth in the share of compensation in GDP (than the EU-27 average), for the Czechia, Poland and Slovakia, the VAIC-based indicators for these countries declined compared to the EU average. Hungary, which was the only country to see an improvement in VAIC-based indicators, was at the same time characterized by the lowest growth in *Real GDP* and *Real GDP to Employment* (1) during the period under review (Figure 1).

This confirms that the improvement in VAIC-based indicators for Hungary was mainly the result of a decline in the share of employee compensation in GDP. In addition, VAIC-based indicators show declines in human capital efficiency in the three V4 countries, which are successively reducing the gap to the EU-27 average (Figure 3 and Figure 4). Therefore, it does not correctly reflect the long-term trends in human capital efficiency in the analyzed economies.

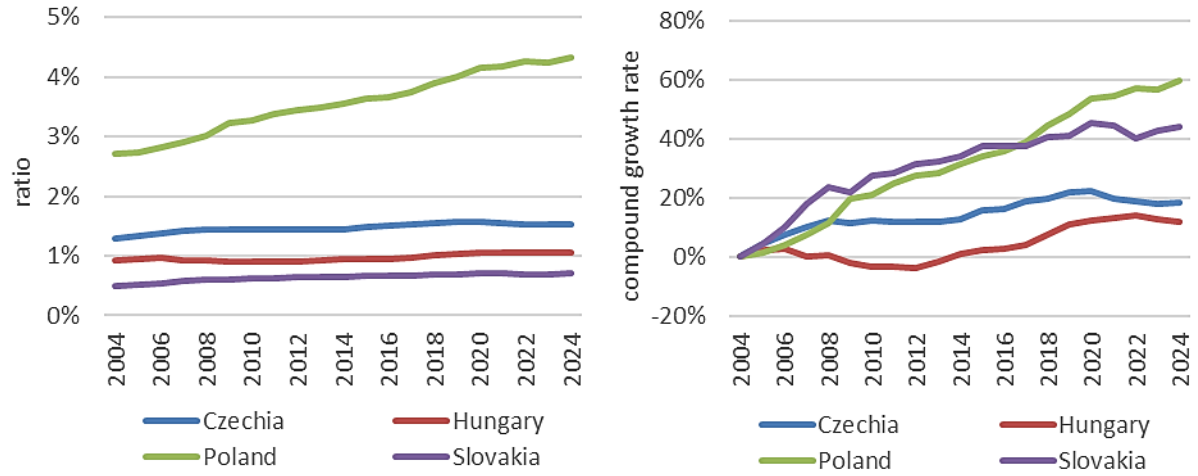


Figure 3. *GDP* of each V4 country to *GDP* of EU from 2004 to 2024. Cumulatively (year 2004 = 0%). GDP data at constant market prices from 2010.

Source: own compilation based on Eurostat data (as in Figure1).

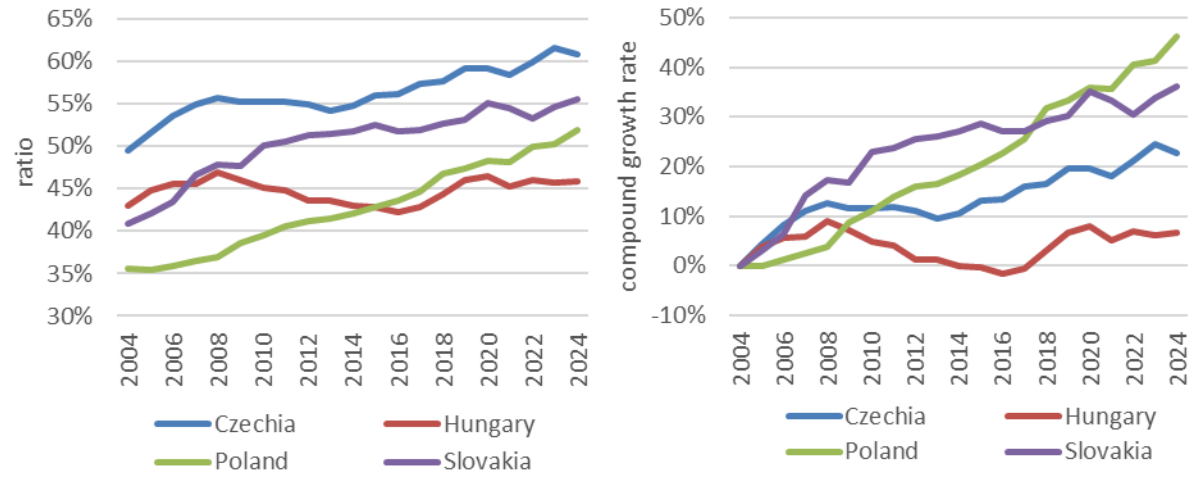


Figure 4. *Real GDP to Employment ratio* of each V4 country to *Real GDP do Employment ratio* of EU from 2004 to 2024. Cumulatively (year 2004 = 0%). GDP data at constant market prices from 2010.

Source: own compilation based on Eurostat data (as in Figure1).

In all the economies considered, there is a statistically significant, strong, positive and confirmed by high R^2 readings, correlation between *Real GDP* and the *Real GDP to Employment indicator* (1) (Table 1). A statistically significant correlation, although no longer necessarily positive and not as strong, also exists for the V4 economies between *Real GDP* and the other two indicators considered, based on the level of employee compensation. It should be noted that in the case of Hungary, the correlation for the indicators relating to the level of wages was strong and positive (which is due to the aforementioned falling share of compensation in GDP). In the other three V4 countries, the correlation for these indicators turned out to be relatively strong, but of a negative nature. Taking into account the above conclusions, we assume that the first hypothesis is not confirmed. *Real GDP to Employment* ratio (1) is a better long-term measure of changes in human capital efficiency than VAIC in international comparisons.

Table 1.
Pearson correlation (r) and determination coefficients (R2) between Real GDP and selected human capital efficiency indicators (1,2,3) in the Visegrad countries and the EU-27

		Real GDP				
		EU-27	**Czechia**	**Hungary**	**Poland**	**Slovakia**
Real GDP to Employment (1)	*r*	0,9650*	0,9876*	0,9153*	0,9960*	0,9859*
	R^2	0,9312	0,9754	0,8378	0,9921	0,9720
Nominal Gross Value Added to Compensation of Employees (2)	*r*	-0,3376	-0,8244*	0,8824*	-0,6642*	-0,8263*
	R^2	0,1140	0,6796	0,7787	0,4411	0,6827
Nominal GDP to Compensation of Employees (3)	*r*	-0,4005	-0,8447*	0,8194*	-0,7674*	-0,8726*
	R^2	0,1604	0,7135	0,6715	0,5888	0,7614

* correlation significant at the 0.05 level.

Source: own compilation based on Eurostat data (as in Fig.1).

Given these conclusions, further research focuses only on the *Real GDP to Employment* ratio (1), as an indicator showing the efficiency of human capital across economies.

Hypothesis H2 presented in the article assumes that growth in education of employees in the economies of the V4 countries is associated with the acquisition of foreign investment.

It should be emphasized that, during the period under analysis, there was a significant change in the educational composition of the workforce in the V4 countries as well as in the EU as a whole. These changes were accompanied by variations in real GDP relative to employment (Figure 5). The share of employees with at least a secondary education (the sum of those with secondary and higher education) was higher in the V4 countries than the EU-27 average throughout the analyzed period. In recent years, the proportion of employees with higher education in Poland has exceeded the EU-27 average.

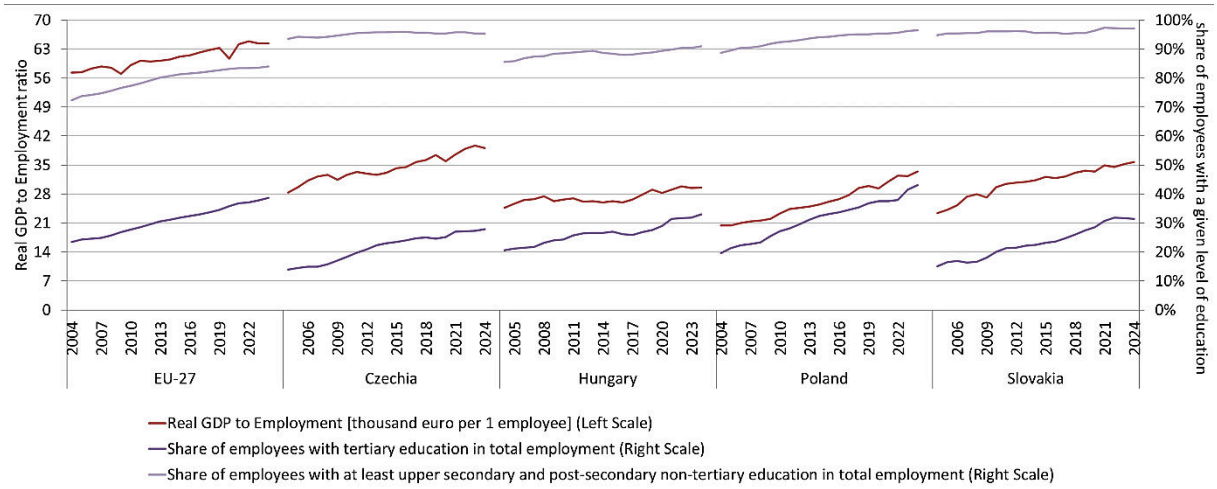


Figure 5. Real GDP to Employment and changes in the share of employees with secondary and tertiary education in the EU-27 and Visegrad Countries, 2004-2024.

Source: own compilation based on Eurostat data: Population and social conditions, Labor market, Employment and unemployment, GDP and main components (output, expenditure and income).

One of the factors supporting economic growth and labor productivity is the foreign investment attracted by individual economies. The economies of the V4 countries were characterized by a simultaneous increase in the scale of direct investment and the *Real GDP to Employment ratio* (1) during the analyzed period (Figure 6).

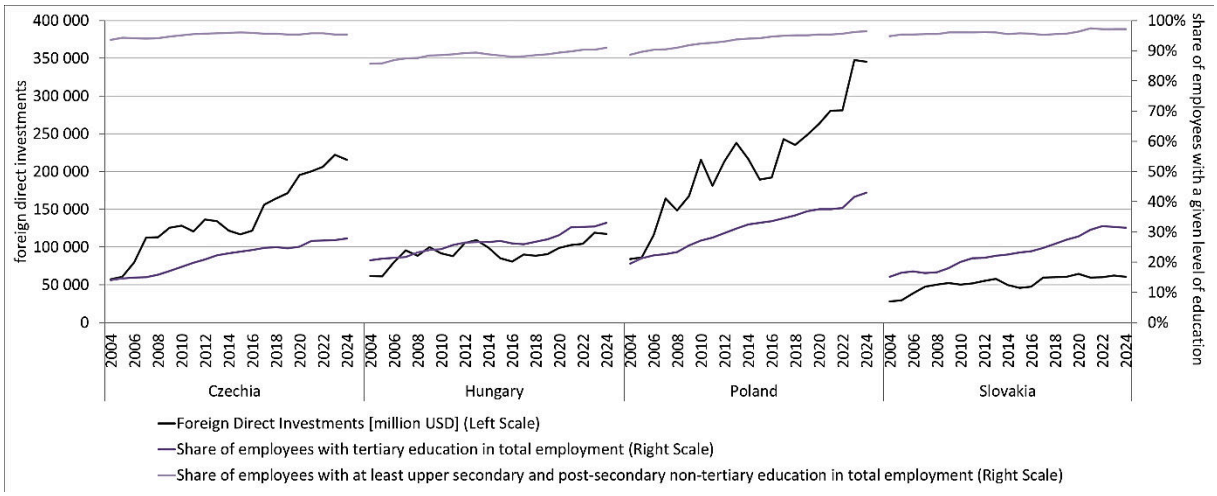


Figure 6. Foreign Direct Investment and the Employment Share of Employees by Education Level in the EU-27 and Visegrad Countries, 2004-2024.

Source: own compilation based on data from Eurostat (Population and social conditions. Labor market, Employment by sex, age and educational attainment level), UN (UNCTAD stat: Foreign direct investment. Inward and outward flows and stock, annual) and Stooq.com.

Table 2 shows the correlation between direct investment and employment structure from the perspective of education level. The correlation between the scale of direct investment and the *Real GDP to Employment ratio* (1) for all V4 countries turned out to be generally strongly positive, statistically significant and confirmed by generally high R^2 values (Table 2).

Table 2.
Pearson correlation (r) and determination coefficients (R^2) between direct investment and selected indicators in Visegrad countries

		Foreign Direct Investments (stock)			
		Czechia	**Hungary**	**Poland**	**Slovakia**
Share of employees with tertiary education in total employment	*r*	0,8847*	0,7627*	0,9428*	0,7900*
	R^2	0,7827	0,5817	0,8890	0,6240
Share of employees with at least upper secondary and post--secondary non-tertiary education in total employment	*r*	0,6049*	0,9112*	0,9238*	0,6444*
	R^2	0,3660	0,8302	0,8535	0,4153

* correlation significant at the 0.05 level.

Source: own calculations based on Eurostat data (as in Fig. 5).

In all cases considered (EU-27 and V4 countries), there is a statistically significant, strongly positive correlation between the share of workers with tertiary education and the value of foreign direct investment (assets at the end of the period), confirmed at the same time by high values of R^2. Such a high correlation did not occur in Czechia and Slovakia with regard to the share of employment of people with at least secondary education.

The results obtained indicate that hypothesis H2 should be considered confirmed. The acquisition of foreign investment is accompanied by an increase in the efficiency of human capital. The observed correlations indicate that direct investment in the V4 countries is largely concentrated in sectors requiring highly educated workers.

5. Discussion

The motivation to write this article was to check whether the reduction of the difference between the economic development of the V4 countries (Czech Republic, Poland, Hungary, Slovakia) and the EU-27 average can be explained by the employees' education level affecting the efficiency of human capital and direct investment. Statistical data indicate that the pace of "catching up" the economic backwardness is different, depending on the increase in the efficiency of human capital, the share of wages in GDP and the starting position. The Real GDP to Employment ratio (1) is growing the fastest in the case of Poland, which at the beginning of the period under review was in last place in the ranking, which is consistent with the neoclassical growth theory (Kokocinska, Puziak, 2018; Vatsa, Pino, 2023).

The reason for Hungary's peculiar situation can be attributed to the fact that the share of indirect taxes adjusted with subsidies in GDP during the period under review increased in this economy by 3%, reaching 16% (Poland was second, where this share increased by 1%, to 14%). Increasing state fiscal interference in the economy was accompanied by relatively high employment growth (although lower than in Poland and Slovakia) (Eurostat database: Population and social conditions, Labor market, Employment and unemployment). The weakest relationship between GDP and compensation in Hungary may affect the limited

motivation to undertaking studies by employees (Lee et al., 2015), which the long term results is the slowest catch-up with the EU-27 average. Such conclusions in the case of Hungary are supported by definitely the lowest growth in the number of employees with higher education among the V4 countries during the analyzed period (although slightly higher than the EU average) and the highest growth in employment of people with secondary education (Eurostat database: GDP and main components i.e. output, expenditure and income).

High-quality jobs are created, in part, as a result of direct investment, requiring adequately prepared personnel (Ali et al., 2018; Diebolt, Hippe, 2019; Mei, 2023). The high correlation between the level of direct investment and the share of people with higher education among those employed indicates that they are located in sectors requiring highly educated workers.

From the perspective of investors' assessment of human capital before making an investment decision, it is important to conclude that in all V4 countries there was a strongly positive, statistically significant correlation of the level of investment with the share of employment of people with higher education, which in the case of the share of employment of people with at least secondary education was observed only in Hungary and Poland.

The generalization of the results of this study is limited by the nature of the V4 economies, catching up with the most developed and benefiting from participation in the EU common market since 2004. The measures recommended in the last part of the article may have less effect in the case of underdeveloped countries, which attract direct investment with lower levels of technological sophistication. The article uses only macroeconomic data, without delving into a number of issues affecting the effectiveness of human capital (e.g., the quality and structure of education, changes in the sectoral structure of economies, the structure of direct investment).

6. Conclusions

Strong correlations between the analyzed data indicate that an increase in the efficiency of human capital and the attraction of foreign investment have contributed to narrowing the economic gap between the V4 countries and the average (UE-27). Such conclusions arise from the analysis of the relationship between the Real GDP to Employment ratio (1) and other indicators characterizing human capital, the situation in the economy and the labor market. The VAIC as a measure of human capital efficiency in relation to research in the long term at the macroeconomic scale has not worked well. This may be partly due to the variation in wage levels across the V4 countries (Ståhle et al., 2011), but a more important factor seems to be long-term changes in the share of compensation in GDP. This conclusion contributes to the discussion on the usefulness of the VAIC model for estimating human capital efficiency.

An important conclusion of the presented research is the significantly higher impact on the growth of human capital efficiency of the share in employment of people with higher education than those with secondary education.

The results allow two recommendations to be made for the economic and social policies of the countries under consideration. First of all, since education (especially higher education) affects the efficiency of human capital and the scale of direct investment attracted, the state should support a high level of enrollment in higher education (Bal-Domańska, 2022; Schultheiss et al., 2023). Second of all, fiscal interference accompanied by a decline in the share of compensation in GDP should be limited, as this leads to a reduction in investment in human capital on the part of workers and, consequently, a reduction in the rate of growth of human capital efficiency.

Directions for further research in the topic undertaken are to include in the analysis of changes in the efficiency of human capital an in-depth analysis of the quality of teaching (the level of teaching in the first years of education, the structure of higher education), the structure of foreign investment, changes in the sectoral structure of economies, as well as adjustments and linkages between these factors. Such research will enable more precise definition of recommendations for educational and economic policy aimed at increasing the effectiveness of human capital.

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References

1. Ali, M., Egbetokun, A., Memon, M.H. (2018). Human capital, social capabilities and economic growth. *Economies*, *Vol. 6*, *Iss. 1*, pp. 1-18. DOI: https://doi.org/10.3390/economies6010002
2. Andrijauskiene, M., Dumciuviene, D., Stundziene, A. (2021). EU framework programmes: positive and negative effects on member states' innovation performance. Equilibrium. *Quarterly Journal of Economics and Economic Policy*, *Vol. 16*, *Iss. 3*, pp. 471-502. DOI: https://doi.org/10.24136/eq.2021.017

3. Antohi, V.M., Zlati, M.L., Ionescu, R.V. (2019). Visegrad Economies' Active Implication in a "new" EU. *A New Regional Economic Approach. The World Economy*, *Vol. 42*, *Iss. 10*, pp. 2924-2974. DOI: https://doi.org/10.1111/twec.12823
4. Antonelli, G., Antonietti, R., Guidetti, G. (2010). Organizational change, skill formation, human capital measurement: evidence from Italian manufacturing firms. *Journal of Economic Surveys*, *Vol. 24*, *Iss. 2*, pp. 206-247. DOI: https://doi.org/10.1111/j.1467-6419.2009.00615.x
5. Bal-Domańska, B. (2022). The impact of macroeconomic and structural factors on the unemployment of young women and men. *Economic Change and Restructuring*, *No. 55*, pp. 1141-1172. DOI: https://doi.org/10.1007/s10644-021-09341-9
6. Becker, G.S. (1993). *Human capital: a theoretical and empirical analysis with special reference to education*. Chicago: University of Chicago Press. p. 412.
7. Buesselmann, S. (2009). *Human Capital and Economic Growth, Analyzing the Impact of Skilled Labor on Economic Prosperity*. Saarbruecken: VDM Verlag. p. 256.
8. Carrère, C., Grujovic, A., Robert-Nicoud, F. (2020). Trade and Frictional Unemployment in the Global Economy. *Journal of the European Economic Association*, *Vol. 18*, *Iss. 6*, pp. 2869-2921. DOI: https://doi.org/10.1093/jeea/jvz074
9. Castell´o-Climent, A. (2019). The Age Structure of Human Capital and Economic Growth. *Oxford Bulletin of Economics and Statistics*, *Vol. 81*, *Iss. 2*, pp. 394-411. DOI: https://doi.org/10.1111/obes.12274
10. Dakhli, M., De Clercq, D. (2004). Human capital, social capital, and innovation: a multi-country study. *Entrepreneurship & Regional Development*, *Vol. 16*, *Iss. 2*, pp. 107-128. DOI: https://doi.org/10.1080/08985620410001677835
11. Dangerfield, M. (2008). The Visegrád Group in the Expanded European Union: From Preaccession to Postaccession Cooperation. *East European Politics and Societies and Cultures*, *Vol. 22*, *Iss. 3*, pp. 630-667. DOI: https://doi.org/10.1177/0888325408315840
12. Diebolt, C., Hippe, R. (2019). The long-run impact of human capital on innovation and economic development in the regions of Europe. *Applied Economics*, *Vol. 51*, *Iss. 5*, pp. 542-563. DOI: https://doi.org/10.1080/00036846.2018.1495820
13. Dmytrów, K., Bieszk-Stolorz, B. (2019). Mutual relationships between the unemployment rate and the unemployment duration in the Visegrad Group countries in years 2001-2017. Equilibrium. *Quarterly Journal of Economics and Economic Policy*, *Vol. 14*, *Iss. 1*, pp. 129-148. DOI: https://doi.org/10.24136/eq.2019.006
14. Eurostat (2024). *Data on employment and GDP*. Retrieved from: https://ec.europa.eu/eurostat/, 1-31.10.2024.
15. Flabbi, L., Gatti, R. (2018). *A Primer on Human Capital*. Policy Research Working Paper 8309, World Bank Group. Retrieved from: http://documents.worldbank.org/curated/en/514331516372468005, 20.01.2025.

16. Goldin, C. (2016). Human Capital. In: C. Diebolt, M. Haupert (Eds.), *Handbook of Cliometrics* (pp. 55-86). Heidelberg, Germany: Springer Verlag.
17. Habib, M., Abbas, J., Noman, R. (2019). Are human capital, intellectual property rights, and research and development expenditures really important for total factor productivity? An empirical analysis. *International Journal of Social Economics*, *Vol. 46*, *Iss. 6*, pp. 756-774. DOI: https://doi.org/10.1108/IJSE-09-2018-0472
18. Hanushek, E.A., Woessmann, L. (2008). The Role of Cognitive Skills in Economic Development. *Journal of Economic Literature*, *Vol. 46*, *Iss. 3*, pp. 607-668. DOI: https://doi.org/10.1257/jel.46.3.607
19. Huggins, R., Prokop, D., Thompson, P. (2017). Entrepreneurship and the determinants of firm survival within regions: human capital, growth motivation and locational conditions. *Entrepreneurship & Regional Development*, *Vol. 29*, *Iss. 3-4*, pp. 357-389. DOI: https://doi.org/10.1080/08985626.2016.1271830
20. Iazzolino, G., Laise, D. (2013). Value added intellectual coefficient (VAIC). *Journal of Intellectual Capital*, *Vol. 14*, *Iss. 4*, pp. 547-563. DOI: https://doi.org/10.1108/jic-12-2012-0107
21. Klinger, S., Weber, E. (2019). GDP-Employment Decoupling in Germany. *Structural Change and Economic Dynamics*, *No. 52,* pp. 82-98. DOI: https://doi.org/10.1016/j.strueco.2019.10.003
22. Kónya, I. (2018). Labor Input and Labor Income. In: I. Kónya (Ed.), *Economic Growth in Small Open Economies. Lessons from the Visegrad Countries* (pp. 29-45). Cham, Switzerland: Palgrave Macmillan. DOI: https://doi.org/10.1007/978-3-319-69317-0_3
23. Kraay, A. (2018). Methodology for a World Bank Human Capital Index. Washington: World Bank. *Policy Research Working Paper, 8593*, pp. 1-59. Retrieved from: https://openknowledge.worldbank.org/handle/10986/30466, 04.02.2025.
24. Lee, S.Y., Shin, Y., Lee, D. (2015). The option value of human capital: higher education and wage inequality. *NBER Working Paper Series, 21724.* National Bureau of Economic Research. https://www.nber.org/papers/w21724
25. Lenkei, B. (2019). *Essays on Human Capital*. London: Middlesex University.
26. Lim, S.S., Updike, R.L., Kaldjian, A.S., Barber, R.M., Cowling, K., York, H., Friedman, J., Xu, R., Whisnant, J.L., Taylor, H.J., Leever, A.T., Roman, Y., Bryant, M.F., Dieleman, J., Gakidou, E., Murray, C.J.L. (2018). *Measuring human capital: a systematic analysis of 195 countries and territories, 1990-2016.* Seattle, WA, USA: Institute for Health Metrics and Evaluation, University of Washington. DOI: http://dx.doi.org/10.1016/S0140-6736(18)31941-X
27. Mačerinskienė, I., Aleknavičiūtė, R. (2017). National intellectual capital influence on economic growth in the European Union countries. Equilibrium. *Quarterly Journal of Economics and Economic Policy*, *Vol. 12*, *Iss. 4*, pp. 573-592. DOI: https://doi.org/10.24136/eq.v12i4.30

28. Manuel, N. (2024). Does the labour market value field of study specific knowledge? An alignment score based approach. *Economics of Education Review*, *No. 101*, 102561. DOI: https://doi.org/10.1016/j.econedurev.2024.102561
29. Marzo, G. (2022). A theoretical analysis of the value added intellectual coefficient (VAIC). *Journal of Management and Governance*, *Vol. 26*, *Iss. 3*, pp. 551-577. DOI: https://doi.org/10.1007/s10997-021-09565-x
30. Mulliqi, A., Adnett, N., Hisarciklilar, M., Rizvanolli, A. (2018). Human Capital and International Competitiveness in Europe, with Special Reference to Transition Economies. *Eastern European Economics*, *Vol. 56*, *Iss. 6*, pp. 541-563. DOI: https://dx.doi.org/10.1080/00128775.2018.1502612
31. Naval, J., Silva, J.I., Vázquez-Grenno, J. (2020). Employment effects of on-the-job human capital acquisition. *Labour Economics*, *No. 67*, 101937. DOI: https://doi.org/10.1016/j.labeco.2020.101937
32. OECD (2021). *Education at a Glance 2021: OECD Indicators*. Paris: OECD Publishing. DOI: https://doi.org/10.1787/b35a14e5-en
33. OECD (2023). *Bildung auf einen Blick 2023: OECD-Indikatoren*. Paris: wbv Media, Bielefeld/OECD Publishing. DOI: https://doi.org/10.1787/34087b82-de
34. Olagunju, K.O., Adebayo., I.O., Kunle., F.O., Ibrahim, O.R., Kolawole, O. (2019). Welfare Impact of Globalization in Developing Countries: Examining the Mediating Role of Human Capital. *Economies*, *Vol. 7*, *Iss. 3*, pp. 1-24. DOI: https://doi.org/10.3390/economies7030084
35. Østergaard, A., Marinova, S.T. (2018). Human Capital in the Entrepreneurship Ecosystem. *International Journal of Entrepreneurship and Small Business*, *Vol. 35*, *Iss. 3*, pp. 371-390. DOI: https://doi.org/10.1504/IJESB.2018.095907
36. Prohorovs, A., Bistrova, J. (2022). Labour Share Convergence in the European Union Labour Share Convergence in the European Union. *Economies*, *No. 10*, 207. DOI: https://doi.org/10.3390/economies10090207
37. Pulic, A. (2000). VAIC™ an accounting tool for IC management. *International Journal of Technology Management*, *Vol. 20*, *Iss. 5-8*, pp. 702-714. DOI: https://doi.org/10.1504/ijtm.2000.002891
38. Pulic, A. (2004). Intellectual capital – does it create or destroy value? *Measuring Business Excellence*, *Vol. 8*, *Iss. 1*, pp. 62-68. DOI: https://doi.org/10.1108/13683040410524757
39. Rossi, F. (2019). *Human Capital and Macro-Economic Development: A Review of the Evidence*. The University of Warwick. http://wrap.warwick.ac.uk/133718
40. Sasso, S., Ritzen, J. (2019). Sectoral cognitive skills, R&D, and productivity: a cross-country cross-sector analysis. *Education Economics*, *Vol. 27*, *Iss. 1*, pp. 35-51. DOI: https://doi.org/:10.1080/09645292.2018.1515309

41. Schmidt, A. (2016). Friends forever? The role of the Visegrad Group and European integration. *Politics in Central Europe*, *Vol. 12*, *Iss. 3*, pp. 113-140. DOI: https://doi.org/10.1515/pce-2016-0019
42. Schultheiss, T., Pfister, C., Gnehm, A-S., Backes-Gellner, U. (2023). Education expansion and high-skill job opportunities for workers: Does a rising tide lift all boats? *Labour Economics*, *Vol. 82*, *Iss. C*, pp. 1-23. DOI: https://doi.org/10.1016/j.labeco.2023.102354
43. Schwabe, M. (2021). GDP Growth and Unsaturated Demand on Labour Markets: Is the Visegrad Group Ready for An Increased Immigration? *Ekonomista*, *No. 4,* pp. 482-507. DOI: https://doi.org/10.52335/dvqigjykff24
44. Singla, H.K. (2020). Does VAIC affect the profitability and value of real estate and infrastructure firms in India? A panel data investigation. *Journal of Intellectual Capital*, *Vol. 21*, *Iss. 3*, pp. 309-331. DOI: https://doi.org/10.1108/JIC-03-2019-0053
45. Škare, M., Lacmanović, S. (2015). Human capital and economic growth: a review essay. *Amfiteatru Economic*, *Vol. 17*, *Iss. 39*, pp. 735-760. DOI: http://hdl.handle.net/10419/168945
46. Somers, M.A., Cabus, S.J., Groot, W., van den Brink, H.M. (2019). Horizontal mismatch between employment and field of education: Evidence from a systematic literature review. *Journal of Economic Surveys*, *Vol. 33*, *Iss. 2*, pp. 567-603. DOI: https://doi.org/10.1111/joes.12271
47. Ståhle, P., Ståhle, S., Aho, S. (2011). Value Added Intellectual Coefficient (VAIC): a critical analysis. *Journal of Intellectual Capital*, *Vol. 12*, *Iss. 4*, pp. 247-268. DOI: https://doi.org/10.1108/14691931111181715
48. Stooq (2024). *EURUSD historical data*. Retrieved from: https://stooq.pl/q/d/?s=eurusd, 1-31.10.2024.
49. Ulum, I., Ghozali, I., Purwanto, A. (2014). Intellectual capital performance of Indonesian banking sector: A modified VAIC (M-VAIC) perspective. *International Journal of Finance & Accounting*, *Vol. 6*, *Iss. 2*, pp. 103-123. DOI: https://doi.org/10.5296/ajfa.v6i2.5246
50. UNCTAD (2024). *Foreign direct investment: Inward and outward flows and stock, annual*. Retrieved from: https://unctad.org/statistics, 1-31.10.2024.
51. Vatsa, P., Pino, G. (2023). Spatial spillovers and labor productivity convergence in Canada. *Economics Letters*, *Vol. 230*, *Iss. C*, pp. 1-3. DOI: https://doi.org/10.1016/j.econlet.2023.111276
52. Vladušić, L., Živković, A., Pantić, N. (2020). Macroeconomic analysis of GDP and employment in EU countries. *Ekonomika*, *Vol. 66*, *Iss. 1*, pp. 65-76. DOI: https://doi.org/10.5937/ekonomika2001065V

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SOFT VS. HARD COMPETENCES ON THE MOVE: EDUCATIONAL CHOICES AND MOBILITY BEHAVIOURS AMONG YOUNG ADULTS

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Purpose: The main objective of this article is to identify which competencies, i.e. hard or soft, young adults are more inclined to develop, when they engage in this development, and whether their needs related to competency development influence their communication behaviour.
Design/methodology/approach: Empirical research was conducted in the second quarter of 2025 using the Computer-Assisted Web Interview (CAWI) method. The research tool consisted of 27 substantive questions and 13 questions concerning the socio-demographic characteristics of the respondents, with this article focusing on the analysis of selected results.
Findings: Young adults are more likely to develop hard competences than soft competences. What is more, they are more inclined to devote their leisure time to developing hard competences. However, this does not directly translate into aspects related to travelling to training sessions and courses, in particular the frequency of travel and the distance covered.
Research limitations/implications: The geographical scope of the study was limited to the Upper Silesian-Zagłębie Metropolis (GZM), which is characterised by specific infrastructural, cultural and spatial conditions. A potential direction for further research could be young adults classified as NEET (Not in Education, Employment, or Training), i.e. young people who are not working, studying or actively seeking employment.
Practical implications: This research may provide guidance for training institutions and the GZM in shaping the careers of young adults and developing educational programmes. It also provides interesting conclusions for entities responsible for managing transport systems in the GZM.
Social implications: When young adults have free time, they are more likely to improve their hard competences than their soft competences.
Originality/value: The analysis allows us to learn about the attitudes and behaviours (including communication behaviours) of young adults living in the GZM who develop their competences in leisure time.
Keywords: competences development, leisure mobility, sustainable mobility, young adults.
Category of the paper: Research paper.

1. Introduction

In today's dynamic times, characterised by technological and digital progress, access to vast amounts of data, and increased awareness of sustainable development, economies are facing staff shortages. Symela and Stępnikowski (2021) point out that as a society we face challenges such as personalised universal education, digital illiteracy and technological unemployment.

As part of its activities related to the development and education of European Union citizens, the European Commission (2025) pointed out that:

- Nearly 78% of companies in the EU report difficulties in finding employees with the necessary qualifications.
- In 42 sectors – from construction and healthcare to engineering and IT – have staff shortages,
- 4 in 10 adults in the EU lack basic digital skills, even though these are needed in over 90% of jobs.

That is why the Skills Union was created in 2025 to support the development of skills for high-quality jobs, upskilling and reskilling.

Among adults, young adults may consider their competence development complete at the level of first or second cycle studies. The current trend provides grounds for concluding that it is necessary to continuously acquire knowledge, skills and social competences, which are the key to professional success. In their report "Competences of the Future", Woch and Śledziewska (2021, p. 21) note that it may be interesting to examine more closely the role played in shaping employees' competences by the training courses that employees undertake independently in their leisure time. This idea guided the authors of this article. The study conducted for the purposes of this work therefore aimed to identify the competences that young adults living in the GZM are most interested in, in particular those developed in their leisure time outside of work and study. It was also noted that young adults' interest in developing their skills may be reflected in their communication behaviour, leading them to travel more frequently and further to attend training courses.

Post-pandemic changes related to the spread of remote educational services are affecting sustainable urban mobility, including leisure mobility (Kos et al., 2022, p. 96). The need to improve competences in stationary and hybrid forms affects mobility of people participating in such activities. It contributes to the generating of additional communication needs. If the activity is carried out during free time from work or formal education, it directly affects leisure mobility. Leisure mobility is linked to the category of optional travel. Travel undertaken by residents of urban areas in connection with leisure activities is an important, though underestimated, issue for those responsible for planning and managing sustainable urban mobility. Therefore, one of the objectives of the presented study is to determine whether the activities undertaken by young adult residents of the GZM in leisure time to improve their

competences have an impact on their transport behaviour in terms of the frequency and distance of their journeys.

The topic of competences, time, place and mobility in this area is, on the one hand, very interesting and, on the other hand, important in terms of market needs. With this in mind, this article considers the issue of competences development, although for the time being only in relation to young adults who are already participating in the labour market or are about to enter it. The main objective of the study was to identify the competences that are most often developed by young adults, especially in leisure time, and how these activities relate to their communication behaviours.

This publication presents the findings of key studies on the issue of competences development. It highlights the importance of competences development in the context of technological and social change. It also presents the key findings of identified studies on the mobility of young adults, pointing to an existing research gap on the issue of young adult mobility related to voluntary competence development. The publication presents the research methodology adopted and findings focused on the relationships between the declared preferences of the study group regarding the improvement of two types of competences: soft and hard. The results were discussed and key directions for future research were indicated.

2. Literature review

2.1. Competences and their development

Dynamic technological progress creates many opportunities and leads to the improvement of processes, which translates into new forms of work and the development of new competences. Furthermore, based on their research, Ciesielska-Maciągowska & Skrzek-Lubasińska (2024, p. 155) believe that these changes may lead to a reduction in the demand for certain professions, while increasing the demand for employees with high qualifications and digital competences.

On the other hand, Ćwiek & Maj-Serwatka (2024, p. 50) argue that digitalisation influences the behaviour, attitudes and sometimes even the personality of people who use technology. The authors point out that this also carries the threat of exclusion from the labour market due to a competences gap, which should be understood as the difference between the skills that employees have and those that are needed in the workplace.

On the one hand, it is clear that it is necessary to improve competences, but on the other hand, market data does not inspire optimism, as Przybył (2025) notes that only 33% of Poles aged 25-65 have a positive attitude towards learning, as many as 37% are sceptical, and 29% have a neutral attitude. Approximately 50% agree with the statement that learning is

enjoyable and satisfying, and over 60% agree that it is important for them to enrich their knowledge and skills. At the same time, almost 42% say that they no longer want to learn.

There is no consensus in the literature on the definition of competence itself (Filipowicz, 2004; Kwiatkowska-Ciotucha et al., 2021; McKinnon et al., 2017). Therefore, for the purposes of this publication, it is assumed that competence is a *set of skills, abilities, knowledge, attitudes and motivation that a person needs to effectively cope with tasks and challenges related to work* (Hecklau et al., 2016, p. 2).

Many researchers are trying to identify a competency model and develop an appropriate tool for its implementation. For example, Kannan & Garad (2021) presented a list of key competencies required of employees to cope with specific jobs and tasks in Industry 4.0, divided into three main areas: Garad (2021) presented a list of key competencies required of employees to cope with specific jobs and tasks in Industry 4.0, divided into three main established categories of competencies: technical, methodological, and social.

This publication initially divides competences into specialist-technical, managerial, social and personal competences (Szmit, 2018, pp. 17-29), but ultimately categorised them according to Armstrong (2011) into technical competences, also referred to as hard competences, and behavioural competences, also referred to as soft competences. As Benek (2024, p. 146) notes, the division of competences into soft and hard is particularly important in the educational process, which is significant in the context of improving the competences of young adults.

2.2 Young adults and their communication behaviours

Young people who use urban mobility systems are a group whose needs are poorly taken into account in transport planning processes, although they are a group characterised by a high level of mobility (Porter, Turner, 2019). However, it should be noted that the issue of young adults' transport behaviour is increasingly being analysed by the scientific community. Researchers working on this topic point to the relationship between transport behaviour and the stage of social life (Simons et al., 2017; Bopp et al., 2019; Haseeb, Mitra, 2024).

The authors of the report *Youth on the move: Young people and transport in the 21st century* (2024) point out that young people's motivations for travelling depend on both subjective factors (e.g. related to individual aspirations) and objective factors. The latter include, among others, the availability and quality of infrastructure. Interestingly, research shows that despite young adults being perceived as more sensitive to environmental issues, paradoxically, when it comes to transport choices, they do not necessarily choose more sustainable forms of travel (Suchanek, Szmelter-Jarosz, 2019; Vávrová, Brůhová Foltýnová, 2023). The way young adults travel is increasingly influenced by the availability of new mobility services (Gkartzonikas et al., 2025) and the availability of ICT tools (Wu et al., 2019).

People's preferences regarding how they spend their leisure time are one of the factors influencing transport needs (Szołtysek, 2011, p. 22). Unlike obligatory travel, leisure-related mobility is significantly dispersed spatially and lacks fixed patterns, which makes it difficult to manage urban mobility systems (Ohnmacht et al., 2009).

The research presented in this publication on leisure mobility related to activities aimed at improving hard and soft competences is an attempt to fill the gap in knowledge about the travel patterns of young adults.

3. Methods

This publication is based on empirical research conducted in the second quarter of 2025 using the Computer-Assisted Web Interview (CAWI) method. The proprietary research tool consisted of 27 substantive questions and 13 questions concerning the socio-demographic characteristics of the respondents. The research was conducted on a group of 500 people aged 18-34 who live in the Upper Silesian-Zagłębie Metropolis. The selection of respondents was quota-based and reflected the age structure of the general population of young adults living in the GZM. The dominant group were the oldest respondents, i.e. those aged 30-34 (49.8%), and the smallest group were the youngest respondents, under 19 (5.8%). Respondents aged 19-24 accounted for 26.8%, while those aged 25-29 accounted for 17.6%.

As presented in the introduction, the aim of this article is to identify which competences young adults improve more often. For this reason, variables directly related to the survey questionnaire questions referring to specific competences were used for the analysis. In addition, the competences considered were grouped into hard and soft competences (according to Armstrong, 2011; see Tables 1 and 2) based on the following sources of information: the Integrated Skills Strategy 2030, DigComp 2.2, the Global Skills and Competence Framework for the Digital World (SFIA 9), GreenComp, European Skills, Competences, Qualifications and Occupations, and the 2025 key competences from The Future of Jobs Report 2025 World Economic Forum. Talent management was added to the soft competences due to the fact that the focus is on a set of psychosocial skills and personality traits.

In addition to the variables directly corresponding to the questions in the research tool, additional variables were also created to express the respondent's general interest in improving the competences belonging to the analysed groups. Thus, two new variables were constructed, referring to (a) hard and (b) soft competences. When creating them, the number of hard and soft competences that each respondent has developed or has been developing over the last three years was counted (summed up). Since the number of soft competences to choose from (7) was higher than the number of hard competences (5), both variables were normalised by dividing

their values by 7 and 5, respectively. In this way, it was possible to compare distributions and perform analyses based on the summary variables thus created, without fear that the number of competences analysed would affect, for example, the results of the tests carried out. Similarly, two further variables were constructed to express respondents' interest in developing hard and soft competences in the future.

The Wilcoxon signed-rank test for dependent samples (Wilcoxon, 1945) was used to compare variables reflecting respondents' interest in improving their hard and soft competences. This test is designed for ordinal and metric variables that do not have a normal distribution. In addition, it is used for variables from dependent samples, which is important in this case, as the young adults surveyed could participate in different forms of training from both competence groups at the same time.

The relationships between variables expressing interest (current and future) in improving competencies (hard and soft) and those relating to the characteristics of relocation for the purpose of developing these competences were also examined. For variables measured on an ordinal scale, Spearman's rank correlation coefficient (Spearman, 1904) was used. For nominal variables, the chi-square test and Cramer's V measure (Cramer, 1946) were used, which additionally allowed the strength of the relationship identified by the chi-square test to be determined. Furthermore, in some cases, when a significant interdependence between the analysed non-metric variables was discovered, a correspondence analysis (Greenacre, 2021) was also performed, which allowed the categories of these variables to be linked together.

Within the framework of this study, referring to the objectives of the article, the following research hypotheses were formulated:

H1: Young adults living in the GZM developed hard competences more often than soft competences.

H2: Young adults living in the GZM are more likely to spend their leisure time developing hard competences than soft competences.

H3: Young adults living in the GZM are more likely to travel further and more often in leisure time to develop hard competences than soft competences.

The next section of this article provides a empirical results and a discussion. The conclusion summarises the paper and indicates applications and further research directions.

4. Results

Of the 500 participants in the study, i.e. young adults from the GZM, as many as 425 people have improved or are improving their competences over the last 3 years. These individuals were more likely to declare that they were developing hard competences than soft competences, although most of the soft competences indicated were also being improved by about half of the

people in this group (Table 1). Most often, the respondents participated in training courses on specialist industry knowledge (60.2%). Popular hard competences also included technology skills (54%) and digital skills (54%). Among soft competences, most people indicated the development of creative thinking (54.6%). Interestingly, respondents who declared that they preferred remote training accounted for only 13.2% to 29.2% of this group.

Table 1.
Current interest in improving hard and soft competences – percentage of respondents declaring the development of specific competences over the last 3 years

Type of competences		Participating in competence development	
		in any form [%]	remotely [%]
Hard	Specialised industry knowledge	60,2	25,8
	Technology skills	54,0	26,2
	Digital skills	54,0	29,2
	Interest in new ideas and the need to develop knowledge	45,0	16,6
	Service and customer orientation	39,8	15,8
Soft	Creative thinking	54,6	21,4
	Analytical thinking	49,4	22,0
	Resilience, flexibility, agility	46,8	17,2
	Empathy and active listening skills	46,8	14,8
	Self-motivation and awareness of one's strengths and weaknesses	46,2	19,0
	Leadership skills	38,8	13,2
	Talent management	32,8	13,8

Source: authors' own work.

Respondents were also asked about the competences they would like to improve in the future. This time, out of 500 respondents, only 2 indicated that they were not interested in developing their competences. Again, the respondents' answers slightly more often concerned hard competences than soft competences (Table 2).

Table 2.
Declared future interest in improving hard and soft competences – percentage of respondents declaring a willingness to develop specific competences

Type of competences		Participating in competence development	
		in any form [%]	remotely [%]
Hard	Technological knowledge enabling the performance of the profession	83,0	32,8
	Ability to use artificial intelligence and big data	78,6	33,6
	Cyber security skills	76,8	39,8
	Data management and analysis	70,2	30,2
Soft	Creative thinking	79,6	32,0
	Time management	77,6	34,8
	Team management	72,2	24,2
	Management skills	69,6	26,0
	Management of environmental issues	62,0	25,8

Source: authors' own work.

When comparing the declarations of young adults living in the GZM regarding the improvement of hard and soft competences, summary variables were used to express the general interest in developing these competences (described in section 3). The distributions of the analysed variables (Fig. 1) suggest that it is correct to conclude that young adults are more likely to participate in training and courses that allow them to improve their hard competences than their soft competences.

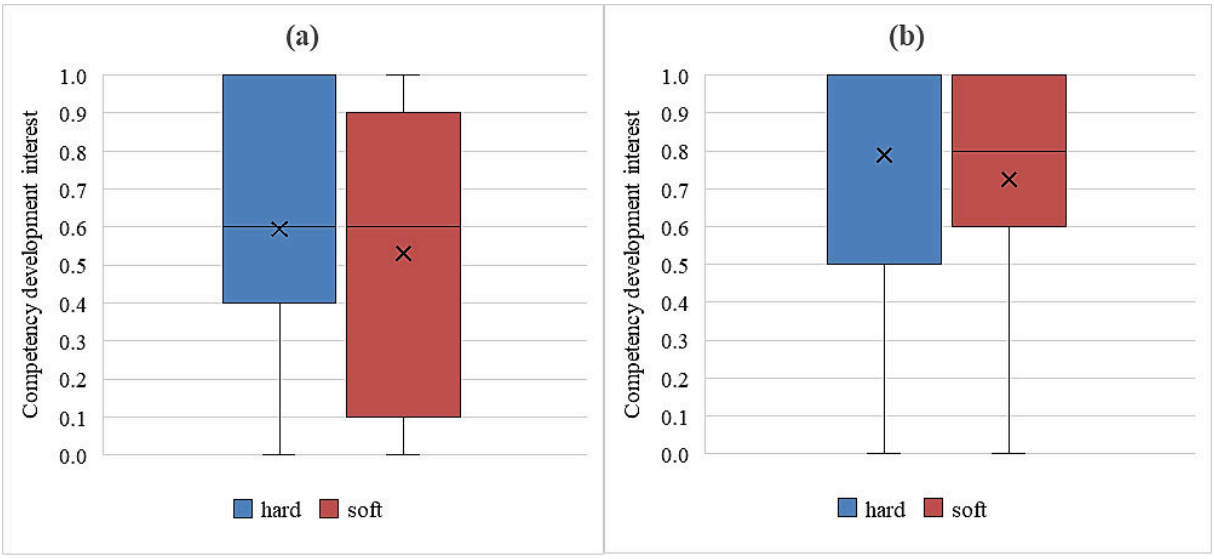


Figure 1. Current (a) and future (b) interest of young adults in developing hard and soft competences.
Source: authors' own work.

However, in order to formally show the differences in interest in developing competences, as measured by the aforementioned summary variables, the Wilcoxon rank test for dependent samples was used. The calculated p-value, which is lower than the assumed significance level (0.05), indicates the rejection of the hypothesis that in the group of young adults from the GZM, interest (both current and future) in improving hard competences is at the same level as for soft competences (Table 3). This also confirms the first hypothesis (H1) put forward in the article.

Table 3.
Wilcoxon test results for dependent samples regarding current and future interest in improving two types of competences

Compared variables	Wilcoxon test results	
	Standardised test statistic value	p-value
Current interest in developing hard vs. soft competences	-5.09	< 0.001
Future declared interest in developing hard vs. soft competences	-3.97	< 0.001

Source: authors' own work.

It was also found that current interest in developing hard and soft competences translates moderately into planned efforts in this direction in the future. The calculated Spearman's rank correlation coefficients between the analysed summary variables range from 0.37 to 0.46 (Table 4), which indicates a moderate relationship. Thus, those currently undergoing training

will not necessarily continue to improve their competences. However, young adults who have not yet participated in any form of competences development have such plans.

Table 4.
Matrix of Spearman's rank correlation coefficient values

Variables	Variables	
	Future interest in developing hard competences	**Future interest in developing soft competences**
Current interest in developing hard competences	0.413	0.420
Current interest in developing soft competencies	0.368	0.456

Note. In each case, p-value < 0.001.

Source: authors' own work.

A particularly interesting subgroup of young adults from the GZM are those who decide to devote their free time outside of study and work to improving their competences. This attitude generally indicates greater awareness on the part of the respondent regarding, among other things, the market situation, the demand for specific competences and the need to invest in their own self-development. In the surveyed group of 425 people who declared that they had developed their competences in the last three years, 80% of respondents improved their hard skills in their leisure time, and 75.8% improved their soft competences (Table 5).

Table 5.
Distribution of respondents in terms of the time indicated in which they improved their competences

Time during which the respondent developed their competences	Competences			
	hard		soft	
	number of responses	percentage	number of responses	percentage
At least partly during leisure time	340	80.0	322	75.8
Only during studying or working	62	14.6	47	11.1
Did not develop this type of competences	23	5.4	56	13.2

Source: authors' own work.

The difference between these groups of people (80% vs. 75.8% of respondents) does not seem significant. However, the Wilcoxon rank test for dependent samples, also conducted in this case, confirms that it is significant (Table 6).

Table 6.
Results of the Wilcoxon test for dependent samples concerning interest in improving two types of competences during leisure time

Compared variables	Wilcoxon test results	
	Standardised test statistic value	p-value
Interest in developing hard vs. soft competences, but in leisure time	-4.32	< 0.001

Source: authors' own work.

Furthermore, the distributions reflected in the box plots indicate that interest in improving hard competences during leisure time is, on average, higher than in the case of soft competences (Fig. 2). This confirms the validity of the second hypothesis (H2).

The conclusion that the value of work is very important is therefore valid, but in addition to material and existential values, the younger generation wants to fulfil themselves in their free time, outside of work. Therefore, we can talk about the emergence of a new, communicative work ethic, which is a symptom of a change in the value system of the younger generation (Kukla Nowcaka, 2019).

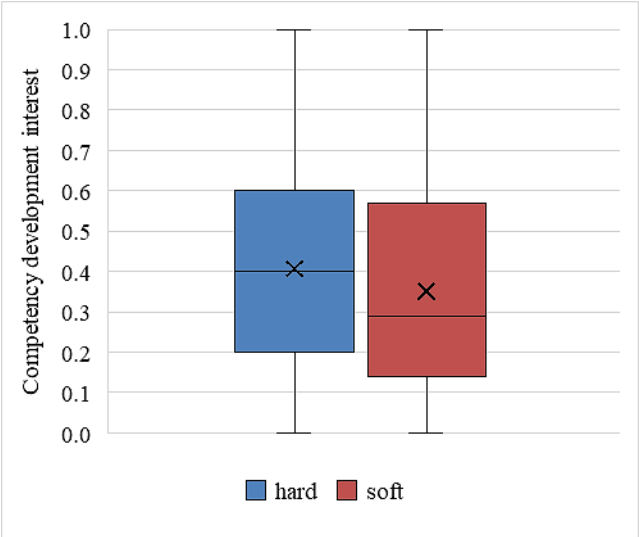


Figure 2. Current interest of young adults in developing hard and soft competences in their leisure time outside of study and work.

Source: authors' own work.

The rest of the analysis aimed to check whether, in addition to devoting their leisure time, young adults are also willing to travel more often and further to improve their hard competences s rather than their soft competences. To examine this relationship, the chi-square test and the V-Cramer measure were used to assess the strength of the correlation. As the results show, interest in hard competences is significantly related to the frequency and length of trips taken for training and courses (in both cases $p \leq 0.001$, Table 7). However, the low values of the V-Cramer measure (0.23 for travel frequency and 0.19 for travel length) indicate that this relationship is rather weak. The results also show that interest in soft competences is significantly related to the frequency of travel for the purpose of improving these types of competences ($p < 0.001$, Table 7). Moreover, this relationship ($V = 0.26$) is slightly higher (though still weak) than in the case of hard competences ($V = 0.23$). However, commitment to developing soft competences does not translate into a tendency to travel longer distances ($p > 0.05$). These conclusions lead to the rejection of hypothesis three (H3).

Table 7.
Chi-square test results and V-Cramer's measure values

Type of competences	Characteristics of travels aimed at developing competences					
	frequency of travel			travel distance		
	χ^2	p	V	χ^2	p	V
Hard	36.25	< 0.001	0.23	25.17	0.001	0.19
Soft	41.93	< 0.001	0.26	15.00	0.059	–

Source: authors' own work.

An additional correspondence analysis leads to interesting conclusions that can be drawn from the correspondence maps obtained (Fig. 3 (a) and (b)):

- people with a high interest in hard competences tend to attend training courses frequently, i.e. at least twice a week; moreover, they most often choose training centres located approx. 5-15 km away from their place of residence,
- respondents with an average interest in hard competences generally travel sporadically (several times a month) or rarely (a few times a year); they are also quite diverse in terms of the training centres they choose – some of them are willing to travel even more than 30 km, some 15-30 km, but there are also those who choose training courses that take place relatively close by (1-5 km),
- respondents who are least interested in hard competences usually do not travel, as they choose remote training.

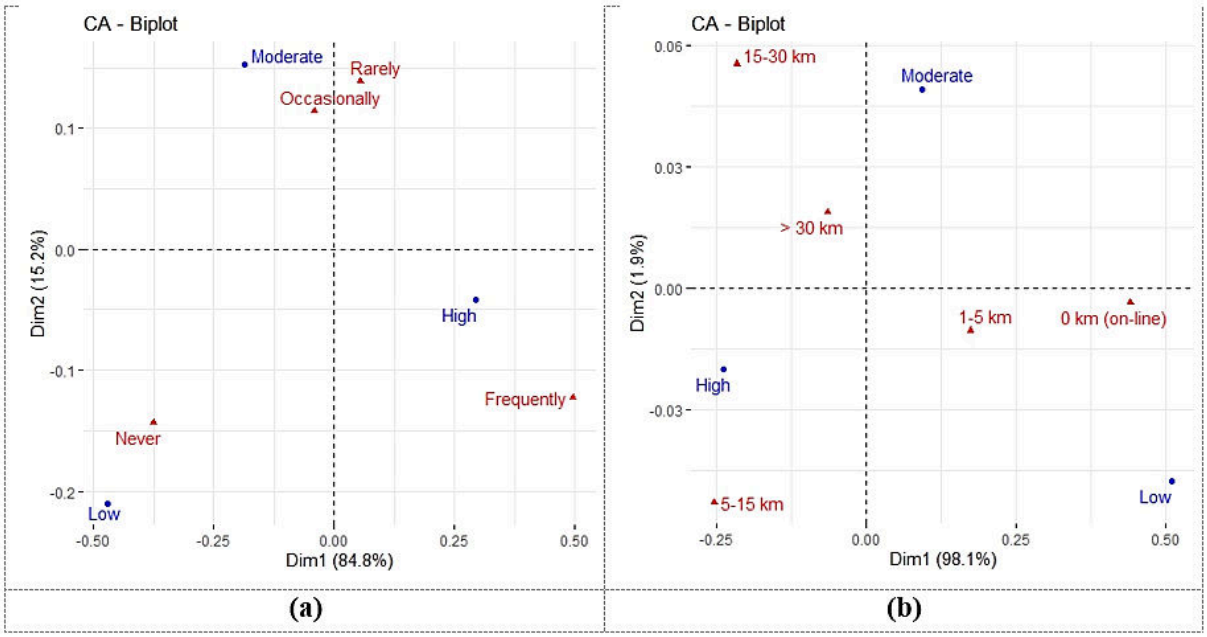


Figure 3. Correspondence maps showing how often (a) and how far (b) young adults from the GZM travel to develop hard competences*.

Source: authors' own work.

* Dim1 and Dim2 form a new coordinate system that was created during the execution of the correspondence analysis algorithm.

The correspondence map in Figure 4 shows that:

- people who are highly interested in improving their soft competences are willing to travel to training courses up to twice a week,
- some respondents with average interest will travel rarely (at most a few times a month), while others will choose online training and will not travel,
- those least interested in this type of competence will generally either choose training courses that take place sporadically (several times a year) or are conducted remotely (and therefore will not travel).

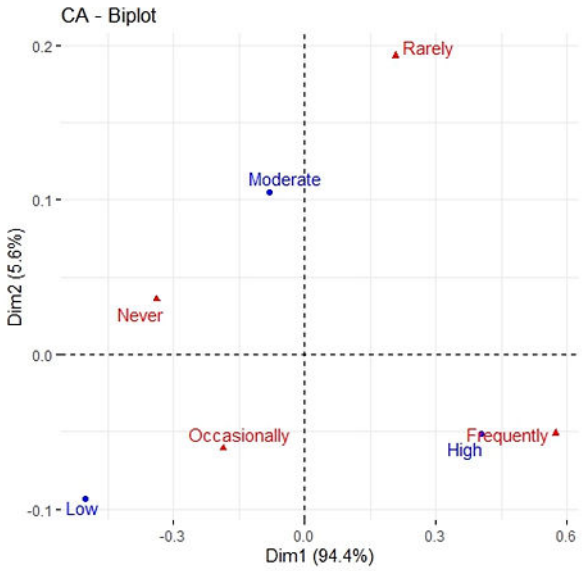


Figure 4. Correspondence map showing how often young adults from the GZM travel to develop soft competences*.

Source: authors' own work.

It is worth clarifying that the correspondence analyses only took into account those young adults who declared that they train in their leisure time (at least partially) from work and study, developing hard and soft competences accordingly. This was due to the fact that the question in the survey questionnaire asked respondents about travelling to develop their competences in their leisure time. In addition, the summary variables expressing interest in improving competences were categorised and in each case three categories were created: low, moderate and high interest.

* Dim1 and Dim2 form a new coordinate system that was created during the execution of the correspondence analysis algorithm.

5. Discussion

As Przybył (2025) notes, in Poland we are dealing with "success masking failure", as the analysis of the ESI (European Skills Index), Poland ranks third in the EU in terms of matching competences to current jobs, but at the same time ranks only 17th in terms of competences development. This means that neither employers nor employees are investing enough in the competences of the future.

From the perspective of the last few decades, the requirements for hard competences can be considered constant (Varkoly et al., 2019). However, soft competences are becoming increasingly important. Moczydłowska (2021, p. 9) refers to a study by ASTOR, in which 89% of participants assessed that in the near future they would most need technical competences outside their field, and 61% saw a need for development in their field. Nearly half of the respondents (47%) considered soft competences to be necessary.

Research by Deloitte Access Economics shows that by 2030, professions requiring a high level of soft skills will account for 66% of all jobs (PARP, 2023). According to a report by pracuj.pl (2024), 49% of young respondents indicate that soft competences are the most important for development, while the third most important skill mentioned by young people is specialist skills (42%). Despite this, research conducted for the purposes of this article shows that young adults still focus on hard competences. This may be due to the fact that soft competences cannot be easily quantified, while hard competences are more "touchable". Additionally, according to the Oxford Economics report (2021, p. 5), the main characteristics of young adults from Generation Z are agility, creativity and curiosity, which translates into their perception of soft skills as those that are seemingly easier to achieve.

The relatively low propensity of the surveyed group towards remote forms of training (13.2-29.2% of respondents) may seem surprising in the context of the post-pandemic spread of online education (Kos et al., 2022) and the availability of ICT tools (Wu et al., 2019). The preference for relatively short distances (5-15 km) combined with a high frequency of travel (at least twice a week) among those most involved in competence development suggests that respondents seek to optimise the time spent commuting - young adults are willing to invest their leisure time in their development, but do not want to waste it on unjustified, long and distant journeys. These data may also indicate the relatively high availability of activities aimed at improving the competences of young adults in the GZM area.

The identified differences in the transport behaviour of people developing hard and soft competences may provide guidance for institutions responsible for planning and managing sustainable urban mobility in the GZM area. The optional nature of the journeys studied, combined with their relatively high frequency, may hinder the achievement of sustainable urban mobility goals in the GZM area. Considering that young adults, according to the findings of Suchanek and Szmelter-Jarosz (2019) and Vávrová and Brůhová Foltýnová (2023), do not

always follow environmental criteria in their transport choices, despite their pro-ecological attitudes, it is worth considering expanding the transport offer with flexible solutions, such as Demand-Responsive Transport (DRT) based on zero-emission means of transport, supporting people who are improving their competences in forms that require physical travel. Mobility related to independent competences development in leisure time, still overlooked in scientific research, can be considered as a separate category, combining the characteristics of optional and quasi-obligatory travel: voluntary, but potentially regular, especially in the case of people who are strongly interested in improving their competences.

6. Summary

In today's world, young adults' perception of employees' knowledge, skills and social competences is changing in terms of their effective use by employers. Young adults want to acquire the necessary skills and competitive competences to manage increasingly complex and dynamic processes.

The research conducted for this article showed that young adults are more interested in developing hard competences than soft competences. Moreover, they are also more likely to spend their leisure time improving their hard competences than their soft competences. However, this interest does not directly translate into a desire to travel more often and further in order to improve these hard competences. The conclusions obtained therefore only confirm the first two hypotheses put forward in this study.

The authors are aware of the limitations of this study, which was conducted in the Upper Silesian Metropolis, which is characterised by specific infrastructural, cultural and spatial conditions. Furthermore, the conditions relating to leisure time and the mobility behaviour of young adults in order to improve their competences are not discussed in the literature, and it is difficult to use ready-made models in research.

A significant limitation of the study is the inability to relate the results concerning the mobility of young adults to the voluntary (leisure time) improvement of competences by this group. A review of the available literature indicates a significant research gap in this area. Furthermore, the authors did not find any relevant studies on other age groups. This may be due to the specific nature of this type of mobility needs (dispersion and instability can generate significant problems related to the management of this type of mobility).

The authors believe that it is possible for other researchers interested in this field to replicate the results obtained. One potential direction for further research is to extend the geographical scope of the study beyond the GZM area to other metropolitan areas and to focus not only on young adults, but also on other age groups (adults) or young adults outside the education system, representing the NEET (*not in education, employment or training*) group. The authors

also see a need for in-depth research on the impact of independent competences development activities on the communication behaviour of metropolitan residents.

Acknowledgements

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References

1. Armstrong, M. (2004). *Zarządzanie zasobami ludzkimi*. Kraków: Oficyna Ekonomiczna.
2. Benek, K. (2024). Nowe wyzwania dla polskiej nauki: kompetencje miękkie. *Zeszyty Naukowe Akademii Górnośląskiej, Nr 1(13),* DOI: 10.53259/2024.01.16
3. Bopp, M., Wilson, O.W.A., Duffey, M., Papalia, Z. (2019). An examination of active travel trends before and after college graduation. *Journal of Transport & Health, 14*, 100602. https://doi.org/10.1016/j.jth.2019.100602
4. Ciesielska-Maciągowska, D., Skrzek-Lubasińska, M. (2024). Zmiany technologiczne a struktura rynku pracy w Polsce. *Studia i Prace Kolegium Zarządzania i Finansów, 199,* 139-156. https://doi.org/10.33119/SIP.2024.199.7 (In Polish)
5. Cramer, H. (1946). *Mathematical methods of statistics*. Princeton University Press.
6. Ćwiek, M., Maj-Serwatka, K. (2024). Digital Competence of Young Adults in Poland. *Acta Universitatis Lodziensis. Folia Oeconomica, 3(368),* 46-68. https://doi.org/10.18778/0208-6018.368.03
7. European Commission (2025). *A skills union (COM(2025) 90 final)*. Retrieved from: https://eur-lex.europa.eu/legal-content/PL/TXT/PDF/?uri=CELEX%3A52025DC0090, 18.08.2025.
8. Gkartzonikas, C., Dimitriou, L., Alogdianakis, F. (2025). Analyzing young people's behavioral intention on using demand‐responsive transportation and ride‐matching apps. *Journal of Urban Mobility, 7,* 100122. https://doi.org/10.1016/j.urbmob.2025.100122
9. Greenacre, M. (2021). *Correspondence analysis in practice* (3rd ed.). Chapman and Hall/CRC Press, https://doi.org/10.1201/9781315369983
10. Haseeb, A., Mitra, R. (2024). Travel behaviour changes among young adults and associated implications for social sustainability. *Transportation Research Part A: Policy and Practice, 187*, 104189. https://doi.org/10.1016/j.tra.2024.104189

11. International Transport Forum (2024). Youth on the move: Young people and transport in the 21st century. *International Transport Forum Policy Papers, No. 128.* OECD Publishing. https://doi.org/10.1787/686a7ed5‑en
12. Kannan, K.S.P.N., Garad, A. (2021). Competencies of quality professionals in the era of industry 4.0: a case study of electronics manufacturer from Malaysia. *International Journal of Quality and Reliability Management, 38(3),* 839-871. https://doi.org/10.1108/IJQRM-04-2019-0124
13. Kos, B.M., Krawczyk, G.A., Mercik, A.M., Tomanek, R. (2022). *Mobilność miast przyszłości.* Praca Naukowa. Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach. https://doi.org/10.22367/uekat.9788378758235
14. Moczydłowska, J.M. (2021). Kluczowe kompetencje zmieniających się organizacji - nowe wyzwania na rynku pracy. *Marketing i Rynek, t. XXVIII, nr 1.* DOI: 10.33226/1231-7853.2021.1.1
15. OECD (2024). *Do Adults Have the Skills They Need to Thrive in a Changing World? Survey of Adult Skills 2023*. Retrieved from: https://www.oecd.org/en/publications/do-adults-have-the-skills-they-need-to-thrive-in-a-changing-world_b263dc5d-en.html, 18.08.2025.
16. Ohnmacht, T., Götz, K., Schad, H. (2009). *Leisure mobility styles in Swiss conurbations: Construction and empirical analysis. Transportation, 36(2),* 243-265. Scopus. https://doi.org/10.1007/s11116-009-9198-8
17. Oxford Economics (2021). *Gen Z's Role in Shaping the Digital Economy.* Economic Consulting Team Oxford Economics, https://www.oxfordeconomics.com/resource/gen-z-role-in-shaping-the-digital-economy/, 22.09.2025.
18. PARP (2023). https://www.parp.gov.pl/component/content/article/84511:kompetencje-miekkie-twardy-orzech-do-zgryzienia, 18.08.2025.
19. Porter, G., Turner, J. (2019). Meeting Young People's Mobility and Transport Needs: Review and Prospect. *Sustainability, 11(22),* 6193. https://doi.org/10.3390/su11226193
20. Przybył, C. (2025). Między chęcią a działaniem – cichy impas kompetencyjny na polskim rynku pracy. *Tygodnik Gospodarczy, 42*, https://pie.net.pl/tygodnik-gospodarczy-42-2025-23-pazdziernika-2025/#6, 28.10.2025.
21. *Raport*: *Pokolenie Z – kluczowe kompetencje i benefity. Badanie Pracuj.pl,* https://media.pracuj.pl/324282-pokolenie-z-kluczowe-kompetencje-i-benefity-badanie-pracujpl, 22.09.2025.
22. Simons, D., De Bourdeaudhuij, I., Clarys, P., de Geus, B., Vandelanotte, C., Van Cauwenberg, J., Deforche, B. (2017). Choice of transport mode in emerging adulthood: Differences between secondary school students, studying young adults and working young adults and relations with gender, SES and living environment. *Transportation Research Part A: Policy and Practice, 103*, 172-184. https://doi.org/10.1016/j.tra.2017.05.016
23. Spearman, C. (1904). The Proof and Measurement of Association between Two Things. *The American Journal of Psychology, Vol. 15, Iss. 1*, pp. 72-101, doi: 10.2307/1412159

24. Suchanek, M., Szmelter-Jarosz, A. (2019). Environmental Aspects of Generation Y's Sustainable Mobility. *Sustainability, 11(11),* 3204. https://doi.org/10.3390/su11113204
25. Symela, K., Stępnikowski, A. (2021). Wyzwania kompetencyjne w rozwoju sztucznej inteligencji w Polsce. *Polityka Społeczna, 568(7),* 21-28. doi: 10.5604/01.3001.0015.3356.
26. Szmit, D. (2018). Zarządzanie kompetencjami pracowniczymi w aspekcie rozwoju organizacji. *Zeszyty Naukowe Politechniki Częstochowskiej Zarządzanie, Nr 29.*
27. Szołtysek, J. (2011). *Kreowanie mobilności mieszkańców miast*. Warszawa: Wolters Kluwer Polska, p. 22.
28. Varkoly, L., Jędrzejczyk, W., Kucęba, R., Kulej-Dudek, E. (2019). Kształtowanie kompetencji kluczowych w społeczeństwie wiedzy. Zeszyty *Naukowe Politechniki Poznańskiej, Nr 79, Organizacja i Zarządzanie,* DOI:10.21008/j.0239-9415.2019.079.14.
29. Vávrová, L., Brůhová Foltýnová, H. (2023). *Transport behaviour across generations: The role of new social phenomena*. SSRN. https://doi.org/10.2139/ssrn.4646990
30. Wilcoxon, F. (1945). Individual comparisons by ranking methods. *Biometrics, Vol. 1, No. 6*, pp. 80-83, https://doi.org/10.2307/3001968
31. Włoch, R., Śledziewska, K. (2021). *Kompetencje przyszłości jak je kształtować w elastycznym ekosystemie edukacyjnym?* Raport. Polski Fundusz Rozwoju. https://stsw.edu.pl/wp-content/uploads/2021/12/Kompetencje_przyszlosci_Raport.pdf, 22.09.2025.
32. Wu, G., Hong, J., Thakuriah, P. (2019). Assessing the relationships between young adults' travel and use of the internet over time. *Transportation Research Part A: Policy and Practice, 125*, 8-19. https://doi.org/10.1016/j.tra.2019.05.002

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ORGANIZATIONAL RESILIENCE AND THE IMPLEMENTATION OF SUSTAINABLE DEVELOPMENT GOALS – THE EXAMPLE OF WARSAW STOCK EXCHANGE COMPANIES – COMPARATIVE ANALYSIS

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Purpose: The article aims to assess how companies listed on the Warsaw Stock Exchange, including those belonging to the WIG-ESG index, cope with the turbulent environment and how effectively they use available ESG tools, management strategies, and standards to increase their organizational resilience.
Design/methodology/approach: The study was based on a review of domestic and international publications, using the Web of Science and Scopus databases, legal sources regarding the ESG standard, and survey results, presented as percentages, conducted as part of the second phase of the study, entitled "Organizational Resilience in the Perspective of Sustainable Development".
Findings: The conducted survey allowed for establishing that 98% of companies from the WIG-ESG index and 97% of other companies on WSE Main Market are implementing new strategies, new business models as well as new management practices and are expanding into new markets in order to build their organizational resilience.
Research limitations/implications: The conclusions regarding the use of the sustainable development concept in building organizational resilience are based on slightly more than half of the companies on the WSE Main Market, and on over 83% of the companies on the WIG-ESG index.
Practical implications: The results obtained from most respondents indicate a positive relationship between the implementation of the sustainable development concept and building organizational resilience in a turbulent environment.
Social implications: This research is a premise for further, consistent implementation of the concept of sustainable development to increase the level of corporate responsibility in the environmental, social, and managerial spheres.
Originality/value: The main value of the article is the observation about the significant role of the sustainable development concept in building the organizational resilience of companies listed on the WSE Main Market.
Keywords: sustainable development, organizational resilience, listed companies, ESG.
Category of the paper: Research paper.

Introduction

The topic of sustainable development has been appearing for years in numerous publications, media, and discussions among academics (representing various fields of science), as well as representatives of business, politics, and law. Therefore, it is a critical issue, although there are several statements questioning its significance on a regional, national, and international scale (businessinsider.com.pl, 2025).

The concept of sustainable development is based on three fundamental pillars: social, economic, and environmental, while strong, democratic institutions are the "cement" that holds these three pillars together. Leaving aside the numerous conferences, congresses, and the resulting documents, it is worth referring to those that currently define the challenges within these three pillars:

- The UN General Assembly (2015) adopted a global plan for the sustainable development of nations until 2030, which is known as the 2030 Agenda. This document comprises the Sustainable Development Goals (SDGs). It assumes that implementing 17 priorities will enable the creation of a sustainable future in which there are no socioeconomic inequalities, and the needs of nations are met in harmony with the planet's resources. According to this plan, the need to preserve the natural environment in the best possible condition, and thus to slow climate change, will be both a consequence and a condition for sustainable development.
- The European Union promotes and regulates environmental, social, and governance aspects to increase sustainable investment and business transparency. Key regulations include the Sustainable Development Reporting Directive (2022) and the related European Sustainability Reporting Standards (ESRS) (2023) as well as the EU Taxonomy for Sustainable Investments (2020).

The regulations indicated above create a framework for sustainable transformation and constitute the basis for creating a sustainable development standard.

Until recently, sustainability standards were primarily assumed to be a neutral set of ethical guidelines rooted in corporate social responsibility. However, it is increasingly clear that these standards can be used as a tool for exerting pressure, selecting access to capital, and controlling global value chains. In practice, ESG standards have begun to function as measures whose power stems from controlling narratives, standards, and certifications (IPS, 2025).

In this context, it is worth examining listed companies in Poland and answering the research question: to what extent do their operations follow sustainable development standards to build their resilience in the face of complex and dynamically changing operating conditions? The article aims to assess how companies listed on the Warsaw Stock Exchange, including those included in the WIG-ESG index, are coping with turbulent environment and how effectively they are applying available ESG tools, management strategies, and standards to increase their resilience.

The study uses a comprehensive review of domestic and foreign publications, using the Web of Science and Scopus databases, legal sources regarding the ESG standard. The theoretical part of this study is supplemented by a descriptive presentation of the results of surveys conducted as part of the second stage of research entitled "Organizational resilience in the perspective of sustainable development" (Samborski, 2024). The survey results are reported mainly via percentage distributions.

Contemporary organizational environment - the world full of challenges

Crisis situations, shocks, and turbulence are nothing new in the business world. Since their very beginning, companies have been facing various situations that threaten their existence. Since the 1960s, however, the importance of external factors related to the environment, which destabilize the achievement of economic equilibrium, has significantly increased. Today, the term VUCA, borrowed from military science, is often used to describe the world we live in. It is an acronym for the following English words (Taskan, Junça-Silva, Caetano, 2022):

- Volatility means rapid and unexpected changes that make planning difficult and traditional strategies insufficient.
- Uncertainty represents a lack of certainty about future events and their consequences, which makes it difficult to predict and make rational decisions.
- Complexity means considering many interrelated factors that make the situation difficult to understand and analyze.
- Ambiguity represents the lack of clear cause and effect relationships and various interpretations of the situation, which leads to confusion and makes it difficult to take action.

VUCA describes business reality as dynamic, unpredictable, and difficult to analyze, which requires companies and their leaders to be flexible, adaptive, and innovative to function effectively in such an environment.

BANI is another term used to describe the contemporary environment in which businesses operate. It is also an acronym for the following words (Cascio, 2022):

- Brittle. It conveys a false sense of strength and resilience. The world is brittle and prone to sudden collapse. The collapse of one element can trigger an avalanche of others, which shows the vulnerability of modern systems.
- Anxious. The world is filled with anxiety caused by information overload, fake news, cyberattacks and the constant need for vigilance, which makes it difficult to make informed decisions.
- Non-linear. Traditional cause-and-effect logic loses its relevance. Small decisions can have huge consequences, and significant changes do not always lead to predictable results.

- Incomprehensible. The multitude of factors leads to a complicated and difficult to understand world in which misunderstanding becomes the norm.

The BANI concept emerged in 2020 as an extension of the VUCA model, which was deemed insufficient in the new, chaotic realities. The BANI concept was aimed to better define and respond to the new reality, characterized by extremely rapid and unpredictable changes, as seen, among others, during the global pandemic.

The twentieth edition of the "Global Risks Report 2025" illustrates the characteristics of the contemporary environment described in the VUCA and BANI models, their evolving structure, and the intensity of their impact. This publication reveals an increasingly fragmented global landscape, in which growing geopolitical, environmental, social, and technological challenges threaten stability and progress at the global, regional, and organizational levels. In recent years, the spread and escalation of conflicts, a proliferation of extreme weather events exacerbated by climate change, widespread social and political polarization, and relentless technological advances that accelerate the spread of false or misleading information have been experienced (Table 1). In such circumstances, the risk of misjudgment by various entities, including businesses, is high.

Table 1.
Top 10 global risks ranked by severity over the 2025, 2027 and 2035

Rank	2025 year	Risk categories	2027 year	Risk categories	2035 year	Risk categories
1.	State-based armed conflict	Geopolitical	Misinformation and disinformation	Technological	Extreme weather events	Environmental
2.	Extreme weather events	Environmental	Extreme weather events	Environmental	Biodiversity loss and ecosystem collapse	Environmental
3.	Geoeconomic confrontation	Geopolitical	State-based armed conflict	Geopolitical	Critical change to Earth systems	Environmental
4.	Misinformation and disinformation	Technological	Societal polarization	Societal	Natural resource shortages	Environmental
5.	Societal polarization	Societal	Cyber espionage and warfare	Technological	Misinformation and disinformation	Technological
6.	Economic downturn	Economic	Pollution	Environmental	Adverse outcomes of AI technologies	Technological
7.	Critical change to Earth systems	Environmental	Inequality	Societal	Inequality	Societal
8.	Lack of economic opportunity or unemployment	Societal	Involuntary migration or displacement	Societal	Societal polarization	Societal
9.	Erosion of human rights and/or civic freedoms	Societal	Geoeconomic confrontation	Geopolitical	Cyber espionage and warfare	Technological
10.	Inequality	Societal	Erosion of human rights and/or civic freedoms	Societal	Pollution	Environmental

Source: based on (Global Risk Report, 2025).

In 2025, the risk of armed conflicts, which were overlooked as a major threat just two years ago, is first in the ranking (Global Risks Report, 2025). Another geopolitical factor, geoeconomic confrontation, ranks among the top three. The risk associated with the emergence of extreme weather phenomena is found to be second in the ranking. Compared to these threats, risks related to technological and social issues are considered to have a slightly weaker impact. In turn, over the next two years, threats related to disinformation are forecast to generate the greatest risk. Risks related to extreme weather phenomena and the threat of armed conflict remain in the top three. The long-term forecast primarily highlights risks related to environmental degradation, extreme weather phenomena, and natural resource shortages. Expected technological risks will continue to be related to disinformation and cyber fraud. Social risks, however, will primarily concern social polarization and social inequality.

Building organizational resilience

The characteristics of the contemporary environment described in the previous section remain, on the one hand, a cause for concern, but on the other, they require managers to address the challenges of coping with new circumstances. Both the VUCA and BANI models provide general guidance on how to manage in turbulent environments (Table 2).

Table 2.
Ways of managing in models VUCA and BANI

VUCA world		BANI world	
Factors	**Reactions**	**Factors**	**Reactions**
Volatility	**Vision:** Instead of detailed plans, it is important to develop a company vision or a vision for a specific project (e.g., a vision for entering a new market), i.e., a description of the target situation. A vision allows for establishing direction in conditions of volatility and serves as a "lighthouse" for managers during storms.	Brittle	**Resilience:** The ability to quickly adapt to change, anticipate potential threats, and cope with setbacks needs to be developed. It is essential to create a flexible plan "B" that will help to face a crisis. A planned alternative serves as a "parachute" providing greater security, while a managed contingency plan will stop the domino of failures.
Uncertainty	**Understanding:** The ability to obtain feedback from stakeholders (employees, customers, suppliers, etc.) is the response to uncertainty. Effective management requires communication skills from managers and the creation of conditions for open communication at all levels of the company so that the acquired information reaches decision-makers as quickly as possible.	Anxious	**Collaboration:** Support, empathy (including professionally), and the presence of others is the best antidote to anxiety. By strengthening organizational and personal structures and working as a team, you can share knowledge and use this collective intelligence, rely on others in times of uncertainty, and cope more effectively with adversity. Building strong networks and strategic alliances is key to overcoming this state of anxiety and promoting stability.

Cont. table 2.

Complexity	**Clarity:** Managers develop a clear management system within the company, ensuring that employees receive clearly defined tasks and processes. Managers' decisions, focused on achieving the vision, give employees a sense of being headed in the right direction, despite the chaos in their surroundings. Employee development is also crucial, ensuring they are prepared to deal with complex situations.	Non-linear	**Innovation:** Both within the organization and at the individual level. You must be willing to challenge existing norms, develop innovative approaches, seek creative solutions, and adapt to new ways of working. This constant iteration is what keeps you afloat in an unpredictable world.
Ambiguity	**Agility:** It means the ability to recognize situations through experimentation. Establishing a hypothesis and then conducting a test allows for determining whether a given action will produce the intended result. Instead of engaging in lengthy discussions, it is better to evaluate a solution and see what the effect will be.	Incompre-hensible	**Empowerment:** It represents better preparation and a spirit of lifelong learning. It also means investing in improving skills and knowledge, enhancing professional qualifications, and following the latest trends. This is essential for making informed decisions and seizing emerging opportunities.

Source: based on (Santander, 2023; EY, 2023).

Building organizational resilience is the antidote to coping with today's fragile, unpredictable environment (Table 2). This is not a new concept – it first appeared in 1973 (Holling). The literature on the subject offers its many interpretations. Leaving aside the various contexts of its application, based on publications obtained from the Web of Science and Scopus databases, it can be stated that organizational resilience is its ability to survive, adapt, and grow in the face of turbulent changes (Fiksel 2006). Bhamra (2015), in turn, states that it is an overarching concept that not only allows an enterprise to continue its business, but also to develop, learn, and progress regardless of the environment. Hillmann and Guenther (2021) speak similarly about organizational resilience, pointing out that it is the ability of an organization to maintain functions and recover fast from adversity by mobilizing and accessing the resources needed. An organization's resilient behavior, resilience resources and resilience capabilities enable and determine organizational resilience. The result of an organization's response to adversity is growth and learning.

Building effective resilience to crises is the result of synergistic actions at various organizational levels, which together protect the enterprise from potential damage and enable it to successfully survive even in the most challenging circumstances. The key elements that enterprises can implement to build a solid foundation for organizational resilience include:

- Mission, values, and organizational culture: a positive organizational culture based on collaboration and trust among employees are fundamental pillars that not only define a company's identity but also constitute a key element in effective crisis management. In times of crisis, organizations that are grounded in a clearly defined mission and values have clear directions for action. An identity developed based on mission and values

serves as a compass that guides decisions in challenging times. Companies with a strong identity are more capable of a focused response, eliminating decision-making chaos.

- Employees: loyal, engaged employees who identify and confront disruptions are crucial to an organization's survival and growth, especially in tough times.
- Leaders: resilient leaders who can navigate dynamic and uncertain environments shape resilience at lower levels of the organization.
- Internal communication: effective internal communication ensures cohesion, enabling immediate response to crises and strengthening team morale. Collaborating with the team on internal communications can build trust and provide valuable information that will help to manage the crisis more effectively.
- Procedures and strategies: implementing appropriate procedures, strategies, and systems (e.g., early warning systems) inside an organization is essential to building its adaptive capacity. Procedures not only minimize chaos and confusion in challenging times but also enable rapid and coordinated actions. Continuous improvement of these procedures is also crucial. Analyzing actions after a crisis and updating procedures based on lessons learned allows the company to adapt to the evolving situation and minimize potential damage in the future.
- Organizational structure: a transparent and efficient organizational structure supports the effectiveness of operations, which is crucial in crisis situations.

It can therefore be concluded that organizational resilience is a complex and multifaceted concept that strongly determines the condition of an organization. It is therefore important to consciously shape the mechanisms that ensure this resilience and thus create conditions for maintaining organizational stability in a turbulent environment.

Organizational resilience of the Warsaw Stock Exchange listed companies in the light of survey research

The experiences of recent years (to mention only the consequences of the pandemic, the war in Ukraine, and the growing climate crisis) have prompted research on the assessment of companies from the perspective of their resilience to several types of environmental turbulence. A diagnosis of companies' behavior in the context of building their organizational resilience was conducted as part of the second stage of the research entitled "Organizational Resilience in the Perspective of Sustainable Development" (Samborski, 2024; Department of Business Management, 2024; Center for Research and Development, 2024). The research focuses on analyzing the activities of companies listed on the Warsaw Stock Exchange Main Market. The survey was sent to all companies operating on the WSE Main Market, i.e., 410 entities. This group includes companies included in the WIG-ESG index. This index

was introduced in September 2019 and groups companies listed on the WSE that meet international ESG standards. In 2024, 60 such entities operated on the WSE. A total of 210 companies completed the survey, representing 51.22% of all surveyed entities. Among the WIG-ESG companies, 53 responded, representing 88.33% of the group of companies surveyed. It indicates the relatively high representativeness of the results.

The survey was completed by individuals directly or indirectly involved in crisis management in the company. Respondents were given a five-point Likert scale, with the following descriptions: 1 – strongly disagree, 2 – somewhat disagree, 3 – hard to say, 4 – somewhat agree, 5 – strongly agree. Excel tools were used to streamline calculations.

Among companies belonging to the WIG-ESG index, 64% recognize, monitor, and anticipate the possibility of various disruptions in their environment (e.g., the COVID-19 epidemic, environmental disasters, geopolitical shifts, social changes, AI revolution), another 30% cannot clearly define this, and 6% do not identify or anticipate external disruptions (Figure 1). Among the remaining companies on the WSE Main Market, 52% demonstrate sensitivity to environmental turbulence, 39% cannot clearly define this, and 9% do not identify or anticipate disruptions in the environment.

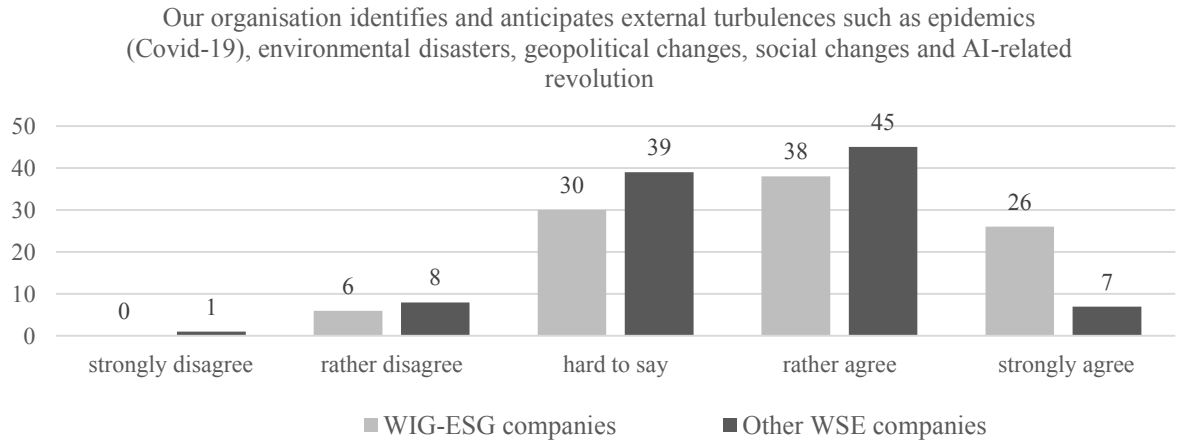


Figure 1. Percentage of surveyed WIG-ESG index companies and other WSE Main Market companies identifying and anticipating external disruptions.

Source: based on (Department of Business Management, 2024; Center for Research and Development, 2024).

Another issue included in the survey concerned effective management of external disruptions, meaning the proper and effective use of various available resources to quickly adapt to changes and overcome challenges (Figure 2). 36% of the surveyed WIG-ESG companies undoubtedly manage external disruptions effectively, and another 40% of those in this category tend to implement such management. 21% of the surveyed companies cannot clearly state whether such management is implemented, and another 4% rather do not identify effective management of external disruptions. Among companies outside the WIG-ESG index, 74% confirm taking effective measures to manage external disruptions. Similarly to WIG-ESG

companies, 20% of the remaining companies cannot clearly state whether such management is implemented, and another 7% do not identify effective management of a turbulent environment.

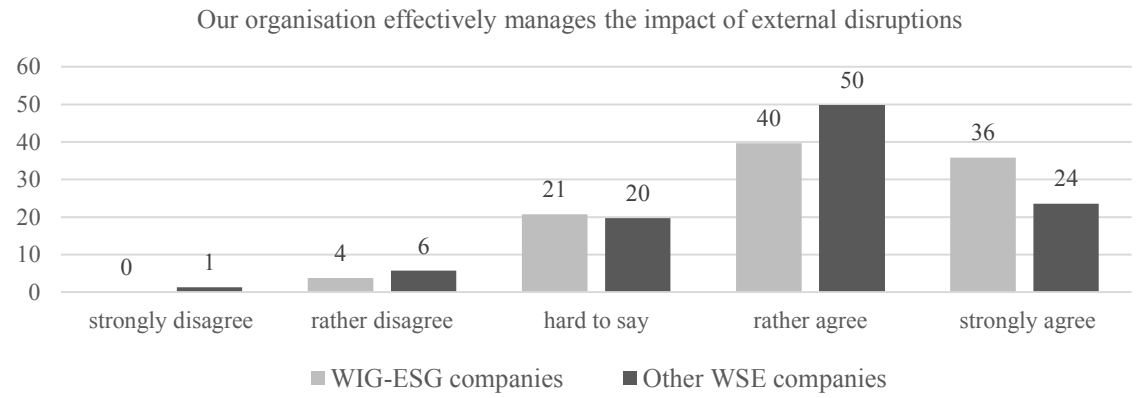


Figure 2. Percentage of the surveyed WIG-ESG index companies and other WSE Main Market companies effectively managing the impact of external disruptions.

Source: based on (Department of Business Management, 2024; Center for Research and Development, 2024).

The next statement in the survey questionnaire concerned the implementation of various solutions that can be considered crucial for building organizational resilience, such as new strategies, new business models, new management practices, and ultimately, expansion into new markets (Figure 3). Based on the responses obtained from respondents from WIG-ESG index companies, it can be concluded that essentially 98% of them believe that taking these remedial actions contributes to building and strengthening their resilience in a volatile, complex, and unpredictable environment. Only one company representative disagrees with this opinion. Nearly identical responses are received from representatives of the remaining companies on the WSE Main Market.

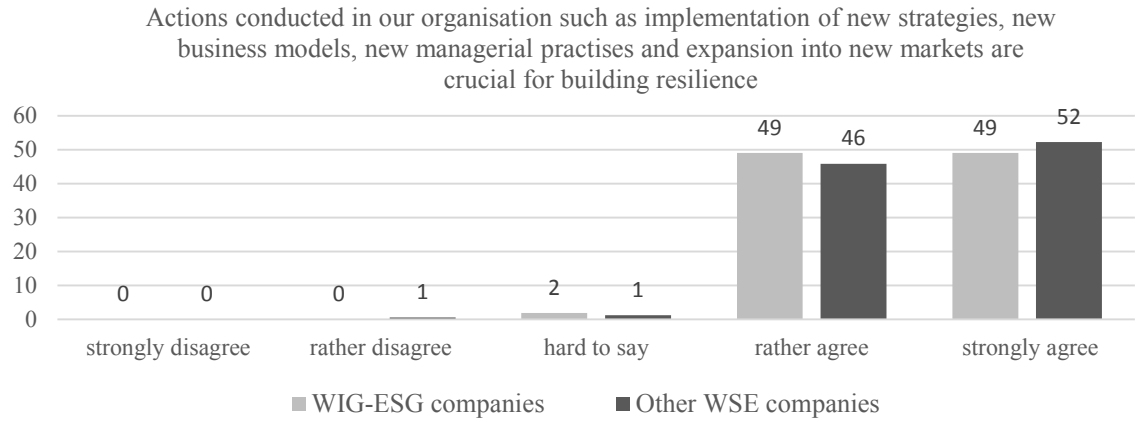


Figure 3. Percentage of surveyed WIG-ESG index companies and other WSE Main Market companies using various measures to build organizational resilience.

Source: based on (Department of Business Management, 2024; Center for Research and Development, 2024).

Currently, monitoring companies' progress in meeting ESG-related challenges is a key tool for building organizational resilience. Environmental standards (E) primarily address practices related to reducing emissions of harmful substances, waste management, and energy efficiency. Social standards (S) address practices related to managing employee relations, ensuring good working conditions, and engaging local communities. Governance standards (G), on the other hand, address operational transparency, business ethics, and risk management. 75% of surveyed WIG-ESG companies and 78% of other WSE Main Market companies strongly confirm their adherence to these standards, while a further 17% of WIG-ESG companies and 15% of other listed companies surveyed tend to confirm their implementation of ESG standards. Four of the surveyed WIG-ESG companies (8%) were unable to confirm this statement, which may be surprising, as these companies are WIG-ESG members (Figure 4).

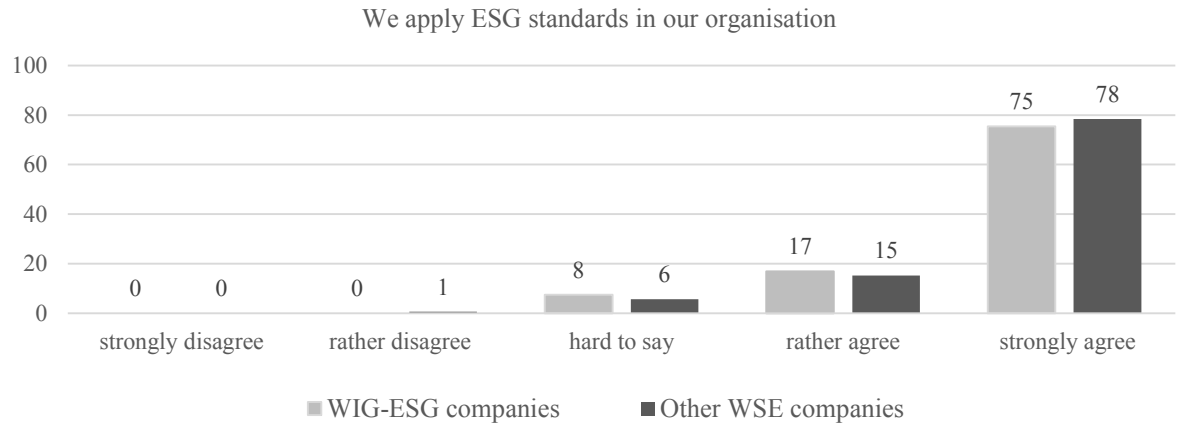


Figure 4. Percentage of surveyed WIG-ESG index companies and other WSE Main Market companies applying the ESG standard.

Source: based on (Department of Business Management, 2024; Center for Research and Development, 2024).

Many companies associate the implementation of a sustainable development policy based on ESG standards with a crisis management strategy. Among respondents representing WIG-ESG companies, 28% strongly support this view, with another 57% tending to agree. Another five companies (9%) have no firm opinion on this matter. However, three surveyed companies (6%) do not link sustainable development goals to a crisis management strategy, which could consequently impact building resilience in the face of future challenges (Figure 5).

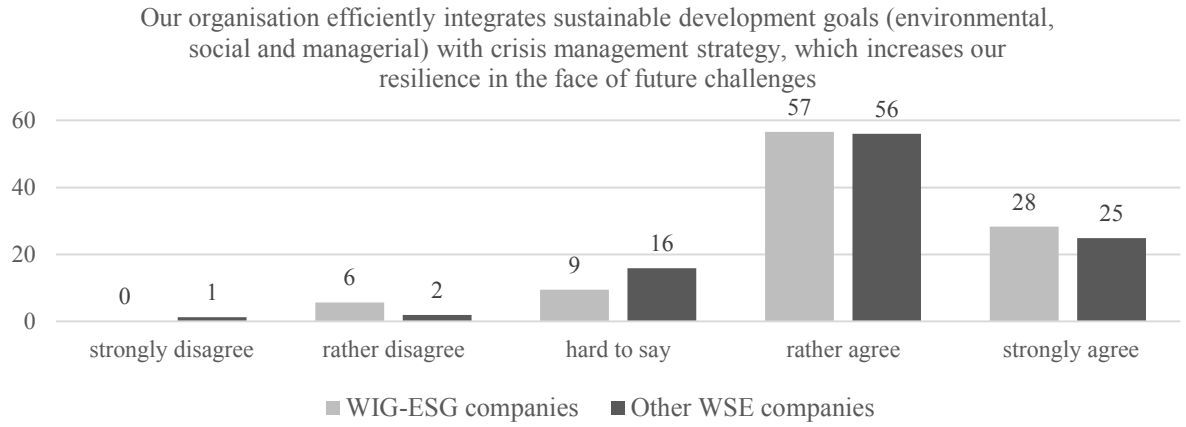


Figure 5. Percentage of surveyed WIG-ESG index companies and other WSE Main Market companies integrating sustainable development goals with their crisis management strategy.

Source: based on (Department of Business Management, 2024; Center for Research and Development, 2024).

The answers of respondents representing other companies on the WSE Main Market seem to be similar, with 16% of those who do not have a clearly developed opinion on this issue, and 3% of them (5 surveyed companies) do not associate the implementation of a sustainable development policy with building organizational resilience at all or almost at all.

Conclusions

The concept of sustainable development functions as a tool for responsible management in an increasingly turbulent environment. Promoted primarily by international institutions and investor groups, it has become a response to the climate crisis, social inequality, and the need for transparency in management. Analysis and evaluation of a survey conducted among 210 companies on the WSE Main Market (including 53 companies belonging to the WIG-ESG index) allows for formulating the following conclusions:

- A significantly higher percentage of WIG-ESG companies respond to environmental disruptions compared to other companies on the WSE Main Market. This can be explained by the fact that WIG-ESG companies are more sensitive to changes in environmental, social, and governance matters and have appropriate research tools (e.g., reporting) to detect upcoming changes in their environment.
- The study reveals no significant differences between WIG-ESG index companies and other companies on the WSE Main Market in terms of effective management of external disruptions. A positive finding is that approximately three-quarters of the surveyed companies implement such management.

- For almost all the surveyed companies (98% of the WIG-ESG index and 97% of the remaining companies on the WSE Main Market), implementing new strategies, new business models, new management practices, and expansion into new markets are key elements of building their organizational resilience.
- The conducted study shows that approximately three-quarters of the surveyed companies, both from the WIG-ESG index and other entities on the WSE Main Market, implement ESG standards, although this does not always go hand in hand with the awareness of building organizational resilience.
- 85% of the surveyed WIG-ESG index companies and 81% of the remaining companies on the WSE Main Market link the implementation of sustainable development goals with a crisis management strategy and building organizational resilience.

The presented survey results and conclusions indicate that awareness of sustainable development and ESG implementation are increasing. Companies must undoubtedly consider challenges in implementing this concept, such as additional costs (estimated at approximately 15% of revenue), structural changes involving the designation of a person(s) responsible for sustainability or ESG issues, accessing experts and sustainability specialists, and changes in reporting policies. On the other hand, nearly 45% of managers admit that their company has already had to present a carbon footprint and sustainability report to contractors (ESG Report 2024). Therefore, sustainability is no longer just a fad; it is becoming a key element of organizational resilience and building stakeholder relationships.

The analyses conducted prompt further investigation into how companies listed on the Warsaw Stock Exchange respond to environmental turbulence and whether they apply sustainable development practices, taking into account not only the division into companies that apply/do not apply ESG standards. Further research should include an assessment of companies from the point of view of their size, the industries/sectors to which they belong, and various stock market indices, e.g., WIG-20, mWIG-40, sWIG-80, WIG-POLAND, etc. An interesting study would be to assess the implementation of ESG standards as a basis for building resilience, taking into account the gender of decision-makers.

References

1. Bennetta, N., Lemione, G. (2014). What a difference a word makes: Understanding threats to performance in a VUCA world. *Business Horizons, T. 53, No 3*, pp. 311-317.
2. Bhamra, R. (2015). *Organizational Resilience Concepts, Integration, and Practice*. Boca Raton: CRC Press.
3. businessinsider.com.pl (2025). https://businessinsider.com.pl/wiadomosci/onz-donald-trump-krytykuje-organizacje-i-jej-misje-globalna/bgs1gxb, 26.09.2025.

4. Cascio, J. (2022). *Human Responses to a Bani World*. https://medium.com/@cascio/human-responses-to-a-bani-world-fb3a296e9cac, 2.07.2025.
5. Center for Research and Development (2024). *Organizational resilience in the perspective of sustainable development*. Research task carried out by the Department of Business Management. Survey results. Companies listed on the Warsaw Stock Exchange. NewConnect. University of Economics in Katowice.
6. Corporate Sustainability Reporting Directive*,* 2022/2464/UE. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022L2464, 25.09.2025.
7. Department of Business Management (2024). *Organizational resilience in the perspective of sustainable development*. Research assignment conducted by the Department of Business Management. Survey questionnaire. University of Economics in Katowice.
8. ESRS (2023) COMMISSION DELEGATED REGULATION (EU) of 31.7.2023 supplementing Directive 2013/34/EU of the European Parliament and of the Council as regards sustainability reporting standards. 20230803_ESRS_-_rozporządzenie_delegowane_KE_wersja_EN.pdf, 25.09.2025.
9. EXACTO. *Budowanie odporności kryzysowej – jak firmy mogą stawać się odporniejsze na kryzysy?* https://www.exacto.pl/budowanie-odpornosci-kryzysowej-jak-firmy-moga-stawac-sie-odporniejsze-na-kryzysy/#:~:text=Odporno%C5%9B%C4%87%20kryzysowa%20%E2%80%93%20solidne%20fundamenty%2C%20silna%20narracja,pozwalaj%C4%85c%C4%85%20mu%20skutecznie%20przetrwa%C4%87%20nawet%20najtrudniejsze%20sytuacje, 12.08.2025.
10. EY (2023). *Świat BANI, czyli świat oparty na niepewności*. https://www.ey.com/pl_pl/insights/workforce/swiat-bani-co-to-jest, 21.09.2025.
11. Fiksel, J. (2006). Sustainability and resilience: toward a systems approach. *Sustainability: Science, Practice and Policy*, *Vol. 2(2)*, pp. 14-21. https://doi.org/10.1080/15487733.2006.11907980
12. *Global Risk Report* (2025). https://www.weforum.org/publications/global-risks-report-2025/digest/, p. 8, 21.08.2025.
13. Hillmann, J., Guenther, E. (2021). Organizational Resilience: A Valuable Construct for Management Research? *International Journal of Management Reviews, Vol. 23*, pp. 7-44*,* doi.org/10.1111/ijmr.12239
14. Holling, C.S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecological Systems*, *Vol. 4(1),* pp. 1-23, doi.org/10.1146/annurev.es.04.110173.000245
15. IPS (2025). *ESG jako instrument dominacji? Polska w pułapce globalnych regulacji*. https://fips.pl/esg-jako-instrument-dominacji-polska-w-pulapce-globalnych-regulacji/, 20.09.2025.
16. ONZ (2015). *Przekształcamy nasz świat: Agenda na rzecz zrównoważonego rozwoju 2030*. Rezolucja Zgromadzenia Ogólnego ONZ A/RES/70/1 z 25 września 2015, 26.09.2025.

17. Raport ESG (2024). *Raport ESG – szanse i ryzyka*. Polskie Stowarzyszenie ESG. 15190-raport-esg-szanse-i-ryzyka-polskie-stowarzyszenie-esg PDF (www.teraz-srodowisko.pl), 12.10.2025.
18. Samborski, A. (2024). Organizational resilience in the perspective of sustainable development. *Research task carried out by the Department of Business Management.* University of Economics in Katowice.
19. Santander (2023). *BANI world: reality seen through another lens*. https://www.santanderopenacademy.com/en/blog/bani-world.html, 21.09.2025.
20. Taskan, B., Junça-Silva, A., Caetano, A. (2022). Clarifying the conceptual map of VUCA: a systematic review. *International Journal of Organizational Analysis*, *Vol. 30(7)*, pp. 196-217, https://doi.org/10.1108/IJOA-02-2022-3136
21. *Taxonomy Regulation - Regulation (EU) 2020/852*. https://viewpoint.pwc.com/dt/gx/en/eu/eu-sustainability-regulation/eu-sustainability-regulation/eu-green-taxonomy/taxonomy-regulation-regulation-eu-2020-852.html, 10.08.2025.
22. Tshetshe, Z. (2025). Recognizing 'Being' in the BANI world. *International Journal for Multidisciplinary Research*, *T. 7(1)*, pp. 1-9.

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